

Preparing for Climate Change:

Adapting to Impacts on British Columbia's Forest and Range Resources



Ministry of Forests and Range



May 18, 2006

Executive Summary

Purpose

The Ministry of Forests and Range (MoFR) Climate Change Task Team was established by the Forests Stewardship Division (FSD) Management Team in June 2005. The Task Team was requested to prepare a report for the Chief Forester on how the MoFR should strategically position itself with respect to the potential impacts of climate change on the province's forest and range resources

The mandate of the Task Team emphasized the need to understand and plan for the potential impacts of climate change. The team focused on identifying potential risks and opportunities, knowledge and research gaps, and some short- and long-term adaptive responses to climate change that the MoFR and others could undertake. This report therefore primarily addresses "adaptation" to climate change as opposed to "mitigation", which is aimed at reducing greenhouse gases (GHG) in the earth's atmosphere.

The MoFR has a key role to play in mitigating the risks of future climate change by managing forests and soils to remove and store GHG, such as carbon dioxide, from the atmosphere and by developing opportunities for biofuels as alternative energy sources to fossil fuels. These "mitigation" strategies, which are largely subject to federal government direction, were outside the scope of the Task Team's assignment and are not addressed in this report. However, opportunities for reducing GHG emissions from MoFR operations were examined.

This report has been prepared for both MoFR and public review and comment. Most of the recommendations in this report have also been amalgamated with those derived from the Future Forest Ecosystems symposium held in December 2005 (MoFR 2005), the report on species management in mountain pine beetle impacted timber supply areas (Martin et al. 2005), and other MoFR activities into a Future Forests Ecosystems Initiative, which will explore opportunities to adjust approaches to forest management in response to rapidly changing conditions. Through this initiative the chief forester will seek additional input from stakeholders, communities and First Nations.

Climate Change

The global climate has always been subject to natural, sometimes dramatic, variation and species and ecosystems have adapted accordingly. However, climate scientists have concluded that much of the global climate warming observed during the latter half of the 20th century is due to anthropogenic factors, and that the rate of warming is likely to accelerate significantly during the 21st century (IPCC 2001). This projected rate of increase is faster than has likely occurred in the last 2000 years (Moberg et al. 2005). This rapid rate of climate change will drive significant changes in natural systems, and challenge the ability of natural resource managers and resource-based communities to adapt.

Implications of Climate Change for BC's Forest and Range Resources

By the end of the 21st Century, the mean annual temperature for western North America could be 2-5 °C above the mean annual temperatures of the last 1000 years (IPCC 2001). An increase in winter precipitation and a decrease in summer precipitation may also occur (AIRG 2005), although precipitation scenarios vary considerably.

These changes will significantly affect forest and range ecosystems and the sectors and communities that rely on them. Projected changes include migration of some species northward and up in elevation, new assemblages of species occurring in space and time, overall loss of biodiversity, and changes in disturbance regimes, forest productivity and hydrology. These changes are expected to have a number of adverse, and in some cases, positive effects on British Columbia's forest and range resources. Forest and range productivity may increase in some areas. However:

- As climate changes, trees may become poorly adapted to the sites they currently occupy, adversely affecting overall forest health and productivity. Climate change may make new geographical locations more suitable for individual tree species. However, seedlings may not become established on newly suitable sites if the sites are too far from the species' current range, or if the seedlings are unable to compete successfully with other species.
- Climate change is also expected to increase the incidence of insect and disease outbreaks, and spread of invasive species. The current mountain pine beetle (MPB) epidemic in British Columbia is caused, in part, by warmer winters (CCIAD 2004). Another possible indicator of climate change is the increased incidence of *Dothistroma* needle blight in lodgepole pine forests (Woods et al 2005).
- Warmer temperatures are expected to increase the frequency and severity of forest-damaging events such as, fires, ice storms, floods and droughts – varying from year-to-year and region-to-region. The large catastrophic fires which occurred in BC's southern interior in 2003 and 2004 have also been attributed, in part, to warmer than usual summer temperatures and extended drought (CCIAD 2004)
- Warmer winters may reduce the length of the winter logging season, and forests could be closed in summer more often due to drought and fire risk. Roads, bridges and culverts will also be affected due to changes in precipitation and soil hydrology, increased storm frequency, earlier snow melt, and the melting of permafrost in northern regions (Spittlehouse and Stewart 2003).

While the potential risks of a changing climate may significantly outweigh the benefits, there are a number of opportunities available that could minimize the impacts and improve results if we act now. These include, for example:

- facilitated migration of species and populations to capitalize on the warmer climates anticipated;
- managing for diversity to increase resilience to biotic and abiotic influences; and,
- reducing costs and exposure through wiser and more efficient investment.

The ratio of risks to opportunities may be influenced by the rate and degree of climate change. The IPCC Third Assessment Report (2001) and the report from the recent Exeter conference on Avoiding Dangerous Climate Change noted that a global temperature increase of 1 degree C may benefit a few regions (e.g. high latitude areas) and sectors (e.g. agriculture). The Exeter conference also noted that the literature suggests increasing damage if the globe warms about 1 to 3 degrees C above current levels, and that "the world will, in the absence of urgent and strenuous mitigation actions in the next 20 years, almost certainly be committed to a temperature rise of between about 0.5 degrees and 2 degrees C relative to today by 2050."

The biophysical effects of climate change will have numerous corresponding and inter-related socio-economic effects. Throughout Canadian forests, many communities are heavily reliant on the forest sector market economy. Increased fire and pests, along with inability of trees to adapt to the new climate regime may result in a reduction in timber supply, which would have wide-ranging effects on local industries and communities. Effects will also extend to the provincial and federal government levels, where the revenues from taxes and resource rents provide the basis of program and service provision. In addition to those benefits captured by the market system, non-market forest values, including aesthetic, cultural, and heritage values, will also be affected. (Ohlson et al 2005).

Parks and protected areas, which provide valued recreation opportunities and serve important conservation and heritage aims, may face particular challenges if the maintenance of native species and ecosystems is not possible in their current locations (Scott et al. 2002). Perhaps most overlooked are the potential effects on the ecosystem services provided by Canada's forests, including air and water purification, wildlife habitat, medicinal plants, nutrient cycling, and erosion control.

Preparing for Climate Change

Given the reality of climate change and the apparent vulnerability of forests, forest resource users, and communities, it is prudent that forest managers and forest-based community leaders begin to develop adaptive strategies to minimize the risks and maximize the benefits of climate change (Spittlehouse and Stewart 2003, Standing Committee on Agriculture and Forestry 2003).

Adaptation to climate change can be either reactive (responding after the fact to climate change) or proactive (preparing in advance). In many cases, it will be acceptable to 'react' to climate change through ongoing small adjustments (adaptive management). In other cases (e.g. species and seed selection) there will likely be benefits in taking a proactive approach. Because of the uncertainty about many aspects of future climate and its impacts, adaptation measures should ideally convey benefits now as well as (potentially) in the future. For example, the "fire smart" initiative addresses existing as well as potential future risks of forest fire to communities.

The large scale of B.C.'s forested land base means that much of the forest will have to adjust autonomously to climate change without human intervention. Human adaptation efforts will have to focus on the major commercial tree species and perhaps a few animal

species, while the majority of forest plants and animals will adjust on their own (Spittlehouse 2005).

The MoFR is charged with managing, protecting and conserving the forest and range resources of the province. Climate change adds another layer of complexity to these management responsibilities. There are two broad challenges for the MoFR: how to manage standing forests to ensure they continue to provide during the decades of change to come the goods and services that BC relies on; and how to design and manage future forests that are suited to the climate and other conditions of the future.

The MoFR participated in the development of the provincial plan, Weather, Climate and the Future: BC's Plan, and is the lead agency for implementation of seven forest-related climate change actions. These actions include: incorporating carbon management into forest management objectives, modelling and protecting incremental forest sinks, developing mitigation strategies and limiting the socio-economic costs of the mountain pine beetle, and improving fire protection for communities.

The provincial plan also sets out a number of foundation actions to be implemented across government, including MoFR. These actions are designed to increase overall provincial capacity to prepare for climate change and its impacts, and include: addressing climate change in planning and operations, implementing effective monitoring and reporting procedures, developing climate models and other tools for assessing risks and adaptation options, supporting applied research and developing capacity throughout B.C. to respond to extreme weather and climate change.

In addition to the actions identified in the provincial climate plan, the MoFR is undertaking other initiatives to prepare for the potential impacts of climate change. These activities include the development of fuel management strategies, climate based seed planning zones, climate profiles for provenances and species, and high spatial resolution climate data for climate change analysis. MoFR is also working with BIOCAP Canada Foundation to support a wide range of university research projects dealing with climate change, carbon sequestration and alternatives to fossil fuels

Conclusions and Recommendations

Climate change represents a very significant risk to B.C.'s forest and range resources. Preparing for this risk will require a long-term, sustained response that includes:

- (1) a comprehensive assessment of the potential impacts of climate change on MoFR and BC's forest and range resources and operations, and the vulnerability of forest- and range-based communities to these changes;
- (2) further research on the impacts of climate change in key risk areas, in cooperation with universities and the federal government,
- (3) the development of tools to support adaptation strategies, including climate scenarios, case studies, and decision-making frameworks,

- (4) communication, consultation and awareness raising to ensure that forest and range managers, industry and communities have the information and tools to enable them to prepare for climate change, and
- (5) program-specific management strategies to address key vulnerabilities and program areas – including both short and long-term actions.

While long-term efforts are required in many areas, a number of short-term actions could be undertaken that will allow the MoFR to proactively respond to the potential risks and opportunities of climate change, and support the development of an overall ‘future focused’ forest and range strategy. Such short-term actions should be low risk options that would provide benefits to British Columbians irrespective of magnitude and timing of climate change.

These short-term actions should also serve to:

- complement the Future Forest Ecosystem initiative,
- build on work initiated from the recently completed review of tree species management in mountain pine beetle impacted TSAs,
- increase understanding of climate change and its potential impacts as the basis for undertaking further analysis, strategy development and action, and
- build capacity within the MoFR to respond proactively to the risk of climate change.

The following are recommendations for possible short-term actions the MoFR could undertake. These recommendations should be considered in the context of other ministry initiatives, priorities and resource commitments.

The recommendations are grouped into three main strategies:

- A. Improving knowledge through analysis and research
- B. Reviewing operational policies and practices
- C. Building awareness and capacity within and outside the ministry

A. Improving knowledge through analysis and research

Recommendation 1. Undertake comprehensive assessments of the potential impacts of climate change on BC’s forest and range resources and operations, forest- and range-based communities, and the MoFR. These analyses will identify those resources, regions, and sectors most at risk, which will then help to prioritize further research, analysis, and action.

Recommendation 2. Evaluate various climate and biogeoclimatic (BEC) unit models for projecting future climate and its impacts. This analysis would determine

which models and methods are the most appropriate for projecting the range of plausible changes to BC's ecosystems and climate zones based on data from various global circulation and regional climate models. These maps, with appropriate policies, guidance documents and training, could then be used to inform forest and range management decisions, such as species selection choices, forest health and protection strategies, road and bridge design, and timber supply.

Recommendation 3. 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. This work should be undertaken in cooperation with other provincial agencies involved in monitoring, such as the Ministry of Environment (MoE).

Recommendation 4. Range - Undertake further research, analysis and monitoring related to range management in BC to increase understanding of species shifts in response to climate change. This could include a gap analysis for the range reference program to identify areas or BEC zones that require range reference sites to monitor species shifts, and a gap analysis correlating climate data with the movement of invasive species.

Recommendation 5. Design and establish a long-term multi-species/seedlot trial to test improved genotypes across a diverse array of climatic and latitudinal environments. This study will assist in identifying which species and seedlots will maintain or enhance forest productivity and health under a range of future climates.

Recommendation 6. Undertake an analysis of the potential impacts of climate change on timber supply under alternative species choices. This is a short-term action that will facilitate the longer-term development of a conceptual model for assessing the impacts of climate change on forest values more broadly, and of policy and management options for responding to climate change.

B. Reviewing operational policies and practices

Recommendation 7. Examine opportunities and barriers for increasing species and genetic diversity in plantations. Increased species and genetic (seedlot) diversity in plantations and across the landscape can serve to increase the resilience of forests to changes to climate, forest pests and diseases. This recommendation should be explored further under the auspices of the Future Forests Ecosystem initiative.

Recommendation 8. Examine options for modifying seed transfer limits and systems. Adjustments to the elevational and latitudinal transfer limits of tree species may be warranted to help ensure that planted trees are adapted to future climates. A range of seed transfer systems should be explored with attention to the biological risks and benefits, and policy, operational and cost implications.

Recommendation 9. Examine alternative systems for species selection to ensure that trees will be adapted to future climate. Planting species adapted to future climate

projections may significantly reduce the risk of trees being poorly adapted to the changing climate in the last 2 or 3 decades of their rotation. Future climate maps could be used to facilitate the migration of tree species to areas, but policy and operational issues will require significant consideration and discussion.

Recommendation 10. Conduct an assessment of greenhouse gas emissions produced by the MoFR's internal operations, and work with other agencies to create incentives and remove barriers to reducing MoFR emissions. This analysis could be undertaken in collaboration with MoE and the Ministry of Finance.

C. Building awareness and capacity within and outside the ministry

Recommendation 11. Fire Protection – Inform the public, industry and other agencies of the potential impact of climate change on the fire regime in the province and continue to encourage pro-active actions in regard to fuels management and community protection. These actions can in time be incorporated into the new provincial fire management strategy that is currently under development. This recommendation encompasses the ongoing fuels management initiative guided by the Protection Program and involving the active participation of other agencies (e.g. UBCM). Activity around the information component has been limited to date, but will increase as more knowledge of the potential changes and their impacts is acquired.

Recommendation 12. Increase awareness and understanding of climate change impacts and issues by developing and implementing a climate change communications strategy. Increased awareness of climate change is a pre-requisite for engaging MoFR staff, stakeholders and communities in assessing risks and vulnerabilities to climate change, and, eventually, incorporating these considerations into policies, plans and practices. The strategy should be developed and implemented in collaboration with MoE.

Recommendation 13. Support the implementation and coordination of climate change initiatives across the MoFR and the development of a community of practice. Climate change issues cut across the MoFR. Proper resourcing and coordination are required to ensure that the approved recommendations from this report are implemented and that networks are developed and sustained. This structure should include an executive sponsor, FTE(s) and resources, with appropriate reporting relationships and links to relevant MoFR business areas.

These recommendations do not cover the full range of options presented in the report. Further analysis and discussion of the other possible short- and long-term actions identified in the report should take place, in association with the Future Forest Ecosystems initiative and other MoFR and provincial programs. These actions should be examined through environmental, social and economic lenses, in consultation and cooperation with other government agencies, industry, communities and First Nations.

Table of Contents

Executive Summary	i
Acknowledgements.....	xi
1 Introduction.....	1
2 Overview of Climate Change.....	2
3 Potential Impacts of Climate Change on BC's Forest and Range Resources.....	4
3.1 Biophysical Impacts.....	5
3.2 Socioeconomic Impacts	7
3.2.1 Impacts on Forest Product Markets	7
3.2.2 Impacts on Forest-based Communities.....	8
3.2.3 Impacts on First Nations	9
4 Climate Change Initiatives.....	9
4.1 Government of Canada	9
4.2 Other Provinces.....	10
4.3 British Columbia.....	11
4.4 BC Universities.....	12
4.5 Other Institutions	12
5 Preparing for the Impacts of Climate Change.....	13
5.1 Cross-Ministry Initiatives	14
5.1.1 Climate Change Research.....	15
5.1.2 Monitoring	16
5.1.3 Impact Assessment.....	19
5.1.4 Communication, Consultation and Raising Awareness.....	20
5.1.5 Policy, Planning and Governance	22
5.2 Management Issues and Responses	25
5.2.1 Silviculture and Forest Genetics	26
5.2.2 Forest Health.....	30
5.2.3 Timber Supply	32
5.2.4 Fire Risk and Protection.....	34
5.2.5 Timber Harvesting and Forest Road Engineering Risks.....	38
5.2.6 Range	40

5.2.7	Non-timber Forest Resources	43
5.3	Mitigation.....	44
6	Conclusions and Recommendations	48
	References.....	53
	Appendix 1: Climate Change Task Team - Terms of Reference.....	62
	Appendix 2: MoFR Linkages with Federal and Provincial Climate Change Committees and Initiatives.....	63
	Appendix 3: Current MoFR Climate Change Related Projects, Research and Initiatives	65
	Appendix 4: Possible Climate Change Impacts on Commercial Tree Species in British Columbia.....	67
	Appendix 5 – Example of Decision-Focused Risk Assessment	70
	Appendix 6 – Options for Reducing Emissions from MoFR Operations.....	78
	Appendix 7 - Glossary of Terms.....	80

Acknowledgements

This report was prepared by the Forest Services Division Climate Change Task Team. Members of the team included: Brian Barber (lead), Christine Fletcher, Jenny Fraser (MoE), Kathy Hopkins, Natalie Lavoie, Eric Meyer, Albert Nussbaum, Greg O'Neill, Dave Spittlehouse, Alex Woods.

Valuable comments, advice and information were provided by a number of reviewers:

MoFR: Jim Snetsinger, Henry Benskin, Alvin Yanchuk, Pat Martin, Del Meidinger, Dale Draper, Leslie McAuley, Glenn Moore, Brian Chow, Larry Franklin, Perry Grilz, Richard McKay, Francis Njenga

MoE: Ben Kangasneimi, Donna Sanford

Ernie Fraser and Associates Ltd.

Drafting and editing by Warren Bell, International Institute for Sustainable Development.

1 Introduction

The Ministry of Forests and Range (MoFR) Climate Change Task Team was established by the Forests Stewardship Division (FSD) Management Team in June 2005. The Task Team was requested to prepare advice for the chief forester on how the MoFR should strategically position itself with respect to the potential impacts of climate change on the province's forest and range resources.

The Task Team consisted of staff from the four FSD branches and operations division, and Jenny Fraser from the Ministry of Environment. The executive sponsor for this project was Henry Benskin, A/Deputy Chief Forester. The terms of reference for this task team are included in Appendix 1.

This report contains the analysis and recommendations of the Task Team. It provides an overview of climate change and its observed and potential impacts on the province's forest and range resource. The report also summarizes the climate change related initiatives of the provincial and federal governments, and other agencies. Key issues and knowledge gaps are identified, and options to address them are presented. In support of the latter, potential short and long-term actions that the MoFR and others may undertake are suggested.

The report also identifies communication and extension efforts required to raise awareness of climate change issues. It also identifies the expertise, knowledge and tools required to enable the MoFR, industry, resource managers and client groups to more effectively respond to the risk of climate change.

The mandate of the Task Team emphasized the need to understand and plan for the potential impacts of climate change. The team focused on identifying potential risks and opportunities, knowledge and research gaps, and some short- and long-term adaptive responses to climate change that the MoFR and others could undertake. This report therefore primarily addresses "adaptation" to climate change as opposed to "mitigation", which is aimed at reducing greenhouse gases (GHG) in the earth's atmosphere.

MoFR has a key role to play in mitigating the risks of future climate change by managing forests and soils to remove and store GHG, such as carbon dioxide, from the atmosphere and by developing opportunities for biofuels as alternative energy sources to fossil fuels. These "mitigation" strategies, which are largely subject to federal government direction, were outside the scope of the Task Team's assignment and are not addressed in this report. However, opportunities for reducing GHG emissions from MoFR operations were examined.

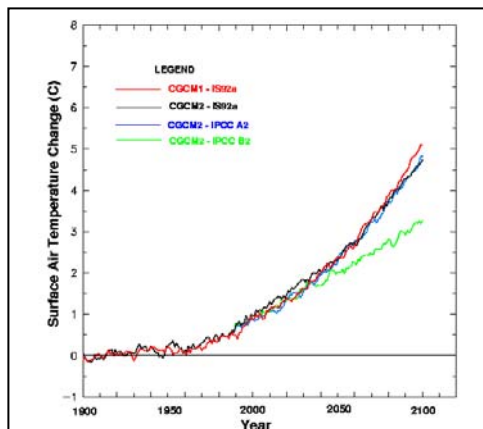
The information gathered and reflected in this report was derived primarily from peer-reviewed and grey literature, consultation with a limited number of staff, and knowledge and experiences of Task Team members. This report does not represent a comprehensive review of climate change, nor do the recommendations contained herein provide definitive solutions for addressing its impacts. Further research and analysis, and

dialogue and partnerships with other government agencies, forest and range licensees, professional associations, communities and First Nations is required to fully develop appropriate responses to climate change.

The chief forester has indicated that the recommendations from this report will be amalgamated with those derived from the Future Forest Ecosystems of BC symposium and workshops held in Prince George in December 2005 (MoFR 2005), the Management of Species in Mountain Pine Beetle Impacted TSA report (Martin et al. 2005), and other ministry activities into the Future Forests Ecosystems Initiative, which will explore opportunities to adjust approaches to forest management in response to rapidly changing conditions. Through this initiative, the chief forester will seek further input from stakeholders, communities and First Nations.

2 Overview of Climate Change

The global climate has always been subject to natural, sometimes dramatic, variation and ecosystems have adapted accordingly. However, there is now growing consensus in the scientific community that the global climate is warming due to anthropogenic factors, and that the rate of warming is likely to accelerate during the 21st century at an unprecedented rate (IPCC 2001). The concern is that this more rapid rate of change will produce new combinations of temperature and precipitation that will challenge the ability of forest and other ecosystems and the communities that rely on them to adapt (Spittlehouse 2005).



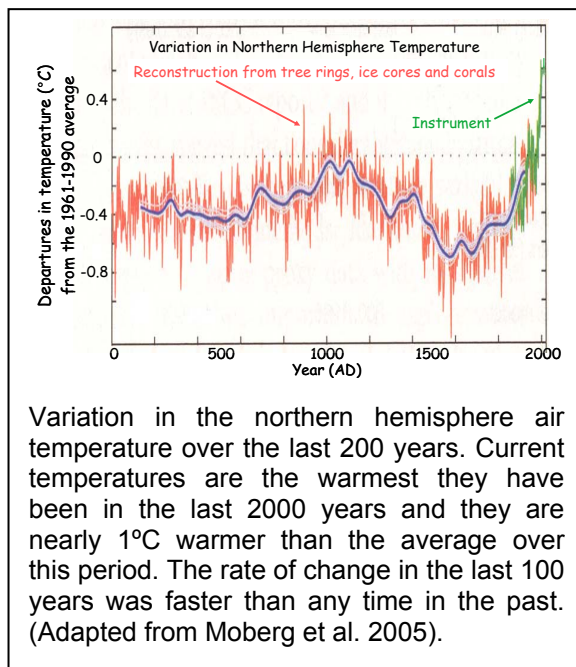
Simulations of the global annual average surface temperature change relative to 1990-1929 for 1900 to 2100. The lines are four greenhouse gas emissions scenarios and two versions of the global climate model. (From the Canadian Climate Centre for Modeling and Analysis, http://www.ccmr.ec.gc.ca/models/cg_m2.shtml)

According to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2001) global atmospheric temperature increased by 0.6°C since the mid-nineteenth century, and is projected to increase an additional 1.4°C to 5.8°C during the 21st century. Much of the observed warming in the latter half of the 20th century is likely due to the burning of fossil fuels and changes in land use and cover (IPCC 2001, Hansen et al. 2004). This projected rate of increase is faster than has likely occurred in the last 2000 years (Moberg et al. 2005). Future climate change will depend on many factors, including how fast greenhouse gases continue to accumulate in the atmosphere, and how the climate system responds.

While the scientific community expresses a high degree of confidence in scenarios of continued atmospheric warming, many uncertainties remain. A key uncertainty relates not to climate

science and global circulation models, but to projections of future greenhouse gas

emissions. These projections are derived from economic models and assumptions about the rate of growth in energy consumption, particularly in the developing world. As there are many possible future global economic development paths, there are many possible future global emission scenarios. Because of the time lag, current global emissions are not expected to significantly affect the magnitude of climate change during the next 30-50 years. However, emissions during the first part of this century will affect the magnitude of climate change in the latter half of this century.



A second key uncertainty relates to the regional and local impacts of climate change. The global circulation models used to simulate potential climate change do not have a high degree of resolution and are consequently not able to provide detailed information about the potential range of impacts at the regional and landscape levels. However, research into improving the resolution of climate models continues and recent developments in downscaling techniques (Ouranos Consortium 2006, Wang et al. 2006) is helping overcome this problem.

Global circulation models project that warming in the Northern Hemisphere will be more pronounced in the north than the south, and that winters will become

warmer and shorter. Historic data and trends suggest that British Columbia is already starting to experience climate change and some of its impacts (Ministry of Water, Land and Air Protection 2002). From 1895 to 1995, the average annual temperatures increased on the coast by 0.6°C (about equal to the global average); in central and southern interior regions by 1.1°C (twice the global average) and in northern British Columbia by 1.7 °C (nearly three times the global average). In particular, minimum temperatures have increased more in winter than in summer months; winter in B.C. is getting less cold.

Climate change scenarios suggest that during the 21st century British Columbia can expect average annual temperatures to warm by 2°C to 7°C, with northern BC continuing to warm faster than other parts of the province, and minimum daily temperatures continuing to warm faster than maximum daily temperatures. While a 3.5 °C temperature increase may not appear very significant, this represents the difference between the average annual temperatures of the southern Okanagan and Prince George.

Increases in air temperature will result in changes in other aspects of climate, including precipitation, air and ocean currents, cloud cover, and the hydrological cycle. Climate change scenarios suggest that annual precipitation could increase by up to 20% by 2100; with more winter precipitation, and a greater proportion of winter precipitation falling as rain rather than snow.

Climate change will manifest itself differently from one region to another. Changes in regional climate drive changes in physical (abiotic) systems (for example, the timing and volume of river flows) as well as in biological systems (for example, the date of bud or leaf emergence).

Projected climate change will have beneficial and adverse effects on both the environment and socio-economic systems. These impacts will occur at global, regional and local scales (IPCC 2001). The vulnerability of these systems will be determined by the nature of climate change, the climate sensitivity of the system, and the capacity of the system to adapt to the changes.

Responding to the risk of climate change can include both mitigation and adaptation:

Mitigation efforts focus on reducing the growth in atmospheric concentrations of greenhouse gases, either by reducing emissions or increasing the removal of carbon dioxide through biological systems (sinks). Because greenhouse gases have global rather than local impacts, a coordinated international effort is required to significantly reduce the growth in atmospheric concentrations.

Adaptation initiatives focus on increasing capacity to prepare for or adjust to climate change and its impacts.

Mitigation on a global scale is expected to slow the rate, and possibly reduce the magnitude, of climate change. Slowing the rate of climate change will make it easier in the future for natural and human-built systems to adapt.

However, regardless of efforts to reduce emissions, climate scenarios project that we are already committed to future climate change. The increase in atmospheric concentrations of greenhouse gases that has occurred over the last 100 years will continue to drive climate change and its impacts for centuries to come (Meehl et al 2005). A comprehensive approach to the risk of climate change therefore requires both mitigation and adaptation strategies.

3 Potential Impacts of Climate Change on BC's Forest and Range Resources

The potential changes to temperature and precipitation patterns identified by the IPCC could have significant impacts on forest and range ecosystems and their utilization by society. Research into potential climate change impacts on forests, and to a lesser extent range, is being undertaken by a number of federal and provincial agencies, universities, private firms and non-profit organizations. While there is relatively little literature on adaptation in forest management, a number of MoFR staff are contributing significantly to this area. This growing body of research has raised awareness of the need to address climate change in forest management practices (Standing Senate Committee on Agriculture and Forestry 2003, CCIAD 2004, Spittlehouse 2005).

3.1 Biophysical Impacts

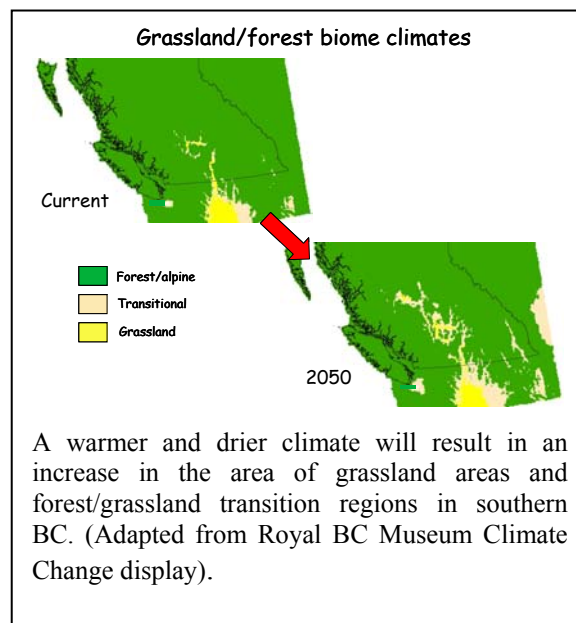
Climate change is expected to result in significant changes to species and ecosystem distribution, processes, and productivity, forest disturbances, and socio-economic systems dependent on forests (Aber et al. 2001, Dale et al. 2001, Hansen et al. 2001, Irland et al. 2001). These changes are expected to have a number of adverse, and in some cases, positive effects on British Columbia's forest and range resources.

In response to shorter warmer winters, plants will break bud earlier in spring. A longer growing season, more frost-free days, warmer soils, and increased precipitation may increase plant

productivity, particularly in northern regions (Rehfeldt et al. 1999, 2001). Some research also suggests that increased levels of CO₂ in the atmosphere may also increase plant productivity and drought tolerance (Aber et al. 2001, Norby et al. 2005).

However, these potential benefits may also be offset by other adverse effects of climate change. Optimum growth conditions for provenances of tree species can be relatively narrow (Rehfeldt et al. 1999, 2001, Parker et al. 2000). Consequently, although species will be able to survive and grow in their current location under a changed climate, growth rates may be affected and there could be increased competition from species or genotypes more suited to the climate. For example, Douglas-fir in southern portions of its range may not receive sufficient chilling during the winter months in order to break winter dormancy in the spring. Insufficient chilling can result in decreased growth, and in some cases mortality (Kimmins and Lavender, 1989).

In a warming climate, temperate tree species generally expand their range northward and upward in elevation, and lose habitat in the southern end of their current distribution (Iverson and Prasad 2002). In mountainous regions, forests could encroach into alpine ecosystems, and drier open forests may be replaced by grasslands (Cummings and Burton 1996, Hebda 1997). A northward expansion of the range of current commercial species could provide new opportunities in northern BC. Similarly, the Coastal Western Hemlock (CWH) zone may move up in elevation into areas now occupied by the Mountain Hemlock (MH) zone. The lower boundary of the MH zone is mostly controlled by snow, and temperature increases will raise that elevation. The positive -- the CWH is much more productive for tree growth than the MH. (D. Meidinger, PC).



However, forests are not expected to immediately occupy new climate environments due to slow reproduction rates and dispersal abilities, and competition with other species, including invasive plants that may quickly occupy disturbed sites. As climate changes, trees may become ill-suited to their climate, adversely affecting forest health and productivity.

In some areas, responses will be limited by physical factors, such as nutrients and soil depth. Inter-species interactions and competition are also difficult, if not impossible, to model. Ecosystem and species shift responses to climate change will therefore not be uniform. It is highly likely that new ecosystems and species associations will occur over time and space.

Climate change is also expected to increase the incidence of insect and disease outbreaks, and spread of invasive species. The current mountain pine beetle (MPB) epidemic in British Columbia is caused, in part, by warmer winters (CCIAD, 2004). Another possible indicator of climate change is the increased incidence of *Dothistroma* needle blight in lodgepole pine forests. Woods et al. (2005) have attributed the recent outbreak in Northwest BC to observed increases in summer precipitation over the past several years.

Forests under stress from drought and other factors may be less resistant to pest attacks and invasive species than non-stressed forests. Forests killed by pests are also more susceptible to fires (Volney and Hirsch 2005).

Warmer temperatures are expected to increase the frequency and severity of forest damaging events such as ice storms, floods and droughts – varying from year-to-year and region-to-region. Drier conditions and a longer fire season are also expected to increase the incidence of forest fires (Flannigan et al. 2005). The large catastrophic fires which occurred in BC's southern interior in 2003 and 2004 have also been attributed, in part, to warmer than usual summer temperatures and extended drought (CCIAD 2004).

The increased incidence of fires and pest damage will also affect hydrological processes, such as evaporation, ground water storage, surface erosion, annual water yields, peak stream flow, and stream stability (Mote et al. 2003, Maloney, 2005).



The red colouring indicates lodgepole pine trees killed by the mountain pine beetle. The recent warmer winters and reduced mortality of the beetle plus a large amount of susceptible pine have resulted in a large area of BC being affected (Carroll et al. 2004). (Photo: Lorraine Maclauchlan)

Increased disturbances, and changes to species and ecosystems in turn will also result in changes to wildlife habitat quality and availability, species populations and behaviour, including predator/prey synchrony. Some changes have already been observed in reproduction, migration, distribution and population sizes of some species due to warmer temperatures (IPCC 2002).

Warmer winters may reduce the length of the winter logging season, and forests could be closed in summer more often due to drought and fire risk. Roads, bridges and culvert will also be affected due to changes in precipitation and soil hydrology, increased storm frequency, earlier snow melt, and the melting of permafrost in northern regions (Spittlehouse and Stewart 2003).



Winter harvesting is often used for sites that are sensitive to disturbance and require the snow to protect the ground and the roads to be frozen. The length of the season depends on the coldness and amount of snow. (Photo: Rita Winkler)

3.2 Socioeconomic Impacts

Biophysical effects will have numerous corresponding and inter-related socio-economic effects. Many B.C. communities are heavily reliant on the forest sector market economy. Significant changes in timber supply, whether through increased forest disturbance or decreased forest productivity, will have wide-ranging effects on local industries and communities. Other socio-economic effects include impacts on recreational services and markets for non-timber forest products. In addition to those benefits captured by the market system, forests also provide numerous non-market benefits to Canadians by providing aesthetic, cultural, and heritage value (Ohlson et al. 2005).

Parks and protected areas, which provide valued recreation opportunities and serve important conservation and heritage aims, may face particular challenges if the maintenance of native forest species and ecosystems is not possible in a fixed location (Scott et al. 2002). Perhaps most overlooked are the potential effects on the ecosystem services provided by Canada's forests, including air and water purification, wildlife habitat, medicinal plants, nutrient cycling, and erosion control.

Economic opportunities arising from changes to climate could include such things as reduction in winter heating costs for MOFR offices, and reduced costs of snow removal from roads.

3.2.1 Impacts on Forest Product Markets

Climate change may also have a wide range of possible impacts on the demand for and supply of forest products. Some researchers (Perez-Garcia et al 2002, Sohngen and Sedjo

2005) have hypothesized that increases in timber productivity resulting from climate change may lead to reductions in market prices for wood products. Such a change in markets, together with potential changes to forest distribution and disturbance regimes could decrease the economic competitiveness of some areas, such as B.C., where harvesting and processing costs are relatively high. On the other hand, the federal report *Climate Change Impacts and Adaptation: A Canadian Perspective* notes that increasing global population may increase demand for wood products, which may offset to some degree price reductions associated with improved productivity. It does not appear that any detailed studies have been undertaken to assess the relevance specifically for B.C. of hypotheses regarding potential market implications of climate change. However, the study by Sohngen and Sedjo (2005) showed that wood producers in South America and Oceania might benefit more than those in North America and Europe due to lower costs and shorter rotations (the latter which allows more rapid adaptation to climate change).

Clearly, these hypotheses are highly speculative, and any impacts would occur decades into the future. Further, the competitiveness of the B.C. forest sector in relation to low cost and/or high productivity areas in the developing world has been a question for some time. The noted studies emphasize the need to monitor regional and global markets closely to ensure that the province has time to develop responses if forest sector competitiveness is threatened by factors related to climate change or other developments.

3.2.2 Impacts on Forest-based Communities

Climate change will affect communities in a variety of ways. It may increase the risk of drought, wildfire, flooding, damage to infrastructure, and health problems related to heat. However, small forest-based communities may also be at risk due to climate change impacts on forest products markets, and other forest-based activities such as recreation and use of non-timber products (Davidson et al. 2003). The MoFR would likely be asked to be intimately involved in the response of small forest-based communities to climate change impacts.

Davidson et al. (2003) hypothesize that "...residents of small, rural, forest-based communities...may tend to disregard information about climate change risk" for reasons related to the importance of the role of the forest industry in local politics and economics and to the association of risk messages with environmental groups. As evidence of the impacts of climate change become clearer, the ministry will likely need to play a role in communicating within forest-based communities about climate change risks, and associated mitigation and adaptation.

Ongoing initiatives such as the Cariboo-Chilcotin Beetle Action Committee and the Omineca Beetle Action Coalition, although not specifically related to climate change, will likely increase awareness of the potential role of climate change in affecting forests and provide examples of how communities can respond to and prepare for climate change.

3.2.3 Impacts on First Nations

Many First Nations live in or close to forests and rely on forests for their economic and cultural well-being (CCIAD 2004). Potential impacts on timber, wildlife, fish, water, and other non-timber products could threaten the sustainability and aspirations of some First Nations communities. Therefore, First Nations can be expected to be concerned about the impacts of climate change on forests.

The First Nations MPB Action Plan explicitly addresses climate change, and commits to “develop and implement institutional structures and policies that ensure the environmental impacts of the MPB epidemic and related climate change impacts are monitored, forecasted, and managed consistent with our perspective of sustainable development, and with the least possible negative impact on First Nations communities and rights.”

Discussions between First Nations and the MoFR about access to timber rights, regulation of forest practices and protection of aboriginal interests may be affected by the impacts climate change. The MoFR will need to work with First Nations to gain mutual understanding of concerns related to climate change, and to design adaptive measures where appropriate.

4 Climate Change Initiatives

A wide range of climate change initiatives are underway in Canada. The federal government and most provincial and territorial governments have plans in place to address climate change, and a substantial level of research is being undertaken at universities and other institutions. This section outlines some of the commitments and progress being made by the federal and provincial governments, and other agencies.

4.1 Government of Canada

On April 23, 2005, the federal government introduced “Moving Forward on Climate Change: A Plan For Honouring Our Kyoto Commitment”. This plan builds on previous federal climate change plans and activities and focuses on mitigation – the reduction of greenhouse gas emissions from sources and the enhancement of removals by sinks. In particular, the federal plan recognizes the significant role of Canada’s forests as a CO₂ sink. At the time of researching and writing this report (early 2006), the new Conservative government had not indicated whether or how the current climate change plan would be modified.

With respect to adaptation, the federal plan indicates that:

- There is an ongoing need for more science, for example into the role of oceans in climate change, and climate system “tipping points” or thresholds;
- Canada’s climate observation network will be enhanced to more fully understand changes that are occurring across Canada;

- Regional and local scale modelling capacity will be developed;
- Canada will expand capacity to transform scientific knowledge into usable information for policy-makers, resource sector managers, and the business community;
- Canada will pursue engagement with other orders of government, universities, industry and community in understanding climate change and developing holistic responses to threats.
- The federal government has also responded directly to the mountain pine beetle epidemic, contributing \$100 million over three years to a response strategy.

In addition to conducting research on the climate change, carbon sequestration, and alternative energy, such as biofuels, the federal government has supported the Canadian Climate Impacts and Adaptation Research Network (C-CIARN). This organization consists of a number of regional and sectoral chapters – including ones for British Columbia and Forests. However, continued funding for this initiative is uncertain...

4.2 Other Provinces

Most provinces in Canada are taking steps to mitigate and assess the impacts of climate change. They are engaged in research and have, or are developing, action plans. A sample of some of the initiatives underway in Quebec, Ontario and Alberta follows. At this time, it appears that no province has implemented any climate change adaptation policies or strategies specific to forest or range management.

The Quebec government, in collaboration with Hydro Quebec, Meteorological Services of Canada and several universities, established the Ouranos consortium in Quebec in 2002. The purpose of this research consortium is two-fold: to generate regional scenarios for the evolution of the climate and its expected impacts; and, to develop expertise and strategies to mitigate the impacts of climate change and to capitalize on potential economic benefits (Ouranos 2006). British Columbia, through the Ministry of Environment, has been a partner in Ouranos and in the development of regional scenarios for the past three years.

Ontario's Ministry of Natural Resources (MNR) prepared a draft climate change strategy and action plan in March 2003. Although this strategy has not been finalized, the MNR is undertaking a number of steps to improve their understanding of climate change, mitigate impacts, and develop adaptation strategies. The MNR has produced a research report summarizing the impacts of climate change on Ontario's forest and held a workshop in November 2004 which identified key issues and suggested actions (NWSI, 2005).

Impacts and adaptation research in Alberta is also in the formative stages. Alberta Environment is developing regionally scaled and adjusted climate models to project plausible climate scenarios for the province. The Forest Genetics Council of Alberta is

also identifying research needs and knowledge gaps associated with climate change and responses to forest trees and ecosystems (AFGC 2005, Barnhardt 2006).

4.3 British Columbia

In December 2004, the BC government published its plan for addressing climate change: *Weather, Climate and the Future: BC's Plan*. This plan outlines 40 actions to reduce provincial greenhouse gas emissions and prepare for climate change and its impacts.

With respect to adaptation, the B.C. plan implicitly recognizes that government has a dual role. Government is an “adaptor” responsible for identifying and managing climate-related risks to public values, including public safety and health, and the health publicly-owned resources such as forests. Government is also a “catalyst” responsible for supporting the development of overall regional capacity – for example, the capacity of municipal governments, First Nations, and small businesses – to recognize and manage climate-related risks.

The B.C. climate change plan includes both “foundation” actions designed to increase overall provincial capacity to prepare for climate change and its impacts, and specific “sectoral” adaptation actions.

The Ministry of Environment (MoE) is the lead agency responsible for provincial climate policy and the implementation of the five ‘foundation’ actions designed to increase overall provincial capacity to prepare for climate change and its impacts:

Action 29: The government will address climate change and extreme weather in planning and operations.

Action 30: The government will implement effective monitoring and reporting procedures for climate change and its impacts in cooperation with partners.

Action 31: The government will help develop climate models and other tools for assessing climate change risks and adaptation options.

Action 32: The government will support applied research that meets the needs of decision-makers.

Action 33: The government will participate in the development of capacity throughout B.C. to respond to extreme weather and climate change.

These ‘foundation’ adaptation actions are generic and apply to all government agencies, including the MoFR. The MoE is working with other agencies to implement these actions and is responsible for monitoring and reporting progress. MoE is also developing a provincial climate change website that will link to sectoral sites maintained by relevant provincial ministries, including MoFR.

The MoFR participated in the development of the provincial plan and is the lead agency for implementation of seven forest-related climate change actions:

Action 16: The government will continue to manage its forests in a sustainable manner, incorporating carbon management objectives where appropriate.

Action 17: The government will continue to assert ownership of any forest sink and associated benefits, and call for recognition of the cost of maintaining that sink.

Action 18: The government will develop a policy framework to provide business certainty and support the creation of incremental forest sinks.

Action 19: The government will continue to improve understanding and protection of the forest carbon sink by supporting modelling and ongoing research, and will continue to protect this sink.

Action 20: The provincial government will enter into discussions with the Government of Canada on forest management mitigation strategies for mountain pine beetle.

Action 21: The government will improve fire protection for communities in British Columbia.

Action 22: The government will limit the economic and social costs of the mountain pine beetle outbreak.

The action items in BC's climate change plan that relate to forest management reflect those activities that the government and the MoFR are, for the most part, already committed to. Actions 16 to 19 are directed towards mitigation, specifically through the maintenance of effective carbon sinks. Actions 20 to 22, although not established with climate change in mind, do convey forest sector adaptation benefits.

MoFR staff are involved in a number of federal, provincial and other climate change initiatives and research and projects. A summary of these activities, and ministry lead projects, are included in Appendix 2.

4.4 BC Universities

A variety of forestry-related climate change research is being conducted by scientists at the Universities of British Columbia (UBC), North British Columbia (UNBC), Royal Roads (RRU), Simon Fraser (SFU), and Victoria, (UVic). For example, the Faculty of Forestry, UBC, is modelling potential climate change impacts to forests communities and tree species, examining limits to current tree species ranges, and investigating provenance responses to temperature and CO₂ (Aitken, 2005). A comprehensive list of other university climate change research applicable to forest and range management is not readily available, nor can this be fairly described within the scope of this report.

4.5 Other Institutions

In October 2005, the Pacific Climate Impacts Consortium was established at the University of Victoria. This consortium is a collaborative effort between the Canadian Institute for Climate Studies, UVic, UBC, BC Hydro and MoE. Like the Ouranos consortium in Quebec, PCIC is intended to provide climate model data, scenarios and

tools to provincial researchers and stakeholders (PCIC, 2006). The MoE provided the seed money for this initiative and will be the focal point for input from other provincial ministries.

5 Preparing for the Impacts of Climate Change

Given the reality of climate change and the apparent vulnerability of forests, forest resource users, and forest-based communities, it is prudent that forest managers and forest-based community leaders begin to develop adaptive strategies to minimize the risks and maximize the benefits of climate change (Spittlehouse and Stewart 2003).

Adaptation can be either reactive (responding after the fact to climate change) or proactive (preparing in advance). For example, the measures taken to address the mountain pine beetle epidemic have largely been reactive. In many cases, it will be acceptable to ‘react’ to climate change through ongoing adjustments (adaptive management). In other cases (e.g. species and seed selection) there will likely be benefits in taking a proactive approach. Because of the uncertainty about many aspects of future climate and its impacts, adaptation measures should ideally convey benefits now as well as anticipated benefits in the future. Examples include the “fire smart” initiative, which addresses existing as well as potential future risks of forest fire.

The large scale of the forested land base means that much of the forest will adapt autonomously to climate change without human intervention. Adaptation efforts will have to focus on the major commercial tree species and perhaps a few animal species, while the majority of forest plants and animals will be left to adapt on their own (Spittlehouse 2005). In turn, society will have to adjust to the result.

The MoFR is charged with managing, protecting and conserving the forest and range resources of the province. Climate change adds another layer of complexity to these management responsibilities. The MoFR is already taking a number of actions to maintain the provincial forest carbon sink and respond to the mountain pine beetle outbreak. Specific initiatives include the development of fuel management and community protection strategies, climate-based seed planning zones, climate profiles for tree species and provenances, and high spatial resolution climate data for climate change analysis. These actions represent initial steps in reducing greenhouse gas emissions and adapting to climate change, but further steps will be required to prepare for climate change.

There are two broad adaptation challenges for the MoFR in the face of climate change: how to manage existing standing forests to ensure they continue to provide, during the decades to come, the goods and services that B.C. relies on; and how to design and manage future forests that are suited to the new climate and other conditions of the future. Adapting to climate change requires a strategy that looks forward into the decades to come. Although climate change will be an important consideration in such a long term strategy, it should be viewed in the context of other long-term risks and current forest and range management goals.

Adapting to climate change will be an iterative process. The MoFR can start now by investing in the development of the tools and knowledge that will provide more information about future climate and its impacts on forests. It can also carry out a comprehensive, high-level assessment of the potential impacts of climate change on forests, and identify potential adaptation strategies. Section 5 describes these types of initiatives in more detail, in two broad areas:

- (1) Cross-ministry initiatives, including research and the development of tools for adaptation, a comprehensive assessment of climate change impacts, and communications and consultation; and
- (2) Management responses – specific to the goals and issues of MoFR program areas.

5.1 Cross-Ministry Initiatives

The potential impacts of climate change cut across many MoFR management objectives and program areas. A corporate response to the risk of climate change can incorporate a number of measures that support efforts in different policy and program areas. These measures can be grouped into three main strategic areas:

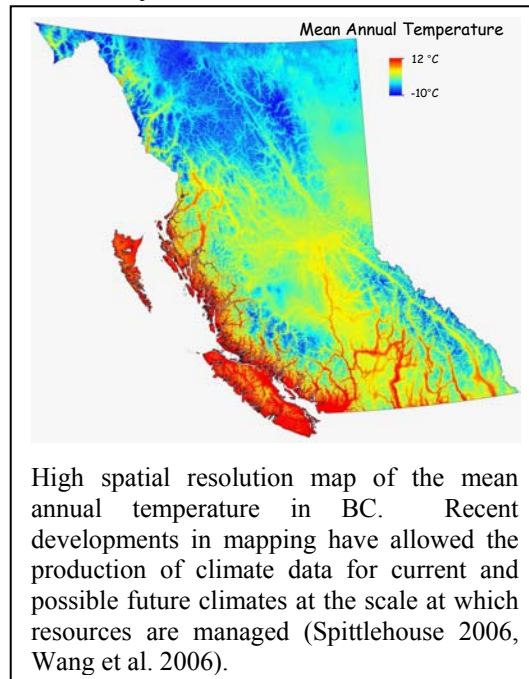
1. Improving knowledge through analysis and research. This could include:
 - A comprehensive climate change impact assessment that would identify the full range of impacts, priorities for MoFR action, and establish a corporate response. The Future Forests Ecosystems Initiative and this climate change report can serve as the foundation of such an assessment.
 - Furthering research in climate change and developing climate models and tools for use in developing policy and assisting in forest and range management decisions.
2. Reviewing policies and practices, such as:
 - Examining opportunities and barriers to increasing species and genetic diversity
 - Developing alternative systems for species selection to ensure that trees will be adapted to future climates
 - Working to reduce greenhouse gas emissions from MoFR operations (vehicles and buildings).
3. Building awareness and capacity, both within and outside of MoFR, by:
 - Increasing awareness of climate change and its impacts within MoFR and among clients and stakeholders
 - Establishing an appropriate governance structure that will ensure clear responsibility and accountability for future climate change work

The following sections discuss issues and options in each of these areas, and identify possible short and long-term actions.

5.1.1 Climate Change Research

A major challenge to responding to change and a major challenge for research is our limited knowledge of the vulnerability of organisms, ecosystems and communities to climate change. Vulnerability is the degree to which organisms, ecosystems and communities are susceptible to or unable to cope with climate change. Different systems are vulnerable to different aspects of change and what may be detrimental to one system could be beneficial to another. Many forest management activities implicitly consider climate. For example, ecosystem mapping is climatically based (Pojar et al. 1987) and seed zones are geographically based but are zones of similar climate (Parker et al. 2000).

The challenge is to develop explicit descriptors of system responses to climate that can be used for management. A first step in this direction is the production of high-resolution, spatial climate data for current and future climate change scenarios for BC (Wang et al. 2006). The challenge now is to link these data with ecosystem and species information to determine impacts of climate change and develop adaptive responses (Spittlehouse 2005). Autecological research is required for evaluating the response of species to climate change. For ecosystems, we need to know which species within an ecosystem are likely to respond similarly.



Broad scale estimates of the implications of climate change have been made (Cummings and Burton 2006, Hebda 1997) but are of limited use for forest management. Preliminary attempts have been made to develop “climate envelopes” for ecosystems and major tree species. Hamann and Wang (2006) developed a correlative model of climate and BEC regional ecosystem units and evaluated where these climates might be in the future under climate change. They used these shifts to assess possible change in range of selected tree species. Meidinger (2005) and Spittlehouse (2006) looked at how the climate might change in an area occupied by an ecosystem and determined the implications for future vegetation in these locations. Work is also in progress to develop climate-based seed zones and climate envelopes for selected tree species (O’Neill pers. com.).

The above-mentioned work needs expanding and there are many areas where little or no research has been done in BC on vulnerability to climate change, e.g., non-timber forest products, wildlife habitat, growth and yield, forest hydrology. Improved knowledge of the productivity and health of orchard seed across wide climatic and latitudinal ranges to

facilitate movement of seed is also required. There is the potential for new climates that currently have no analogues in BC which could make extrapolations from current relationships difficult. Individual species will respond differently to climate change resulting in new associations. Site factors such as soil conditions may exacerbate or ameliorate climate changes. Much of the work that has been done to the present used correlative models that were based on average conditions. Consequently, process-based research is required to evaluate the impact of and response to current and future inter-annual variability and to assess responses new climates.

Forest and range climate change research cannot be undertaken by the MoFR alone. Partnership and collaborative efforts with universities and other research institutions should be encouraged. There are several research funding programs that could be tapped into to support additional forest sector climate change research. These include the Mountain Pine Beetle Action Fund, Forest Science Program, Forest Investment Account, and Forests for Tomorrow.

Possible Actions:

i) short-term

- Evaluate various climate/BEC unit correlative models for current climate
- Evaluate how the climate zones change under a range of climate change scenarios
- Continue genetics research on climate-based seed zones and climate envelopes for provenances.
- Initiate a multi-species orchard seedlot trial to ensure that the gains achieved through four decades of tree breeding in BC will be realized in a future seed deployment system.
- Encourage researchers in other institutions and disciplines to include evaluation of climate change vulnerability as part of their research.
- Compile information on species – climate – site relationships (correlations).

ii) longer-term

- Develop a process oriented approach to including response of species to weather and climate in models.
- Research into autecology of key species, to be used in climate change models.

5.1.2 Monitoring

The climate change issue highlights the importance of climate, forest growth and forest health monitoring networks. Monitoring aids in detecting and quantifying the current

state of the forest environment and plays a key role in assessing change. Long term records are becoming increasingly valuable in assessing natural variability and trends, particularly those associated with human induced perturbations. Monitoring assists in detecting the results of adaptation and mitigation measures, allowing responses to be adjusted to maximize their effectiveness.

Monitoring of hydrological and climate variables is needed to inform a wide range of ongoing operational decisions including wildfire response, road construction standards and replanting strategies. A number of federal and provincial agencies and private industry programs currently exist to address these needs. Meteorological and hydrometric monitoring has a long history in BC with some Environment Canada sites having a continuous record going back into the later 19th century. A number of provincial agencies are also involved in monitoring atmospheric and watershed conditions. Unfortunately, some networks are shrinking in size or being discontinued due to funding constraints or being no longer required by the network owner. When sites are decommissioned and not replaced at the same location, the spatial and temporal discontinuity of the data affects their usefulness for the purpose of tracking change into the future. A recent review (Miles 2003) underscores the need to take a coordinated approach to provide the necessary basic level of spatial coverage.

Monitoring of a variety of environmental elements and processes is necessary to determine the effects of climate change on forest and range resources. Direct impacts on species and ecosystems through indicator variables must also be monitored to determine the scope of potential ecological effects accompanying a changing climate. Monitoring of site productivity for timber growth has long been within the purview of the MoFR and is being extended to include a wider range of vegetation through the National Forest Information System. Forest licensees are responsible for assessing success in forest regeneration after harvesting and achievement of 'free to grow' status. But a system designed to track legal obligations may not necessarily provide a systematic early warning of emerging issues. The forest health surveys such as the Forest Insects and Disease Survey conducted by the federal government for many years provided critical information on the state of the forest. Since 1999, the MoFR has surveyed the majority of the forested land in the province using the overview survey method. The purpose of the survey is to record and report the general trends in disturbance patterns across the provincial forested land base (including provincial parks, private land, and Tree Farm Licenses but not Federal parks).

Data also has to be readily available for use by all in the forest community. Historic climate data current weather data and climate change scenarios are available through the web. Hydrometric data are also available via the web. Wang et al (2006) produced a stand-alone software package to provide downscaled historical climate data for British Columbia. Easy access to biological monitoring data is limited. The Centre for Forest Gene Conservation has developed a web version of its database (ClimateBC) that predicts annual, seasonal and monthly climate variables for any location in BC for current and future periods (CFGC 2006).

Although not all monitoring lends itself to a remote, automated approach, recent advances in the technology are improving our ability to rapidly and reliably collect data in remote areas. For example, low power electronic data logging systems, new environmental sensors and cell phone and satellite communication systems are readily available at reasonable cost. Data collection, quality control and archiving can be done automatically. Increasing interest is being shown in interagency coordination aiming to provide a cost effective, spatially well distributed and representative provincial network of atmospheric and hydrometric monitoring sites.

Air and satellite based systems are being developed that can be an effective tool for tracking vegetation characteristics such as species and forest health.

Long term research plots provide valuable historic trends and have the potential to track future changes as long as they are maintained.

Maximizing the usefulness of data that is collected requires an adherence to standards of equipment, measurement and reporting. In BC these standards are available for many aspects of environmental survey, e.g., ilmbwww.gov.bc.ca/RISC/standards.htm.

Recent developments are aiding our extrapolation of climate data to areas with limited environmental data. These include regional climate models (Laprise et al. 2003) and down-scaled historical climate data and future scenarios that can be interpolated for any point on the landscape (Wang et al 2006).

Possible Actions:

i) short-term

- Determine which climate variables would provide the most value for tracking the impacts of climate change as well as the affected ecological systems and elements.
- Determine the adequacy of existing environmental and biological monitoring networks and identify gaps.
- Evaluate the ability of interpolation techniques to provide data at spatial and temporal scales necessary to describe the environment of biological systems.

ii) Longer term:

- Develop and implement a monitoring plan, in conjunction with other provincial and federal agencies, to maximize the value and efficiency of current environmental monitoring operations.
- Respond to the above-mentioned analysis of adequacy and gaps in biological monitoring networks to monitor the response to climate change.
- Support efforts undertaken by the Canada-BC Hydrometric Network partners to provide long term, stable funding for a sustainable, effective network and for the collection, capture and distribution of non-integrated hydrometric information.

- Support efforts undertaken by BC Hydrometric Network partners to provide long term stable funding to avert network downsizing.
- Create climate and biological data bases for tracking change that are readily accessible to the forest community.

5.1.3 Impact Assessment

Understanding how forests and grasslands and those who rely on them may be impacted by future climate change is a key first step in adaptation. Although this report provides an overview of the potential impacts and risks of climate change, a more comprehensive analysis is required to fully evaluate the vulnerabilities of BC's forest and range resources, and the sectors and communities that rely on them, under a range of possible climate futures.

A comprehensive assessment should be based on a full range of scenarios, and both internal and external consultation. The goal of this assessment would be to identify full range of impacts, and identify which resources, regions, sectors and operations are most at risk. This information will then help to prioritize further research, analysis, and action, and establish a corporate response. The future forests initiative and this climate change report can serve as the foundation of such an assessment.

There are a variety of approaches that have been identified for developing adaptation strategies. The Department of Fisheries and Oceans undertook a broad assessment of the impacts of climate change for the management of Canada's waters and aquatic resources (DFO 2005). This assessment identified risk factors, and evaluated potential impacts and possible responses in a 10 to 20 year planning horizon across the Department's mandate.

There are a number of possible tools that can be developed or adapted and used as part of a comprehensive assessment, including:

- Scenarios of climate change;
- Scenarios of related impacts (e.g. hydrology, vegetation shifts);
- Socio-economic scenarios ('storylines' for different futures – global scenarios exist, the United Kingdom UK has developed national scenarios, possible to develop for BC);
- Costing methodologies – e.g., “Costing the Impacts of Climate Change in the UK: Overview of Guidelines” can be examined for relevance in Canada from The UK Climate Impacts Program (UKCIP); possibly but none Canadian ones

In addition, many tools are available to help sectors prepare for climate change impacts. These include:

- Guidance for specific sectors – for example the Federation of Canadian Municipalities Infraguide program includes climate change in some of its "best practices" materials;
- Decision-making frameworks – such as the Ohlson, McKinnon and Hirsch approach described in section 5.1.5;
- Case studies - UKCIP has a database of these for the UK, and MoE is working to develop some for BC; and,
- Monitoring and data collection networks.

There may be a role for MoFR in supporting (along with MoE and other government agencies) development of tools that are generic in scope and that all can potentially use. Examples are regional climate change scenarios and harmonized monitoring networks. There is also a role for MoFR in leading development of tools that would be of specific use to the forest sector e.g. expanding the Hamann and Wang work on climate envelope modelling and BEC zone scenarios, and developing forest sector case studies (as part of a communications plan).

Possible Actions:

i) short-term

- Undertake more comprehensive assessments of climate change impacts on provincial forest and range resources, the forest sector, and forest-based communities. Such assessment could be used to determine the vulnerability of forest and range resource values and sectors under a range of possible climate futures. These analyses will help identify those resources, regions, and sectors most at risk, which could then assist in prioritizing further research, analysis, and action. Such assessments should involve broad internal and external consultation, which would also serve to raise awareness of climate change and its impacts.

5.1.4 Communication, Consultation and Raising Awareness

Climate change and the related topic of global warming receive a notable amount of media attention and, consequently, are in front of the public and MoFR employees on a regular basis. Many things contribute to this attention, including public/political dialogue and debate over the Kyoto Accord, the recent international climate change meetings in Montreal (Copl1/MOP1) and various natural events such as the Gulf of Mexico hurricanes.

Awareness of climate change and its impacts is a necessary pre-requisite for engaging in informed discussions for building adaptive capacity and developing appropriate responses. However, among MoFR employees, the level of awareness and understanding of climate change generally and to climate changes issues more specifically are not known. While some employees are knowledgeable about climate change, many are not.

The same can be said about external stakeholders. While people obviously follow media coverage and public dialogue about climate change, the level of their awareness and understanding is not clear.

While responding strategically to climate change is a priority for the MoFR, there are a number of challenges associated with communicating climate change issues to MoFR employees, clients and stakeholders:

- While climate change is a very important issue, it is long-term in nature and does not convey a strong sense of immediate urgency;
- Despite the importance of climate change, it must be recognized that communication will occur within the context of heavy workloads, many day-to-day work priorities, the challenges of delivering on Service Plan goals and objectives as well as responding to a myriad of ongoing issues.
- There is an overwhelming amount of information about climate change that can be difficult to sort through.
- Another challenge and opportunity relates to the terminology and jargon associated with climate change, global warming and weather influences. For those who have not been exposed to the issues of climate change, there will be at least some confusion over the language used.

Finally, the scale or scope of responding to climate change varies hugely, with some strategies having to occur across an entire industry or sector, such as forestry, while other responses are focused on actions that can be taken by individuals. It will be important to ensure any communication and information directed at specific audiences makes appropriate distinctions about responsibilities for action

The MoFR has already participated in a number of initiatives within BC to raise awareness of climate change issues in the forestry sector, including:

- Adapting to Climate Change in Northern British Columbia. Prince George, February 2003
- Adapting to Climate Change in the Coastal Pacific Northwest: Challenges for Ecosystems, Communities, Industries and Institutions. Victoria, May 2003
- Climate Change and Forests Genetics. Canadian Tree Improvement Association and Western Forest Genetics Association. Kelowna, July 2004
- Implications of Climate Change in British Columbia's Southern Interior Forests. Revelstoke, April 2005
- Future Forest Ecosystems of BC. Prince George, December 2005.

Organizations other than MoFR and MoE also have a significant role in developing and delivering climate change information. The C-CIARN Forestry centre in Alberta acts as

a clearinghouse for a broad range of forestry-related climate research. Professional bodies also have a role. For example, the Canadian Council of Professional Engineers has been promoting awareness of the impacts of climate change amongst its members, over the past the few years. It is also working to develop new standards and guidelines that take into account the potential impacts of climate change (e.g. greater frequency of return events, such as 10-year floods and storms).

Development of any external MoFR communications will need to be coordinated with MoE for consistency with government's corporate communications strategy and messaging regarding climate change.

Possible Actions:

i) short-term

- Develop and implement a strategy to increase awareness of climate change and its potential impacts on BC's forest and range resources

ii) longer-term:

- Provide on-going information and knowledge transfer to MoFR staff and clients as new information becomes available.

Potential Leads:

Forest Stewardship Division, MoFR, MoE, C-CIARN, universities, professional organizations.

5.1.5 Policy, Planning and Governance

A key management challenge facing the MoFR is how and when to incorporate changing climatic conditions into forest and range policies, planning, and practices. Policy decisions that do not consider climate change may limit future choices. At the same time, action taken now to reduce current climate-related risks may also help to prepare for changes to climate over the next 20-100 years. Assessment of policy choices will require partnerships and on-going dialogue with other government agencies, forest and range licensees, professional associations, communities, First Nations and others.

A growing number of governments and agencies have begun to consider these questions. The National Climate Change Adaptation Framework, developed by a federal, provincial and territorial government working group, also recognizes the importance of incorporating adaptation into policies and operations (ICCIWG 2005). This framework notes that, while this may be a new requirement for many government departments and agencies, it can be accomplished for the most part within existing government structures and in much the same way that governments already identify and develop management strategies for other risks. More effort may need to be devoted to coordination across policy and operational areas to ensure consistency. The framework also emphasizes the importance of reporting on progress in assessing and managing climate-related risks.

Olson, McKinnon and Hirsch (2005) set out a simple planning framework for adaptation that involves four steps:

- Step 1 – Define the problem and set management objectives. Management objectives define the things that matter, the resources or management endpoints that decision-makers and stakeholders care about, and that may be vulnerable to climate change (e.g., maximize timber supply, protect or enhance recreation). Different priorities may be attached to management objectives.
- Step 2 – Assess vulnerabilities. A vulnerability assessment examines the mechanisms or pathways by which climate change could affect timber supply and other management objectives. Vulnerability assessment is discussed in more detail in section 5.2 below.
- Step 3 – Develop risk management strategies. Climate change may have potential impacts across a range of MoFR management objectives and programs. Possible adaptive measures could address management objectives (Step 1) or vulnerabilities (Step 2). For example, using the example of managing a timber supply area, various measures will be available for forest regeneration (e.g., planting drought-tolerant genotypes, controlling invasive species), silviculture treatment (e.g., managing tree densities and species composition, altering rotation age), and fire protection (e.g., increasing suppression capability, developing fire-smart landscapes). Many of these strategies and tools are already in use by forest managers – the difference here is their application in the context of a changing climate (Spittlehouse and Stewart 2003).
- Step 4 – Evaluate strategies and trade-offs. Management strategies will have different implications, uncertainties, costs and benefits. Tradeoffs across strategies or across management objectives need to be considered in the context of priorities. This can be done through a deliberate process that involves decision-makers, stakeholders, experts and analysts.

The Canadian Environmental Assessment Agency, through a committee of experts from its member federal, provincial and territorial governments, has also produced a guidance document for incorporating the climate change considerations into environmental assessment (CEAA 2003).

While these and other initiatives are useful examples, there is no standard approach that can be applied to incorporating climate change into BC's forest and range strategies, programs, policies, plans and practices. Instead, the MoFR's approach to integrating climate change must recognize that different areas within the MoFR will have existing methods and strategies for evaluating and managing risks. The goal is to integrate climate change considerations into these existing approaches.

In order to effectively prepare for the anticipated impacts of climate change, the MoFR will need to develop capacity within the organization and apply resources. The formation of the Climate Change Task Team and this report provide a strong foundation for preparing the MoFR's response to climate change. Additional resources and

executive support will be required to continue this work. Furthermore, in order for the MoFR's response to be successful it must be sustained over the long-term and fully incorporated into the ministry's ongoing activities.

Opportunities:

- Incorporate climate change risks and opportunities into the MoFR's on-going forest and range programs, policies, planning activities, goals, strategies, and practices.
- Increase the MoFR's capacity to address climate change and its impacts in all relevant activities.
- Gain synergy by strengthening partnerships with other institutions working on climate change/forest and range research and issues. This may include academia, other government agencies, licensees, communities, First Nations and others.

Possible Actions:

i) short-term

- Undertake comprehensive assessments and sensitivity analyses to identify the nature and extent of anticipated changes, and quantify realistic opportunities. Use the results to reduce costs and/or exposure, and direct wise and more effective investment;
- Identify opportunities for building adaptive capacity in key areas, for example by providing information, data, tools and other resources to forest health and reforestation professionals;
- Identify opportunities where adaptation actions may be needed in the next few years, and where approaches can build on experience in other sectors (for example in road engineering).
- Identify climate change related activities and targets in the MoFR's annual service plan.
- Consider current and potential climate change in developing or revising policies, strategies, programs, plans and operational decisions, especially where climate is already known to be a risk factor.

ii) longer-term

- For the outcomes that the MOFR is responsible to achieve on behalf of the Province, determine how climate change will affect our ability to achieve them.
- Identify future climate change-related priorities, and make recommendations to executive.

- Establish a climate change policy section within the ministry – responsible for coordinating policy, research, and communications activities across MoFR.
- Expand the climate change community of practice within the MoFR
- Ensure that the appropriate expertise, information, tools, resources and methodologies are provided to those responsible for implementing adaptation initiatives
- Strengthen links between climate change science, policy and operations through on-going coordination and communications.
- Periodically review climate change resourcing and adjust as necessary

Potential Leads:

- Forest Stewardship Division

5.2 Management Issues and Responses

Current forest and range policies and practices are designed for the climate conditions that were present in the province over the past several decades. These conditions are changing, and these policies and practices may therefore no longer convey the desired management outcomes.

Ecological transformation can be expected. A deeper understanding of the nature and extent of those transformations will enable us to plan for the opportunities and avoid wasting effort on lost causes. For example, where the likelihood of crop trees reaching a full rotation is low, options other than reforestation to existing species could be considered to maximize return on investment. Sensitivity analyses could identify areas where consideration could be given to activities with the most positive outcomes, including in some cases best alternative land uses.

Some non-timber forest values may improve with appropriate stewardship. For example, forests and forest soils are important in removing and storing carbon. This may become highly valued as CO² offsets become widely traded. This could allow for selected high value tree removal while fostering robust functioning forests.

Forests are also significant in regulation of the hydrologic cycle, and climate change could make water available throughout the year rather than only seasonally in some areas. This could have direct economic benefits in terms of power generation, fish stocks etc. Power and especially water are likely to become central issues in the near future.

On a global scale relative to other places BC may still have significant areas of land where productivity could increase as temperatures increase in in-situ forests whereas elsewhere declines may be much more likely and major shifts in species mix required as temperatures and summer drought rise.

A comprehensive assessment and sensitivity analyses are essential to identify and quantify realistic opportunities.

While we in BC may have greater potential for an up-side than other places, the reality of a significant down-side (almost certainly greater than the upside) must not be understated. (R. Hebda, PC)

New management strategies may need to be developed and implemented in a number of areas to address climate-related risks. The following sections outline a few potential forest and range management responses to climate change. These topic areas do not represent a complete list of all the potential issues, but correspond to policy and management responsibilities within MoFR.

The discussion of issues and options is preliminary, and further research, analysis and consultation should be considered prior to implementation. This work could include a broader (e.g. ministry-wide) assessment of climate-related risks, establishment of priorities for action and investment (i.e. which risks are most significant, and what areas could most benefit from short term investment), identification and assessment of management options (including stakeholder input), and identification of any barriers to and/or opportunities for action.

5.2.1 Silviculture and Forest Genetics

The narrow adaptive range of individual trees will result in many of BC's natural and planted forests being significantly maladapted within their lifespan or current rotation as a result of climate change. Substantial losses in productivity of natural and planted stands are expected to occur in the south, particularly in the driest and warmest regions of the province, while modest increases are anticipated in the north (Rehfeldt et al 1999, 2001).

Nigh et al. (2004) and Johnson and Williamson (2005) also estimate that forest productivity will generally increase in a warmer climate. However, these projections may only be realized if the climatic conditions do not exceed the genetically programmed physiological tolerances of specific genotypes. Reduced growth or mortality of trees, and their regenerated offspring, may occur even if growing conditions become more favourable.

Four general silvicultural strategies have been proposed to address the issues of poor adaptation of trees and maintaining productivity in managed forests in a changing climate (Parker et al. 2000, Spittlehouse and Stewart 2003):

- move tree species and seed sources beyond



Influence of climate on regulating the growth of lodgepole pine. The young trees on the left are from seed local to the site and are adapted to the climate. The seed that produced the trees on right are from a much warmer climate. They do not respond well to the cooler climate of the planting site. (Photo: Doug Ashby)

their current range or prescribed limits by transferring them further north and higher in elevation (i.e. facilitated migration) to capitalize on a warmer climate;

- increase the number of species and genetic diversity of trees used to establish a stand;
- increase stand density (e.g. increasing target and maximum stocking); and
- breed for environmental stability and pest resistance.

Facilitated migration

Species selection guidelines, stocking standards, and the Chief Forester's Standards for Seed Use ensure BC's planted forests are adapted to the climates they experience. Significant modifications will be required of these guidelines and standards over time to ensure their continued effectiveness.

Facilitated migration may be one of the most effective and least expensive forest management adaptation strategies to address climate change (Andalo et al. 2005; Rehfeldt 1999, 2001; Parker et al. 2000; Tchebakova et al. in press). By planting species and seedlots adapted to a future climate, it may be possible to mitigate productivity declines in some areas, and increase productivity in others (Rehfeldt 2001).

Use of future BEC variant maps (e.g., BEC projections to 2025), or other climate models, as the basis of species and seed selection would help ensure that seedlings planted today would be adapted to the range of climatic conditions projected to occur over the majority of their rotation. Use of future BEC variant maps would also maintain the current system of developing species selection guidelines and stocking standards, and capitalize on decades of autecology research.

Trees are most susceptible to climate-related damage (e.g. frost and drought) when they are young. Persons with reforestation obligations may therefore be reluctant to select species based on future climate projections, especially if there is a perceived risk that they will not survive or reach free growing. Furthermore, developing species selection guidelines based on future climate projections would not ensure that such recommendations will be incorporated into Forest Stewardship Plans and stocking standards. Policy changes, guidance documents, and training in the application of future climate maps and tools for species selection will be required.

Selection of seedlots adapted to future climates will also help ensure healthy and productive future forests. Currently, seed transfer is regulated by a geographic focal point system, in which seedlots must originate from and be used within prescribed geographic and elevational distances. Increasing the upward elevation and northward latitudinal seed transfer limits could make seedlots available from warmer areas. Conservative adjustments to the natural stand seed transfer limits can be made relatively easily through amendments to the Chief Forester's Standards for Seed Use. However, increasing a seedlot's transfer limits would not guarantee that seedlots would be better adapted to future climates.

Eventually, a “climate-based” seedlot selection system will have to be developed and instituted to ensure the appropriate adaptation of planted stock. A broad range of alternative seed transfer systems should be explored and assessed based on their advantages and disadvantages in terms of productivity, accuracy, risk, ability to accommodate a changing climate, cost effectiveness, and ease of implementation and use.

Increasing diversity

Increasing diversity is a well-recognized strategy to deal with uncertainty in many fields. The probability of achieving a harvestable crop under a range of possible climates is increased in plantations that consist of multi-species and/or multi-seedlots. Diversity in forest plantations could be increased by increasing the number of species and the number of seedlots of each species planted at the cutblock and landscape level. Species diversity may also be enhanced through silvicultural practices, such as cutblock design, retention of canopy trees, protection of advance regeneration, and site preparation.

Species diversity was the focus of much discussion in the recent MoFR review of species management in areas impacted by the mountain pine beetle (Martin et al. 2005). As a result of this review, the MoFR is updating the species selection guidelines, examining effects of species choices (including broadleaf tree species) on long-term harvest levels, and assessing means to establish forest-level targets for cutblock species composition. These reviews will also help to inform the implications of species selection options in consideration of climate change.

Genetic diversity at the stand level could also be increased through the deployment on a cutblock of multiple seedlots collected from a range of climatic environments. This strategy may increase the number of seedlings capable of surviving extreme weather events.

Increasing the number of trees that contribute to a seedlot would also increase the genetic diversity of the seedlot. However, this increase would be negligible because current minimum number of parent trees which must contribute to a seedlot already captures the vast majority of genetic diversity. The existing minimum genetic diversity requirement is based on research that indicates 95% percent of the genetic diversity within a population is found within 10 individuals from that population. This percentage does not increase significantly in a population size under 100. Consequently, the probability of achieving a harvestable crop under a range of possible climates is therefore greatest in plantations that consists of multi-species and/or multi-seedlots.

There is already lots of opportunity within regulations and standards for increasing species and seedlot diversity on a cutblock. However, implementation of these options would result in increased administrative and operational costs.

Managing stand density

Increasing planting density may also reduce the risk of plantation failure by increasing genetic diversity (Ledig and Kitzmiller 1992). However, increased planting density may also result in greater moisture stress or increased susceptibility to pests within the

plantation in some regions. In the event of increased summer drought, greater moisture stress may offset any beneficial effect of increased genetic diversity. Increasing stocking density through planting will also result in increased operational costs in the growing and planting seedlings. An investigation of these factors is required before any recommendation can be made regarding stand density.

Breeding for environmental stability and pest resistance

Breeding for environmental stability to address climate change would reduce the gain available for volume, would be time consuming and costly, and would be only slightly effective. It would be more efficient to use species and seed sources that originate from more stressful environments than to develop new populations adapted to a range of environments.

Similarly, breeding for resistance to pests in anticipation of climate change would also take considerable effort. Not only are changes to the pest-host relationship under a changing climate difficult to predict with a high level of certainty, so too would to changes to the host's defence mechanisms. By the time pest tolerant individuals are identified, established in a seed orchard and produce seed, the pest could have evolved to overcome the resistance mechanism or it may no longer be an issue. Implementing other silviculture and forest health strategies would therefore be more effective than breeding for pest resistance. Nonetheless, where pest tolerant parents or populations have already been identified, and such weevil tolerant interior spruce, efforts could be made to increase seed production from these trees.

Adaptive Responses:

- Facilitate migration of species based on future climate change projections
- Facilitate migration of seedlots based on genecology research and future climate projections
- Increase the species and genetic diversity of plantations

Possible Actions:

i) short-term

- Examine the opportunities and impacts of using future BEC variant maps, or other future climate or ecosystem maps, to guide species selection.
- Examine operational and policy barriers to the implementation of facilitated migration and increasing species and genetic diversity in plantations.
- Implement wide-ranging multi-species orchard seedlot productivity trials to identify most productive species and seedlots for sites based on future climate scenarios.
- Explore opportunities to implement climate change related silviculture and genetic strategies within the Forests for Tomorrow program.

- Examine options for expanding current seed transfer limits and alternative seed transfer systems based on current knowledge and climate change trends.

ii) longer-term

- Make incremental adjustments to species selection guidelines and seed transfer limits as more information is obtained.
- Revise productivity and genetic gain estimates for species and breeding populations based on the results of the multi-species/multi-seedlot trials.

Potential Leads:

- Research Branch, Tree Improvement Branch, Forest Practices Branch, Forest Analysis and Inventory Branch.

5.2.2 Forest Health

There is general agreement that temperatures are increasing both globally and regionally due to climate change. Increasing temperatures will lead to range expansions for both hosts and their pests. As many insect pest life cycles are degree-day dependent, it is logical that increases in temperatures could shorten insect life cycles. This in turn could lead to more rapid increases in insect populations resulting in more damage to forest resources.

Warmer temperatures would result in plants breaking dormancy earlier in the year. This could increase the risk of damaging frosts if warming is not sufficient to ensure late spring temperatures remain above zero (Cannell and Smith 1986). This in turn could make the trees more susceptible to pest damage.



One of the many young lodgepole pine plantations in central BC seriously damaged by a needle fungus called *Dothistroma*. This is the result of an increase in the number of warm and wet days in the summer increasing the opportunity for infection of the needles (Woods et al. 2005). (Photo: Alex Woods)

Changes in precipitation regimes, though much more difficult to predict than changes in temperature, will also have significant consequences for forest pests, their hosts and forest management in BC. Evidence of climate change already affecting these complex relationships in the forests of BC has recently been published. The mountain pine beetle epidemic throughout the interior of the province has in part been caused by increases in mean winter temperature (Carroll et al. 2004). A recent marked increase in mean summer precipitation in northwest BC has been linked to an unprecedented *Dothistroma* needle blight epidemic in the area (Woods et al 2005).

The Dothistroma example highlights the uncertainty regarding forest pests and their hosts throughout much of the province. The climate changes that have recently occurred in northwest BC, specifically increased summer precipitation, should have been beneficial to tree growth (Rehfeldt et al 1999, Nigh et al 2004). Instead that increased summer precipitation favoured the development of a pathogen that eliminated any growth benefits that might have occurred. Dothistroma needle blight has gone from relative obscurity in the province to the best known forest pathogen in less than five years. Such changes to host/pest relationships make predictions difficult. A list of other potential forest health risks in response to climate change is included in Appendix 4.

The combinations of hosts and their suite of pests will, of course, be different depending on location throughout the province. However, the scientific fact remains that short-lived insects and fungi will be able to adapt to new environmental conditions under climate change much more quickly than their long-lived hosts. How these relationships will play out is unknown. In some cases, new relationships could be positive for some forest resources. In others, there is a high probability that these new relationships will be negative, particularly in terms of timber productivity. As a result, strategies are required to prepare for a range of scenarios, and diversify managed stands in order to make them more resilient.

Adaptive Responses:

- Implement silviculture strategies that reduce susceptibility of forests to insects and pathogens (e.g., increase species diversity in managed stands to cope with uncertainty and increase resiliency).
- Plant species suited to projected future climate conditions (e.g. facilitated migration)

Possible Actions:

i) short-term

- Identify and assess silviculture strategies that can reduce the potential impact of forest health risks. (see example of a forest health risk assessment in Appendix 5)

ii) longer-term

- Monitor success of mixed species managed stands and modify species composition of newly created plantations as climatic conditions change.
- Incorporate climate change into provincial and timber supply area Forest Health Strategies.

Potential Leads:

- Forest Practices Branch, Regional Forest Health Specialists

5.2.3 Timber Supply

Timber supply is the result of all of the biophysical and socioeconomic variables that affect forest productivity, the availability of land for harvesting, and forest management objectives. Climate change could affect timber supply by changing reforestation success, tree growth, survival and extent of forest pests, wildfire, wildlife habitat ranges, hydrology and other forest management considerations. Assessing the potential timber supply impacts of climate change will require estimates of both the magnitude of and uncertainties associated with the potential changes to these factors.

Timber supply for large management units such as Timber Supply Areas can be viewed as the outcome of the accumulation of considerations, so that offsetting influences may be important to consider. Negative impacts in one location could be counteracted by positive impacts elsewhere. Therefore, an assessment of timber supply implications at the provincial level must account for potential differences in conditions in different ecosystems, and the availability of resources to undertake adaptive or mitigative actions.

Some of the more prominent uncertainties that could affect timber supply are:

- the characteristics and rate of climate change (temperature, precipitation, geographic distribution, extremes).
 - the magnitude and rate of changes;
 - uncertainties related to projections of geographic shifts in biogeoclimatic ecosystems;
 - changes in climate in different areas and/or ecosystems within the province (some ecosystems will likely be subject to more extreme impacts than others).
- the impacts of climate change on trees (regeneration success, productivity).
- variation of impacts as stands age (i.e., how will a specified climate change scenario affect recently established versus young free growing versus mature and old stands?).
- availability of stock for reforestation (i.e., it may be desirable to plant improved stock with particular adaptive characteristics, but how much is available for different ecosystems?).
- changes to disturbance regimes and the effects on stand replacement, forest productivity, etc.
- effects of regulatory, infrastructure and economic factors on adaptation (i.e., are there barriers to desirable change relative to existing standards):
 - free growing requirements

- costs
- market issues (competitiveness)
- milling technologies
- hardwood versus conifer balance.

Adaptive Responses:

Reducing the risk of losses in timber supply due to climate change could involve changes in the following forest management activities:

- choice of species for reforestation
- alternative silvicultural systems
- forest protection or pest management regimes
- harvest cycle (rotation length)

Adaptive responses related to specific values or activities such as reforestation, forest pests and others, will affect timber supply. Therefore, it will be important to examine climate change scenarios and forest management adaptation strategies for their potential timber supply implications. An assessment of the effects of management options to address climate change risk would need to consider the following, and other, issues:

- Should examine a range of options for reforestation and silvicultural systems (e.g., status quo, “best practices”, intermediate) together with scenarios representing a range of climate change.
- What species will be planted in what proportions?
- In which ecosystems will different reforestation regimes be applied?
- Does a reforestation option (e.g., plant mixed species) apply on each block, or could a landscape-level mixed-species strategy be devised?
- What conditions does a management option address?
- Warmest? Full range of temperatures? The extremes (hot and cold)?
- Will there be sources of seed to support each management alternative? (what changes might be required in the tree breeding and/or genetics programs to support different management alternatives?)

Impacts of management alternatives

- Growth and yield

- Probability of plantation success/failure
- Non-timber values (e.g., snow interception, wildlife, etc.)
- Variation of impacts as stands age (i.e., how will a specified climate change scenario affect recently established versus young free growing versus mature and old stands)?

Possible Actions:

i) short-term

- Undertake an analysis of the potential impacts of climate change on timber supply under alternative species choices (including broadleaf tree species).
- Develop a broader conceptual model for assessing the impacts of climate change on forest values, and of policy and management options for responding to climate change. Development of such a model will help to fine tune questions about the spatial and temporal nature of climate change and about the feasibility and efficacy of various responsive actions.

ii) longer-term

- Understanding the timber supply implications of climate change will require an ongoing commitment to analysis of timber supply that incorporates information on climate change, the responses of forest components (e.g., trees) to those changes, and the actual and planned management responses.
- Longer-term action could include an investigation of claims that climate change may lead to a reduction in the competitiveness of the B.C. forest sector if areas of the world with lower production costs benefit more from climate change-related increases in forest productivity.

Potential Leads:

- Forest Analysis and Inventory Branch

5.2.4 Fire Risk and Protection

The kind of fire activity that characterizes a given area is referred to as its fire regime (Merrill and Alexander 1987). Some of the important elements generally considered in a fire regime are fire frequency, intensity, severity, size, type and seasonality. The ecological significance of these elements has been documented for several ecosystems (e.g., Ahlgren and Ahlgren 1960, Malanson 1987, Whelan 1995, Smith 2000, Brown and Smith 2000, NWCG 2001, Sandberg et al. 2002, Neary et al. 2005) and includes fire effects on: nutrient cycling and soils, species composition, landscape and stand structure, water and air quality, successional pathways, and biodiversity. Associated with these are subsequent effects on human health, recreation, social values and economy.

There is a correlation between climate and fire activity in a given area (Flannigan et al. 1998, Fried et al. 2004). In fact, it has been suggested that most, if not all, the elements of a fire regime can potentially be influenced by climate (Dale et al. 2001, Fried et al. 2004, Volney and Hirsch 2005). Moreover, due to the quick response of fire behaviour to changes in fuel moisture (affected by variables such as precipitation, wind speed, relative humidity, and air temperature) and wind speed, fire regime is expected to be highly sensitive to climate change (Weber and Flannigan 1997). Several studies performed in Canada (e.g., Flannigan et al. 1998, Flannigan et al. 2001, Stocks et al. 1998, Wotton et al. 2003) have suggested that a changing climate may lead to significant increases in fire weather and overall fire danger, although regional variations are expected.



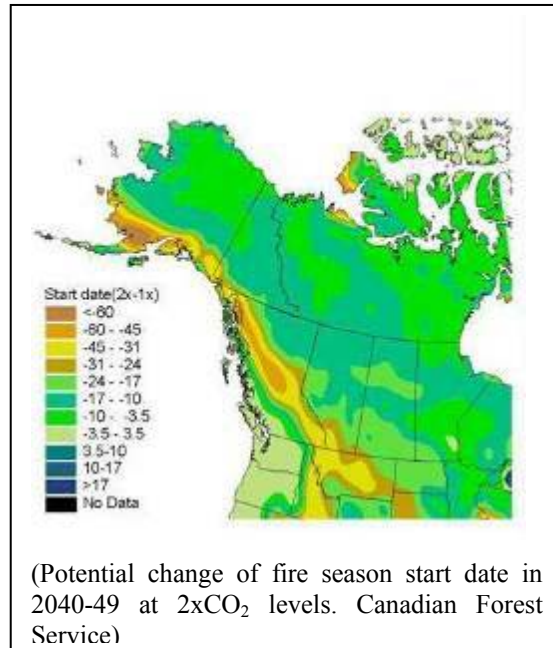
Forest fires are expected to increase in intensity and the fire season will start earlier under a warming climate. (Photo: Canadian Forest Service)

The associated potential effects of global warming on various elements of the fire regime have been studied. For example, it was predicted that seasonal fire severity could increase by 46% across Canada (Flannigan and Van Wagner 1991). Fire season length could also increase by an average of 22% (30 days) across Canada in a double CO₂ scenario (Wotton and Flannigan 1993). Li et al. (2000) have calculated that under the doubling carbon dioxide scenario the Fine Fuel Moisture Code (FFMC) (Van Wagner 1987) would increase by one point compared to its current distribution, potentially leading to changes in the fire regime such as an increase in fire frequency. In Ontario, Wotton et al. (2003) suggested that people-caused ignitions would increase by 18% and 50% for 2050 and 2100, respectively. It is also believed that an increase in convective activity could potentially lead to more opportunities for ignition (Stocks 1993). In the United States, Price and Rind (1994) looked at lightning ignitions and predicted a 44% increase in annual mean number of lightning fires for a 2 x CO₂ scenario.

Despite much inter-annual variability and the uncertainty related to older statistics, it has been observed that area burned has increased in the last part of the century (Flannigan and Van Wagner 1991, Amiro et al. 2001) and further increases have been predicted for the future. For example, the results obtained recently by Flannigan et al. (2005) suggested a 74-118% increase in average area burned by the end of this century (3xCO₂ scenario), without explicitly taking into account other variables that could also influence area burned in the future such as changes in vegetation, ignitions, fire season length and human activity. Previously, Flannigan and Van Wagner (1991) had suggested that the area burned in Canada would increase by approximately 40% in a doubled CO₂ scenario while Li et al. (2000) predicted a 63% increase in area burned. Price and Rind (1994) predicted that area burned would increase in the continental United States by 78% for a 2xCO₂ scenario.

In northern California, Fried et al. (2004) estimated that the number of fires that exceed initial attack containment (escaped fires) would remain the same or increase up to 125%, depending on the area investigated. Moreover, they predicted that the area burned by contained fires would vary between -8% and 41%. It has further been suggested that the rate of change in area burned will not be linear and the effects of higher climate oscillations such as El Nino Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) will be superimposed upon the global warming trend (Flannigan et al. 2005).

General circulation models appear to have difficulties with predictions in complex terrain regions (Flannigan et al. 2005) like the ones encountered in several parts of British Columbia. They nevertheless predicted that the area burned for their ecozone corresponding to most of the province is expected to increase by an average of 122% in a 3xCO₂ scenario (Flannigan et al. 2005). Simulation results also suggested that the fire season could increase by 39% (51 days) (Wotton and Flannigan 1993) in British Columbia in a 2xCO₂ scenario.



A project looking at the effectiveness of Regional Climate Models in the assessment of expected potential impacts of climate change on fire severity, occurrence and fire behaviour in British Columbia, predicted an increase in seasonal fire severity rating and an increase in fire season length of 1-2 weeks by the year 2045 and 2-3 weeks by the year 2085 (Flannigan et al. 2002). A preliminary analysis of the fire history database for the province suggested that the initial attack fire season has been increasing at a rate of 1 to 2 days per year since 1980 (Judi Beck, pers. comm.).

Fire is only one type of disturbance that can affect a forest, and the predictions looking at the effect of climate change on the fire regime generally do not consider the global warming impacts on the whole disturbance regime complex (the net effect of each disturbance regime plus their interactions (Fleming 2000)). The interaction between climate change and the whole disturbance regime may lead to a significant positive feedback that might further drive the global warming (Weber and Flannigan 1997, Dale et al. 2001, Volney and Hirsch 2005, Stocks 1993). The compounded interactions between disturbances may in fact be, under climate change, unprecedented and unpredictable (Dale et al. 2001). Several documents discussing disturbances and their interactions have been published (e.g., Volney and Hirsch 2005, McCullough et al. 1998, Fleming 2000).

It has been suggested that the “interaction between climate change and fire regime has the potential to overshadow the importance of the direct effects of global warming on species

distribution, migration, substitution, and extinction” (Weber and Flannigan 1997, Flannigan et al. 2002) in some ecosystems. It could then become the driving force that accelerates future vegetation shifts (Stocks 1993) due to the immediate influence of weather and climate on fire behaviour (Weber and Flannigan 1997).

Changes in fire regime caused by climate change could lead, for example, to:

- a direct impact on the safety of people and property (Fried et al. 2004, Volney and Hirsch 2005),
- a higher number of escaped fires, linked to an increase in suppression costs (Flannigan et al. 2005, Stocks 1993),
- a decrease in landscape diversity and fragmentation (Weber and Flannigan 1997, Li et al. 2000),
- an effect on the distribution and functioning of forest ecosystems (Flannigan et al. 2002, Stocks 1993), and
- socioeconomic implications, including sustainability of forest dependant communities and federal and provincial revenues from taxes and resource rents (Ohlson et al. 2005, Volney and Hirsch 2005, Stocks 1993).

Adaptive Responses

- Adopt or maintain legislation that has enough flexibility to cover the changes that will impact the forest and range sectors due to climate change and that will be compatible with the new Wildfire Act.
- Approach the impact of climate change on fire (or forests and range) from a landscape management perspective that considers long time scales.
- Support on-going actions (e.g., monitoring and analysis of current databases (e.g., fire weather/climate, fire history); fuel management and community protection activities; adoption of flexible standards (e.g., “flexible fire season versus fixed dates); continued implementation of Filmon’s recommendations (Firestorm 2003)), in particular those that are likely to convey adaptation benefits.
- Adapt or build fire (and forest) management tools and procedures that can be continually updated in order to incorporate new findings on the impact of climate change on (forest and fire) management.

Possible Actions

i) short-term

- Inform the public, industry and other agencies of the potential impact of climate change on the fire regime in the province and continue to encourage pro-active actions in regard to fuels management and community protection.
- Determine how to best incorporate strategic goals and actions related to climate change into the new strategic plan that is currently being developed by the Protection Program (also part of longer term action).

ii) longer-term

- Incorporate the impacts of lengthening fire seasons into the workload analysis that is being undertaken by the protection program. Investigate methods by which to incorporate other climate change impacts into future analyses.
- Identify the main interactions and (positive or negative) feedback mechanisms existing between natural resources, land use and disturbances (e.g. fire, insects, etc.) to determine how they would be affected by different climate change scenarios.
- Consider risk management strategies to address potential increases in the frequency and amplitude of peaks in fire management service demand, including an evaluation of current mutual aid arrangements with other Canadian and American fire management agencies (e.g., one approach could be to contribute to increasing the national fire management capacity through the Canadian Wildland Fire Strategy.
- Collaborate with other provincial, federal, and international fire management (and other) agencies and universities to share data and analytical approaches to this global issue.

Potential Leads

- Protection Program, Land Managers

5.2.5 Timber Harvesting and Forest Road Engineering Risks

Climate change may have economic implications for aspects of forest development relating to timber harvesting and forest roads. For example, warmer winter climate has the potential to shorten the winter harvest season if freeze-up and break-up occurs later

and sooner in the year, respectively. In another example, the expected higher rain intensities in a warming climate, together with a halving of the return period of high intensity rains predicted in the latter part of this century (Bruce 2003), may necessitate the design of larger openings for bridges or culverts on stream crossings to ensure that they pass more frequent and higher peak stream flows.

Climate change may also affect the frequency and magnitude of post-forest development landslides. More severe storm events along coastal British Columbia with warmer climate may negatively affect how steep terrain will respond to clear-cut harvesting, and



Influence of an excessive amount of water on road stability. (Photo: Tim Giles)

road construction and deactivation. More intense rainstorms and rapid snowmelt from enhanced rainfall or sudden temperature increase are likely to increase the probability of occurrence of landslides, including debris flow activity (Wieczorek and Glade 2005).

In the future, Terrain Stability Professionals, as members of Association of Professional Engineers and Geoscientist of BC, may be required to consider, as a potential factor in their terrain stability assessments, the affects of climate change on their engineering estimates,

such as the likelihood of landslide occurrences after forest development planning and operations.

After recent interface wildfire events in the Southern Interior Forest Region, it is recognized that the effects of wildfire on terrain and natural hazards may result in increased flood and landslide risks to human life, property and infrastructure. Warming trends in climate and potential increased occurrence of wildfires, would increase the likelihood of post-wildfire hydrogeomorphic activity.

In addition to raising awareness of climate change amongst its members, the Canadian Council of Professional Engineers is working to develop new standards and guidelines that take into account the potential impacts of climate change (Dakin 2005, CCPE 2005). As evidence of climate change becomes more apparent over time, professional engineers will be expected, as a matter of due diligence, to take this into consideration during their field assessments and designs for forest development planning and operations.

Adaptive Responses:

- Increase awareness of the implications of climate change on timber harvesting and forest roads.
- Assess increased hydrological, landslide, and wildfire risks due to predictions of more severe rainfall intensities, increased flood magnitude and frequency, and increased frequency and severity of drought periods.

- Plan timber harvesting operations, design and construct and maintain forest roads and structures, in consideration of projected climate changes.

Possible Actions:

i) short-term

- Provide training to practicing forestry professionals on climate change and its potential impacts.
- Undertake a more comprehensive risk assessment of climate change on harvesting and engineering activities based on future climate scenarios.

ii) long-term

- Develop guidelines for timber harvesting and forest roads in anticipation of projected climate change.

Potential Leads:

- Resource Tenures and Engineering Branch, Protection Branch, Association of Professional Engineers and Geoscientists of BC, Canadian Council of Professional Engineers, Association of British Columbia Forest Professionals

5.2.6 Range

BC's grasslands and forested rangelands are a key resource, providing grazing for livestock, wildlife habitat, and recreation services. Grasslands also play an important role in carbon sequestration - they have the ability to capture and store carbon due the high proportion of biomass below the ground.

Grasslands are potentially quite vulnerable to climate change. Most rangelands are fragile, with limited nutrients or water and are often characterised by wide variation in weather variables. Climate change could amplify these variations as well as the effects of existing land uses.

Climate change may also expand the range of invasive plants or lead to the introduction of new species. These early seral species establish quickly and have few native enemies. The number and range of native species could shrink if climate changes are not conducive to their survival.

The potential impact of climate change on BC grasslands has not been extensively studied. Consequently, climate change impacts on the extent of range lands, their productivity and distribution are largely unknown. For example, some areas could be desertified, while others may support more forage due to reduced stand densities, or increased precipitation. It is unclear how the amount of carbon in soil layers correlates with changes in climate and species composition.

It is not clear how livestock production will be affected by climate change. A shift in dominant grass species for example, from C3 to a C4 grasses may affect animal productivity because C4 grasses are generally less digestible and palatable than C3 grasses. Additionally, climate change may increase the vulnerability of livestock and wildlife to new diseases.

The implications for industry are unclear, and could be affected by other variables such as demographics. Changes in use could be anticipated, for example towards recreation.



Range reference areas can serve to monitor changes in species, soils, and productivity.
Photo: MoFR

Range reference areas, a few of which date back to the 1930s, are important in monitoring species composition, and changes in soil physical and chemical properties. Data collected from these sites may also improve our understanding of changes in species composition, productivity, diversity, and soil properties caused by climate change. These changes will most likely occur in transition zones, for example, between the Bunchgrass (BG) and the Interior Douglas-fir (IDF) zones.

In general however, data are extremely limited. No local data is available on climate change or nutrients in the soil. Inconsistent funding has meant variable monitoring periods (5 to 20 years) for range reference areas. Using these reference areas as a tool to assess climate change impacts will require a more rigorous and frequent monitoring scheme. A greater distribution of range reference areas may also be needed to assess climate change impacts and adaptation options, particularly in transitional ecosystems

The existing range reference program provides a significant opportunity to correlate shifts in species composition and soil properties with changes in climate. The exclusion of grazing from these plots enables a comparison with adjacent grazed land.

Synergy could be gained by working with MOFR partners to increase their understanding of the long term value of range reference areas. There is an opportunity to work with MOE (including BC Parks department), the ranching industry, recreationists, guide outfitters, and naturalists to gain the benefit of their views and advocate for joint support of long term monitoring infrastructure.

By correlating soil and vegetation data with climate data, it may be possible to predict plant community changes with climatic factors. An assessment over time in different BEC zones would identify impacts and trends. This information could be important in assessing management options.

If climate change results in expansion of grasslands or an increase in forage productivity, ranching opportunities and grassland species could expand in some parts of the Province. For example, a longer growing season in northeastern BC may increase productivity and use of currently underutilized agricultural land. However, where climate change results in a reduction in precipitation and hence productivity, we may see a shift in the areas where ranching occurs in the Province.

The provincial database of invasive plants is a key tool to help monitor the distribution of invasive plants. It pools data from multiple agencies and provides an opportunity to look at species shifts strategically in the face of climate change.

Possible Actions:

i) short-term

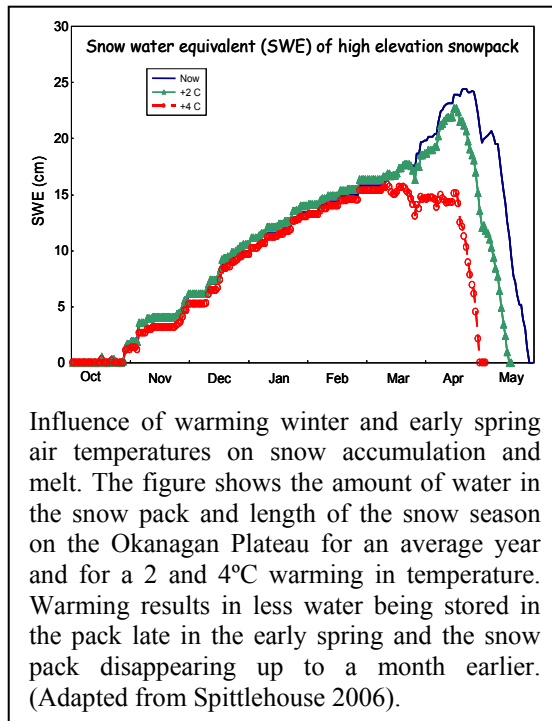
- Undertake a literature review to identify and assess available scientific information relevant to climate change and range management in BC.
- Undertake a gap analysis for the range reference program to identify areas or BEC zones that require range reference sites so that we can properly understand what happens in species shifts as a result of changing climate.
- Do a gap analysis correlating climate data with the movement of invasive species to understand why they're moving where they do. Set up a better reporting structure for when and why species are moving, as a tool for range managers.
- Set up baselines to enable assessment of impact of climate change on practices and plant communities.
- Look at soils more closely to correlate climate change, soil carbon and species composition in reference areas. Data collected could corroborate any information available from research institutions.

ii) long-term

- Improve the monitoring system for range reference areas so that plots are measured every five years and correlated with climate data. A more rigorous system will provide the right information on climate change impacts, and managers will be able to see where the shifts are occurring.
- Build models based on scientific data.
- Enhance adaptive management using the data to reconcile practices with range conditions.

5.2.7 Non-timber Forest Resources

Climate change will also have implications for British Columbia's non-timber and non-range resources. The impact of climate change is of particular concern in many regions of the world. Warmer winters would result in reduced snowpacks – which in turn will lead to reduced availability of water for drinking, irrigation, industrial use and generation of hydro-electricity (CCIAD, 2004). Water quality could also be adversely affected by lower stream flow in summers, and climate induced events, such as wildfires and landslides. Reduced stream flows, and temperature increase during summer will also put freshwater fish populations, including salmon, at risk (Mote et al. 2003, CCIDA, 2004).



Non-timber forest products (NTFPs) such as mushrooms, berries and botanicals are an important part of the rural economy (Forest Practices Board 2004). Availability of some NTFPs may increase due to climate related disturbances, such as fire, or reduced due to competition from invasive species. There will also be changes in cultural and recreation opportunities. Warmer winters will shorten the winter recreational season while summer recreational season will increase, though increased fire risk may limit this increase.

Although the management of many of these resources and activities fall outside the mandate of the MoFR, forest and range activities have an influence on them. The development of forest and range resource adaptation strategies therefore needs to take

into consideration their impacts on non-timber forest resources.

Adaptive Responses:

- In some areas, adaptation to reduce the vulnerability of resources such as water quality and quantity and biological conservation will become the highest priority.
- Forest harvesting and road building may have to increase efforts to mitigate the impacts of changes in the timing of peak flow and volume in streams on infrastructure, fish habitat, and potable water supplies (Mote et al. 2003).
- Warmer and drier summer conditions will increase the need to maintain cool stream temperatures by maintaining riparian cover for streams in harvested areas (Moore et al. 2005).

- The ‘hands-off’ approach to wilderness management may not be an appropriate response in parks and wilderness areas (Scott and Lemieux 2005). Rather than consider park ecosystems “frozen in time” it may be preferable to intervene by planting alternate species.
- Mixing species to a higher degree in managed stands may benefit a number of resource values including biodiversity, resilience, and wildlife habitat.
- Conserving biodiversity and maintaining connectivity in a varied dynamic landscape to aid vegetation and wildlife migration will be a high priority, but connectivity also allows undesirable competitors, such as invasive plants, to move across the landscape.
- Identify areas for preservation where the future climate will become suitable for species whose current range is threatened by climate change.

Short-term options

- Assess risks to water resources, fisheries, recreation, and under different climate scenarios

Long-term options

- Assess risks to other timber forest resources
- Develop adaptation strategies to reduce identified risks

Potential Leads

- Research Branch, Ministry of Environment, Department of Oceans and Fisheries,

5.3 Mitigation

The need for action to reduce greenhouse gas emissions is widely recognized. On December 1, 2005, the Canadian Foundation for Climate and Atmospheric Sciences (CFCAS) along with science leaders from the public and academic sectors issued a call to the Prime Minister urgent action on climate change, citing the observation that Canada is warming faster than most other countries and will be one of the most impacted countries. The statement indicated that over the past 50 years Canada has warmed faster than most regions on the globe and is already experiencing changes that are affecting the lives and health of its citizens. The call was endorsed by 49 eminent Canadian scientists stated that, “significant steps are needed to stop the growth in atmospheric greenhouse gas concentrations, by reducing emissions.”

The risk of climate change can be lowered by reducing greenhouse gas emissions from sources (combustion of fossil fuels, deforestation) and by increasing removals by sinks (forests, agricultural soils). MoFR can play a key role in three broad areas:

- policies and programs that enhance removals through afforestation and reforestation;

- initiatives that support the use of biomass for energy; and
- actions to reduce greenhouse gas emissions from MoFR operations.

The first two areas offer the most potential for reducing net emissions. However, these are addressed through separate federal-provincial initiatives, which are outside the scope of this report. This section is therefore focused on mitigation strategies within MoFR operations.

The main sources of greenhouse gas emissions from MoFR operations are vehicles and buildings. The MoFR owns and leases light-duty vehicles and owns heavy vehicles. Annual MoFR vehicle usage is approximately 1000 vehicle-years of operation totalling more than 15 million kilometres. The MoFR fleet consumes approximately 2 million litres of gasoline and 250,000 litres of diesel fuel annually, and produces approximately 5600 tonnes of greenhouse gas emissions each year (approximately 12% of total BC government fleet emissions). MoFR is taking action on a variety of fronts to reduce these emissions - MoFR has so far exceeded the target for low emission vehicle acquisition, encouraged participation in bike to work week, and facilitated bus pass incentives.

Emissions associated with providing heat and power to the MoFR's offices and buildings are also important, but data on the contribution of buildings was not available for this report.

Emissions from government operations are small relative to the overall provincial economy. Total BC government emissions are approximately 46,000 tonnes per year, or 0.07 percent of total provincial emissions of approximately 63.4 million tonnes.

However, governments in many jurisdictions, including BC, are taking action to reduce greenhouse gas emissions in order to reduce energy costs, lower the environmental impact of their operations, demonstrate leadership, and support the development of the energy efficiency and alternative fuels sectors. For example, federal government targets and actions include the following:

- Currently, all new federal facilities must be built to an energy efficiency level 25% better than the Model National Energy Code for Buildings (MNECB). As of 2005, the construction of new office buildings will be funded to meet the LEED Gold standard.
- Under the Federal Buildings Initiative (FBI), 7,000 federal buildings (about 30% of the government's building stock) have received energy retrofits. The government has committed to retrofitting another 20% of its office buildings by 2010.¹
- 20% of government electricity requirements must be purchased from "emerging renewable sources" (excludes large hydro).
- 75% of all federal road-vehicle gasoline purchases must be ethanol blends by 2010.

¹ Government of Canada (2005), *Moving Forward on Climate Change: A Plan for Honouring our Kyoto Commitment (Project Green)*.

Alberta actions and commitments include:

- A commitment to purchase at least 10% (later increased to 25%) of government electricity requirements from green power sources. That commitment, as well, has been exceeded, with 90% green power in government facilities as of January 1, 2005 – making Alberta Canada's leader in this area.
- New government buildings must be at least 25% more energy-efficient than the MNECB. Alberta Infrastructure is conducting a lifecycle study to support the adoption of LEED Silver for new construction.

Weather, Climate and the Future, British Columbia's climate change plan, commits the Province to show leadership in reducing energy use and greenhouse gas (GHG) emissions in its own operations.² The plan includes specific actions related to buildings, vehicles, and the purchase of office products and services:

Action 25: The B.C. Buildings Corporation (BCBC) is conducting energy audits and retrofits of provincial buildings under a renewed energy management initiative.

Action 26: A new Higher Performance Building Policy will be applied to all new provincially funded buildings.

Action 27: The government will develop guidelines and performance targets for ministries and Crown agencies to acquire cleaner vehicles, fuels, and transportation services. (Under this action, the government will also update guidelines to encourage provincial agencies to purchase office products and services that have less climatic impact.)

The Ministry of Environment (MoE) and the Ministry of Labour and Citizens' Services (MLCS) are taking the lead in developing a green procurement strategy that will contribute to reducing GHG emissions from government operations³. The MoFR can play an important role in partnering with other government agencies to refine and implement a green procurement and management strategy. Such a strategy should address a number of opportunities, including the following:

- Reinstating credits for the incremental purchase costs of hybrid vehicles for use in urban areas, and consideration of fuel costs and emissions in acquisition processes (this would provide incentives within the greater fleet of Forest Service trucks to buy more fuel efficient vehicles),
- Favoring purchases of ethanol and biodiesel blends, by removing administrative barriers to their acquisition. This should be encouraged, even when these fuels are

² Province of B.C. (2004), *Weather, Climate and The Future: B.C.'s Plan*.

³ See *Guidelines for Procurement of Environmentally Responsible Products and Services*, available at: <http://www.pc.gov.bc.ca/>

only available in mid-grade and premium blends. Incentives could include providing credits to ministries for the greater use of ethanol and biodiesel blends, and supporting the expansion of refuelling infrastructure,

- Increased purchases of energy-efficient office equipment (e.g., Energy Star printers, copiers, computers),
- Minimum standards for government buildings, so that leased and owned office space meets at least the LEED Silver standard or equivalent,
- Alternative transportation options for staff – at work and commuting, and
- Increasing staff awareness of opportunities to reduce their environmental footprint.

MoFR can play an active role to ensure that MoFR issues and priorities are addressed in the development and implementation of corporate green procurement strategies.

Examples of MoFR issues include:

- The definition of “clean” vehicles needs to increase the maximum energy size to at least 2.2 litres to give ministries credit for downsizing their fleets (e.g., to smaller 4WD vehicles, such as the Subaru).
- Procurement requirements and standards should not impact on the ministries ability to meet their operational goals, or result in excessive administrative oversight, reporting or regulations.
- BC wood products should be preferred in the construction of LEED-certified green buildings.

Possible Actions:

- Monitor GHG emissions from MoFR buildings and vehicles and identify opportunities to reduce them. This analysis could be undertaken in collaboration with the MoE, MLCS and Ministry of Finance...
- Support the development of the cross-government green procurement strategy being developed by MoE and MLCS, and ensure that MoFR issues, priorities and circumstances are addressed in the strategy (see Appendix 6 for additional examples).
- Participate actively in the implementation of the government green procurement strategy, once approved. Implementation may require additional staff and/or financial resources.

6 Conclusions and Recommendations

Climate change represents a very significant risk to B.C.'s forest and range resources. Preparing for this risk will require a long-term, sustained response that includes:

- (1) a comprehensive assessment of the potential impacts of climate change on MoFR and BC's forest and range resources, and the vulnerability of forest- and range-based communities to these changes;
- (2) further research on the impacts of climate change in key risk areas, in cooperation with universities and the federal government,
- (3) the development of tools to support adaptation strategies, including climate scenarios, case studies, and decision-making frameworks,
- (4) communication, consultation and awareness raising to ensure that forest and range managers, industry and communities have the information and tools to enable them to prepare for climate change, and
- (5) program-specific management strategies to address key vulnerabilities and program areas – including both short and long-term actions.

While long-term efforts are required in many areas, a number of short-term actions could be undertaken that will allow the MoFR to proactively respond to the potential risks and opportunities of climate change, and support the development of an overall 'future focused' forest and range strategy. Such short-term actions should be low-risk options that would provide benefits to British Columbians irrespective of magnitude and timing of climate change.

These short-term actions would also serve to:

- complement the Future Forest Ecosystem initiative,
- build on work initiated from the recently completed review of tree species management in mountain pine beetle impacted TSAs,
- increase understanding of climate change and its potential impacts as the basis for undertaking further analysis, strategy development and action, and
- build capacity within the MoFR to respond proactively to the risk of climate change.

The following are recommendations for possible short-term actions the MoFR could undertake. These recommendations should be considered in the context of other ministry initiatives, priorities and resource commitments.

The recommendations are grouped into three main strategies:

- A. Improving knowledge through analysis and research
- B. Reviewing operational policies and practices
- C. Building awareness and capacity within and outside the ministry

A. Improving knowledge through analysis and research

Recommendation 1. Undertake comprehensive assessments of the potential impacts of climate change on BC's forest and range resources and operations, forest- and range-based communities, and the MoFR. This report provides an initial assessment of the potential impacts of climate change based on the expertise and interests of the Task Team members. It also reflects an emphasis on timber rather than other forest values. For this reason, more comprehensive analyses are required. Further assessment is required to determine the full range of vulnerabilities of the province's forest and range resource values, and the forest and range sectors, under a range of possible climate futures. These analyses will identify those resources, regions, and sectors most at risk, which will then help to prioritize further research, analysis, and action.

Recommendation 2. Evaluate various climate and biogeoclimatic (BEC) unit models for projecting future climate and its impacts on BC forest and range resources. A number of models and methods for relating current and future climate to current BEC units exist. This analysis would determine which models and methods are the most appropriate for projecting the range of plausible changes to BC's ecosystems and climate zones based on data from various global circulation and regional climate models. Subsequent generation of future climate maps could be used to identify the timing and magnitude of climate change and those ecosystems which most vulnerable to those projected changes. These maps, with appropriate policies, guidance documents and training, could then be used to inform forest and range management decisions, such as species selection choices, forest health and protection strategies, road and bridge design, and timber supply. This analysis could be undertaken by team of Research Branch staff, possibly working in collaboration with scientists at various institutions.

Recommendation 3. 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. Monitoring aids in detecting and quantifying the current state of the forest environment and plays a key role in assessing change. Monitoring assists in detecting the results of adaptation and mitigation measures, allowing responses to be adjusted to maximize their effectiveness. There are programs in existence monitoring the physical and biological environment in British Columbia. Some of these are the direct responsibility of the MoFR. Other programs are performed in cooperation with the MoFR or independent of the MoFR. MoFR should review programs under its direct control and also evaluate the effectiveness of programs outside of the MoFR's control to produce information necessary to track changes in forest ecosystems and their environment. Gaps

should be identified and options for addressing them developed. The MoFR should work other agencies to improve their monitoring networks as necessary to provide the information required to track change.

Recommendation 4. **Range - Undertake further research, analysis and monitoring related to range management in BC to increase understanding of species shifts in response to climate change.** This could include a gap analysis for the range reference program to identify areas or BEC zones that require range reference sites to monitor species shifts, and a gap analysis correlating climate data with the movement of invasive species.

Recommendation 5. **Design and establish a long-term multi-species/seedlot trial to test improved genotypes across a diverse array of climatic and latitudinal environments.** This study will assist in identifying which species and seedlots will maintain or enhance forest productivity and health under a range of future climates. Work must begin immediately in order to generate results within the next two decades. Additional staff (research scientist and technician) and significant financing will be required to design and implement this study and to maintain a large number of field installations.

Recommendation 6. **Undertake an analysis of the potential impacts of climate change on timber supply under alternative species choices.** This is a short-term action that will facilitate the longer-term development of a broader conceptual model for assessing the impacts of climate change on forest values, and of policy and management options for responding to climate change. Development of such a model will help to fine tune questions about the spatial and temporal nature of climate change and about the feasibility and efficacy of various responsive actions.

B. Reviewing operational policies and practices

Recommendation 7. **Examine opportunities and barriers for increasing species and genetic diversity in plantations.** Increased species and genetic (seedlot) diversity in plantations and across the landscape can serve to increase the resilience of forests to changes to climate, forest pests and diseases. Opportunity for increasing the number of species and seedlots used to establish a free growing stand already exists within the current policy framework, although there are no policy levers in place to ensure that this would occur. Implementation of these strategies could also result in increased administrative and operational costs. This recommendation should therefore be explored further under the auspices of the Future Forests Ecosystem initiative.

Recommendation 8. **Examine options for modifying seed transfer limits and systems.** Adjustments to the elevational and latitudinal transfer limits of tree species may be warranted to help ensure that planted trees are adapted to future climates. BC's current seed transfer system (geographic focal point) cannot, however, be adequately modified to accommodate the complexities and challenges posed by climate change over the longer-term. A range of seed transfer systems should therefore be explored with attention to the biological risks and benefits, and policy, operational and cost implications. This analysis

could be undertaken by staff within Research Branch and Tree Improvement Branch, in consultation with other MoFR staff, forest industry and members of the Forest Genetics Council of British Columbia.

Recommendation 9. Examine alternative systems for species selection to ensure that trees will be adapted to future climate. Planting species adapted to future climate projections may significantly reduce the risk of trees being poorly adapted to the changing climate during the last 2 or 3 decades of their rotation. Future climate maps, developed under Recommendation #5, could be used to facilitate the migration of tree species to areas that those species do not currently occupy. Policy and operational issues will require significant consideration and discussion. This analysis could begin in conjunction with previous recommendations and follow revisions to the species selection guidelines, currently being completed by Forest Practices and Research Branch.

Recommendation 10. Conduct an assessment of greenhouse-gas emissions produced by the MoFR's internal operations, and work with other agencies to create incentives and remove barriers to reducing MoFR emissions. Reducing greenhouse gas (GHG) emissions will reduce the magnitude and associated risks of climate change. The MoFR is already exploring the use of forests for carbon sequestration and the use of biofuels to offset GHG emissions from fossil fuels. The MoFR could demonstrate leadership in reducing GHG emissions generated from its own operations (e.g. vehicles, heating). The first step would be to estimate the amount of GHG emission the MoFR generates and identify opportunities to reduce them. This analysis could be undertaken in collaboration with the Ministries of Environment and Finance.

C. Building awareness and capacity within and outside the ministry

Recommendation 11. Fire Protection – Inform the public, industry and other agencies of the potential impact of climate change on the fire regime in the province and continue to encourage pro-active actions in regard to fuels management and community protection. These actions can in time be incorporated into the new provincial fire management strategy that is currently under development. This recommendation encompasses the ongoing fuels management initiative guided by the Protection Program and involving the active participation of other agencies (e.g. UBCM). Activity around the information component has been limited to date, but will increase as more knowledge of the potential changes and their impacts is acquired.

Recommendation 12. Increase awareness and understanding of climate change impacts and issues by developing and implementing a climate change communications strategy. Increased awareness and understanding of climate change is a pre-requisite for engaging MoFR staff, stakeholders and communities in assessing risks and vulnerabilities to climate change, and, eventually, incorporating these considerations into policies, plans and practices. Development of a communications strategy, in collaboration with MoE, will help to clarify the MoFR's role in communicating on climate change and how best to engage stakeholders, communities and First Nations in an on-going dialogue.

Recommendation 13. Support the implementation and coordination of climate change initiatives across the MoFR and the development of a community of practice.

Climate change issues cut across the MoFR. Proper resourcing and coordination are required to ensure that the approved recommendations from this report are implemented and that networks are developed and sustained. This should include an executive sponsor, FTE(s) and resources, with appropriate reporting relationships and links to relevant MoFR business areas.

A key element should be a climate change position to coordinate the MoFR's climate change activities, policies and research, and to report out on progress. With the support of the MoFR's executive and the designated working group, the climate change position will be tasked with:

- continuing the work of the Climate Change task team;
- leading the implementation of approved recommendations from this report. This would include working with the appropriate people to establish timelines and deliverables.
- widening the community of practice for climate change within the MoFR;
- strengthening linkages and partnerships with client and stakeholder groups;
- supporting efforts to incorporate climate change into forest and range programs, policies, planning and practices; and,
- implementing the risk analysis and communications strategies identified in Recommendations 1 and 2, respectively.

Include in the governance structure a working group led by a climate change coordinator, with formal representation by all relevant MoFR divisions, regions and branches. This group should be diverse enough to represent all essential disciplines. The climate change work of its members should be reflected in their job descriptions and performance plans.

Through the working group, develop the MoFR's capacity to adapt its forest and range management strategies to a changing climate. This working group will become an expanding "community of practice."

Follow-up

These recommendations do not cover the full range of options presented in the report. Further analysis and discussion of the other possible short- and long-term actions identified in the report should take place, in association with the Future Forest Ecosystems initiative and other MoFR and provincial programs. These actions should be examined through environmental, social and economic lenses, in consultation and cooperation with other government agencies, industry, communities and First Nations.

References

- Aber J. et al. 2001. Forest Processes and Global Environmental Change: Predicting the Effects of Individual and Multiple Stressors. *BioScience* 51(9): 735-751
- Adaptation and Impacts Research Group (2005) Climate Change Scenarios Network - National Node. Available online at <http://www.ccsn.ca/index-e.html>
- AGFC – Alberta Forest Genetics Council. 2005. Annual Report 2004-05. (<http://www.abtreegene.com>)
- Ahlgren, I.F. and C.E. Ahlgren. 1960. Ecological effects of forest fires. *The Botanical Review* 26:483-533
- Aitken, S. 2005. Making choices in uncertain times: species and genetic considerations. Presentation at the Future Forest Ecosystems Workshop. Prince George, BC. December 6, 2005.
- Amiro, B. D., Stocks, B. J., Alexander, M. E., Flannigan, M. D., and Wotton, B. M. 2001. Fire, climate change, carbon and fuel management in the Canadian boreal forest. *International Journal of Wildland Fire*, 10: 405-413.
- Andalo, C., Beaulieu, J., and Bousquet, J. 2005. The impact of climate change on growth of local white spruce populations in Québec, Canada. *For. Ecol. Manage.* 205: 169-182.
- Barnhardt, L. 2006. Personal communication. Manager, Tree Improvement and Seed Centre, Province of Alberta. February 6, 2006
- B.C. Ministry of Water, Land and Air Protection. 2002. Indicators of Climate Change for BC
- Breshears, D.D. and 10 others. 2005. Regional vegetation die-off in response to global-change-type drought. *Proc. Nat Acad. Sci.* 102:15144-15148.
- Brown, J. K.; Smith, J. K., eds. 2000. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 257 p.
- Bruce, J.P. 2003. Implications of climate change for flood damage reduction in Canada. Keynote address at 3rd Canadian Conference on Geotechnique and Natural Hazards. Edmonton Alberta. June 9, 2003.
- Cammell, M.E. and J.D. Knight. 1992. Effects of climatic change on the population dynamics of crop pests. *Advances in Ecological Research* 22:117-162.

- Cannell, M.G.R., and R.I. Smith. 1986. Climatic warming, spring budburst and frost damage on trees. *J. Appl. Ecol.* 23:177-191.
- Carroll, A., S. Taylor, J. Regniere, and L. Safranyik. 2004. Effects of climate change on range expansion by the mountain pine beetle in British Columbia. In: Proceedings of "Mountain Pine Beetle Symposium: Challenges and Solutions", Oct. 30-31, 2003 Kelowna, BC T.L. Shore and J.E. Stone (eds). NRCAN, Can. For. Serv., Pac. For. Cent. Info Rep. BC-X-399, pp 233-244.
- CEAA – Canadian Environmental Assessment Agency. 2003. Incorporating Climate Change Considerations in Environmental Assessment: General Guidance for Practitioners. Prepared by the Federal-Provincial-Territorial Committee on Climate Change and Environmental Assessment. November 2003. Accessed on-line at: http://www.ceaa-acee.gc.ca/012/014/climatechange_e.pdf
- CCPE – Canadian Council for Professional Engineers. 2005. Climate Change. National Position Statement Access on-line at: http://www.ccpe.ca/e/files/positions_climatechange.pdf
- Centre for Forest Gene Conservation. 2006. ClimateBC. <http://genetics.forestry.ubc.ca/cfgc/climate-models.html>
- Climate Change Impact and Adaptation Directorate (CCIAD).2004. Climate Change Impacts and Adaptation: a Canadian perspective. (Lemmen, D.S. and Warren, F.J., eds.). Natural Resources Canada. Ottawa, Ontario. Available on-line at: http://adaptation.nrcan.gc.ca/perspective_e.asp
- Coates, K.D. 2005. Silviculture and ecological strategies for the mountain pine beetle epidemic. Forum. Association of BC Forest Professionals. May-June 2005.
- Cummings, S.G. and P.J. Burton. 1996. Phenology-mediated effects of climatic change on some simulated British Columbia forests. *Climatic Change* 34:213-222.
- Dakin, A. 2005. Adaptation to climate change: implications for engineers and geoscientists. Presentation to Association of Professional Engineers and Geoscientists of BC. October, 14, 2005.
- Dale, V. H.; Joyce, L. A.; McNulty, S.; Neilson, R. P.; Ayres, M. P.; Flannigan, M. D.; Hanson, P. J.; Irland, L. C.; Lugo, A. E.; Peterson, C. J.; Simberloff, D.; Swanson, F. J.; Stocks, B. J.; Wotton, B. M. 2001. Climate change and forest disturbance. *BioScience* 51(9): 723-734.
- Davidson, Debra J., Tim Williamson, and John R. Parkins. 2003. Understanding climate change risk and vulnerability in northern forest-based communities. *Can. J. For. Res.* 33: 2252-2261
- Flannigan, M. D., and Van Wagner, C. E. 1991. Climate change and wildfire in Canada. *Can. J. For. Res.*, 21: 66-72.

- Flannigan, M. D., Bergeron, Y., Engelmark, O., and Wotton, B. M. 1998. Future wildfire in circum-boreal forests in relation to global warming. *Journal of Vegetation Science*, 9: 469-476.
- Flannigan, M. D., Campbell, I., Wotton, B. M., Carcaillet, C., Richard, P., and Bergeron, Y. 2001. Future fire in Canada's boreal forest: paleoecology results, and general circulation model – regional climate model simulations. *Can. J. For. Res.*, 31: 854-864.
- Flannigan, M. D., Logan, K. A., Amiro, B. D., Skinner, W. R., and Stocks, B. J. 2005. Future area burned in Canada. *Climatic Change*, 72: 1-16.
- Flannigan, M.G., Wotton, B. M., Todd, B., Cameron, H., and Logan, K. 2002. Climate change implications in British Columbia: Assessing Past, Current and Future Fire Occurrence and Fire Severity in BC. Report prepared as part of the Collaborative Research Agreement by the Canadian Forest Service for the British Columbia Ministry of Forests and Range, Protection Program.
- Fleming, R. A. 2000. Climate change and insect disturbance regimes in Canada's boreal forests. *World Resource Review*, 12(3): 521-555.
- Forest Practices Board. 2004. Integrating non-timber forest products into forest planning and practices in British Columbia. Special report FPB/SR/19, Forest Practices Board, Victoria, BC.
- Fried, J. S., Torn, M. S., and Mills, E. 2004. The impact of climate change on wildfire severity: a regional forecast for northern California. *Climatic Change*, 64: 169-191.
- Government of British Columbia. 2004. Weather, Climate and the Future: BC's Plan
- Hamann, A. and T.L. Wang. 2006 (in press). Potential effects of climate change on ecosystem and tree species distribution in British Columbia Ecology
- Hansen, A.J., R.P. Neilson, V.H. Dale, C.H. Flather, L.R. Iverson, D.J. Currie, S. Shafer, R. Cook, and P.J. Bartlein. 2001. Global change in forests: response of species, communities, and biomes. *BioScience* 51:765–779.
- Hansen J, Nazarenko L, Ruedy R, Sato M, Willis J, Del Genio A, Koch D, Lacis A, Lo K, Menon S, Novakov T, Perlwitz J, Russel G, Schmidt GA, Tausnev N. 2005. Earth's Energy Imbalance: Confirmation and Implications. *Science*. 28 April 2005; 10.1126/science.1110252
- Hebda, R.J. 1997. Impact of climate change on biogeoclimatic zones of British Columbia and Yukon. In *Responding to global climate change in British Columbia and Yukon*. E. Taylor and B. Taylor (editors). Environment Canada, Vancouver, B.C. pp. 13-1–13-15

ICCIAWG - Intergovernmental Climate Change Impacts and Adaptation Working Group. 2005. National Climate Change Adaptation Framework. Accessed on-line at: <http://adaptation.nrcan.gc.ca/app/filerepository/E84CC04097004024847DEDA0F9CB72C6.pdf>

Intergovernmental Panel on Climate Change (IPCC). 2001. Climate change 2001: the scientific basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. (J.T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell and C.A. Johnson, eds.). Cambridge Univ. Press, Cambridge, United Kingdom and New York, NY. 881 p. Available on-line at <http://www.ipcc.ch/pub/reports.htm>

Intergovernmental Panel on Climate Change (IPCC). 2002. Climate change and biodiversity. IPCC technical paper V. (H. Gitay, A. Suarez, R.T. Watson and D.J. Dokken, eds). Geneva. 77 p. Available on-line at: www.ipcc.ch/pub/tpbiodiv.pdf.

Irland L. C. et al. 2001. Assessing Socioeconomic Impacts of Climate Change on US Forests, Wood-Product Markets, and Forest Recreation . *BioScience* 51(9): 753-764

Iverson, L. R., and A. M. Prasad. 2002. Potential redistribution of tree species habitat under five climate change scenarios in the eastern US. *Forest Ecology and Management* 155: 205-222.

Johnson, M and Williamson, T. 2005. Climate change implication for stand yields and soil expectation values: a northern Saskatchewan case study. *Forestry Chronicle* 81(5): 683-690.

Kimmins, J.P. and D.P. Lavender. 1989. Implications of Climate Change for the distribution of Biogeoclimatic Zones in British Columbia and for the growth of Temperate Forest Species, p. 297-309. In *Woody Plant Growth in a Changing Chemical and Physical Environment. Proceedings of the Workshop of IUFRO Working Party on Shoot Growth Physiology*, July, 1987, Vancouver, B.C. (Lavender, compiler).

Kirschbaum, M.U.F. 2000. Forest growth and species distribution in a changing climate. *Tree Physiology* 20:309–322.

Laprise, R., D. Caya, A. Frigon and D. Paquin. 2003. Current and perturbed climate as simulated by the second-generation Canadian Regional Climate Model (CRCM-II) over northwestern North America. *Climate Dynamics* 21: 405-421.

Ledig, F.T. and Kitzmiller, J.H. 1992. Genetic strategies for reforestation in the face of global climate change. *For. Ecol. Manage.* 50: 153-169.

Leynes, L. 2005. Nothing to say about climate change. *Victoria Times Colonist*. October 27, 2005. p. A12.

- Li, C., Flannigan, M. D., and Corns, I. G. W. 2000. Influence of potential climate change on forest landscape dynamics of west-central Alberta. *Can. J. For. Res.*, 30: 1905-1912.
- Logan JA, Régnière J, Powell JA. 2003. Assessing the impacts of global warming on forest pest dynamics. *Frontiers in Ecology and the Environment*. 1(3): 130-137.
- MacLauchlan, L. E.; Brooks, J. E.; and Hodge, J. C. 2006. Analysis of historic western spruce budworm defoliation in south central British Columbia. *Forest Ecology and Management*. 226(1-3): 351-356.
- Malanson, G. P. 1987. Diversity, stability, and resilience: effects of fire regime. Pages 49–63 in L. Trabaud, editor. *The role of fire in ecological systems*. Academic Publishing, The Hague, The Netherlands.
- Maloney, D. 2005. Mid-term impact of mountain pine beetle on watershed hydrology. Forum. Association of BC Forest Professionals. May-June 2005. p. 23-24.
- Martin, P., Barber, B., DeLong, C., Meidinger, D., and Pelchat, M. 2005. Management of species composition in cutblocks in beetle-impacted TSAs. BC Ministry of Forests and Range, Forest Practices Branch, Victoria, BC. 110 p.
- McCullough, D. G., Werner, R. A., and Newman, D. 1998. Fire and insects in northern and boreal forest ecosystems of North America. *Annual Review of Entomology*, 43: 107-127.
- Meehl, G.A., W.M. Washington, W.D. Collins, J.M. Arblaster, A. Hu, L.E., Buja, W.G. Strand and H. Teng. 2005. How much more global warming and seas level rise? *Science* 307:1769-1772.
- Meidinger, D. 2005. Annual report, FSP Project Y05-1149 (available from author).
- Merrill, D.F.; Alexander, M.E. (editors). 1987. Glossary of forest fire management terms. Fourth edition. National Research Council of Canada, Canadian Committee on Forest Fire Management, Ottawa, Ontario. Publication 26516. 91 pp.
- Miles, M. 2003. BC's Climate Related Observation Networks. BC Min. Environment, Victoria, BC. [ftp://ftp.env.gov.bc.ca/pub/outgoing/Climate%20Change/ BC Climate Related Obs. Network Adequacy Review.pdf](ftp://ftp.env.gov.bc.ca/pub/outgoing/Climate%20Change/BC%20Climate%20Related%20Obs.%20Network%20Adequacy%20Review.pdf).
- Moberg, A., D.M. Sonechkin, K. Holmgren, N.M. Datsenko and W. Karlén. 2005. Highly variable Northern Hemisphere temperatures reconstructed from low- and high-resolution proxy data. *Nature* 433:613-617.
- MoFR - Ministry of Forests and Range. 2005. Future Forests Ecosystems of BC. Proceedings of a symposium and workshops held in Prince George. December 6-7, 2005. Accessed on –line at: http://www.for.gov.bc.ca/hts/Future_Forests/

- Moore, R.D., D.L. Spittlehouse and A. Story. 2005. Riparian microclimate and stream temperature response to forest harvesting – a review. *Journal of American Water Resources Assoc.* 41:813-834.
- Mote, P.W. E.A. Parson, A.F. Hamlet, K.N. Ideker, W.S. Keeton, D.P. Lettenmaier, N.J. Mantua, E.L. Miles, D.W. Peterson, D.L. Peterson, R. Slaughter and A.K. Snover. 2003. Preparing for climate change: The water, salmon and forests of the Pacific Northwest. *Climatic Change* 61:45-88.
- National Wildfire Coordinating Group. 2001. Fire Effects Guide. Available online: <http://www.nwcg.gov/pms/RxFire/FEG.pdf>. 313 p. [accessed January 30th, 2006]
- Neary, D. G.; Ryan, K. C.; DeBano, L. F., eds. 2005. Wildland fire in ecosystems: effects of fire on soils and water. Gen. Tech. Rep. RMRS-GTR-42-vol.4. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 250 p.
- Nigh, G. D., Ying. C.C., and Qian, H. 2004. Climate productivity of major conifer species in the interior of British Columbia, Canada. *Forest Science* 50: 659-671
- Nigh, G.D. 2001. Species-independent height-age models for British Columbia. *Forest Science* 47: 150-157.
- Norby et al. 2005. Forests response to elevated CO₂ is conserved across a broad range of productivity. *Proceedings of the National Academy of Sciences*. 102(5):18502-18056
- NWSI - Northwest Science and Information. 2005. Preparing for change: climate change and resource management in the northwest region. NWSI technical workshop report TWR-04. Prepared by G.D. Racey. Northwest Science and Information. Ontario. June 2005.
- Ohlson, D. W., McKinnon, G. A., and Hirsch, K. G. 2005. A structured decision-making approach to climate change adaptation in the forest sector. *The Forestry Chronicle*, 81(1): 97-103.
- Ouranos Consortium. 2006. www.ouranos.org
- Pacific Climate Impacts Consortium. 2006. www.pacificclimate.org
- Parker, W.C., Colombo, S.J., Cherry, M.L., Flannigan, M.D., Greifenhagen, S., McAlpine, R.S., Papadopol, C., and Scarr, T. 2000. Third millennium forestry: What climate change might mean to forests and forest management in Ontario. *The Forestry Chronicle* 76: 445-463.
- Parker, W.C., S.J. Colombo, M.L. Cherry, M.D. Flannigan, S. Greifenhagen, R.S. McAlpine, C. Papadopol, and T. Scarr. 2000. Third millennium forestry: what climate change might mean to forests and forest management in Ontario. *The Forestry Chronicle* 76:445–463.

- Perez-Garcia, John, Linda A. Joyce, David McGuire and Xiangming Xioa. 2002. Impacts of climate change on the global forest sector. *Climate Change* 54: 439-461.
- Peterson C. J. et al. 2001 Change and Forest Disturbances. *BioScience* 51(9): 723-734
- Pojar, J., K. Klinka and D.V. Meidinger. 1987. Biogeoclimatic ecosystem classification in British Columbia. *Forest Ecology and Management* 22:119-154.
- Price, C., and Rind, D. 1994. The impact of a 2 X CO₂ climate on lightning-caused fires. *J. Climate*, 7: 1484-1494.
- Rehfeldt, G.E., C.C. Ying, D.L. Spittlehouse, and D.A. Hamilton. 1999. Genetic responses to climate for *Pinus contorta*: niche breadth, climate change, and reforestation. *Ecological Monographs* 69:375–407.
- Rehfeldt, G.E., Wykoff, W.R., and Ying, C.C. 2001. Physiological plasticity, evolution, and impacts of a changing climate on *Pinus contorta*. *Climatic Change* 50: 355-376.
- Safranyik, L. 1988. Mountain Pine Beetle: Biology Overview, In: Proceedings-Symposium on the management of Lodgepole pine to minimize losses to the mountain pine beetle. Kalispell, MT. July 12-14, 1988. USDA For. Serv. Gen Tech. Rep. INT-262 pp 9-13.
- Sandberg, D. V.; Ottmar, R. D.; Peterson, J. L.; Core, J. 2002. Wildland fire on ecosystems: effects of fire on air. Gen. Tech. Rep. RMRS-GTR-42-vol. 5. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 79 p.
- Scott, D. and C. Lemieux. 2005. Climate change and protected area policy and planning in Canada. *The Forestry Chronicle* 81:696-703.
- Smith, J. K., ed. 2000. Wildland fire in ecosystems: effects of fire on fauna. Gen. Tech. Rep. RMRS-GTR-42-vol. 1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 83 p.
- Spittlehouse, D. 2006. ClimateBC: Your access to interpolated climate data for BC. *Streamline Watershed Management Bulletin* 99:16-21.
- Spittlehouse, D. 2005. Integrating climate change adaptation into forest management. *Forestry Chronicle* 81(5): 691-695.
- Spittlehouse, D. L., and Stewart, R.B. 2003. Adaptation to climate change in forest management. *BC Journal of Ecosystems and Management* 4(1):1-11
- Standing Senate Committee on Agriculture and Forestry. (2003). Climate change: we are at risk. Final Report. Government of Canada, 37th Parliament, 2nd Session. Available online at <http://www.parl.gc.ca>.

- Stewart, R.B., E. Wheaton, and D.L. Spittlehouse. 1998. Climate change: implications for the boreal forest. In *Emerging air issues for the 21st century: the need for multidisciplinary management*. A.H. Legge and L.L. Jones (editors). Air and Waste Management Assoc., Pittsburgh, Penn. pp. 86–101.
- Stocks, B. J. 1993. Climate change and forest fires in Canada. *Forestry on the Hill*, Special Issue – Forest Wildfires: 9-12.
- Stocks, B. J., Fosberg, M. A., Lynham, T. J., Mearns, L., Wotton, B. M., Yang, Q., Jin, J.-Z., Lawrence, K., Hartley, G. R., Mason, J. A., and McKenney, D. W. 1998. Climate change and forest fire potential in Russian and Canadian boreal forests. *Climatic Change* 38: 1-13.
- Tchebakova, N.M., Rehfeldt, G.E., and Parfenova, E.I. 2005. Impacts of climate change on the distribution of *Larix* spp. and *Pinus sylvestris* and their climatotypes in Siberia. Mitigation and adaptation strategies for global change (in press).
- van der Kamp, B.J., and Spence, M. 1987. Stem diseases of lodgepole pine in the British Columbia interior following juvenile spacing. *Forestry Chronicle* 64: 334-339.
- Van Wagner, C. E. 1987. Development and structure of the Canadian Forest fire Weather Index System. Agriculture Canada., Canadian Forest Service, Ottawa, Ont. For. Tech. Rep. 35. 37 p.
- Volney, W. J. A, and Hirsch, K. G. 2005. Disturbing forest disturbances. *The Forestry Chronicle* 81(5): 662-668.
- Wang, T.L., A. Hamann, D.L. Spittlehouse and S.N. Aitken. 2006. Development of scale-free climate data for western Canada for use in resource management. *International J. Climatology* 26:383-397.
- Weber, M. G., and Flannigan, M. D. 1997. Canadian boreal forest ecosystem structure and function in a changing climate: impact on fire regime. *Environmental Review* 5: 145-166.
- Whelan, R. J. 1995. *The ecology of fire*. Cambridge University Press, Cambridge. 346 pp.
- Wieczorek, and Glade. 2005. Climatic factors influencing occurrence of debris flow. In *Debris-flow Hazards and Related Phenomena*. Eds. M. Jacob and O. Hungr. Springer - Praxis Publishing Ltd. Chichester, U.K.
- Wigley, T.M.L. 2005. The climate change commitment. *Science* 307:1766-1769.
- Woods, A. Coates, K.D, and Hamann, A. 2005. Is an unprecedented *Dothistroma* needle blight epidemic related to climate change? *Bioscience* 55 (9): 761-769

- Woods AJ, Nussbaum A and Golding, B. 2000. Predicted impacts of hard pine stem rusts on lodgepole pine dominated stands in central British Columbia, Can J. For. Res. 30 (3): 476-481.
- Wotton, B. M., and Flannigan, M. D. 1993. Length of the fire season in a changing climate. Forestry Chronicle 69: 187-192.
- Wotton, B. M., Martell, D. L., and Logan, K. A. 2003. Climate change and people-caused forest fire occurrence in Ontario. Climatic Change 60: 275-295.

Appendix 1: Climate Change Task Team - Terms of Reference

Type: Advisory

Chair: Brian Barber, Technical Advisor, Tree Improvement Branch

Responsible/Reporting out through:

Executive Sponsor: Henry Benskin, A/Deputy Chief Forester, on behalf of
Jim Snetsinger, Chief Forester, and Forest Stewardship Division Management Team.

Purpose:

To advise the chief forester on the how the MoFR should strategically position itself in response to the impacts of climate change (CC) on the province's forest and range resources. This advice will be based on assessments of the short- and long-term options for addressing the impacts of climate change (CC) and identification of opportunities for the MoFR to contribute to provincial and national climate change goals.

Scope:

1. Identify and summarize the existing knowledge of the potential impacts of climate change on BC's forest and range resources, and key vulnerabilities and opportunities for these sectors.
2. In consultation with other MoFR staff, other government agencies, industry and academia identify:
 - key knowledge gaps and climate change adaptation options that could be implemented in the near-term, and assess their related policy barriers & opportunities, and resource & funding requirements.
 - CC adaptation options that could be explored over the longer-term, key knowledge gaps with respect to these options, and opportunities for addressing these gaps.
3. Identify action items in *Weather, Climate and the Future; BC's Plan* of relevance to the MoFR, develop recommendations for addressing them and reporting progress.
4. Develop a communication and extension strategy for raising awareness of climate change impacts, mitigation measures, and adaptation options within the division, ministry, and our clientele.
5. Maintain a close working relationship with MoE's Climate Change Section, which is responsible for the provincial government's overall climate change policies.
6. Establish linkages within the ministry, the forest sector, organizations involved in climate change adaptation research (e.g. CFS, C-CAIRN), and with other provincial and national forest sector organizations with an interest in climate change adaptation policy.
7. Ensure that MoFR interests are represented, where appropriate, in provincial and national adaptation policy initiatives, and apprise the chief forester of matters of interest or concern to the ministry.
8. Identify potential mitigation measures that the MoFR could implement to reduce greenhouse gas emissions that contribute to CC.

Appendix 2: MoFR Linkages with Federal and Provincial Climate Change Committees and Initiatives

Level of Initiative	Topic/Organization	Description	MoFR Lead	Involvement	Collaborators
National	National Forests Sinks Committee	Examining Article 3.4 Kyoto Protocol on carbon sinks/credits. Part of Canada's National Implementation Strategy on Climate Change.	D. Draper (D. Spittlehouse)	BC Government Representative on Committee. Prepare recommendations for minister's decision.	Federal Govt, Provinces, Territories <i>Also see</i> Fed Action Plan , IPCC , and Kyoto
	C-CAIRN Canadian Impacts and Adaptation Research Network – Forest Sector	Organization to promote and facilitate the sustainable management of Canada's forests under a changing climate	D. Spittlehouse P. Tschaplinski also Connected to C-CAIRN fisheries.	Member, Advisory Committee	NRCan
	BIOCAP	Not-for-profit research foundation. Promoting development and use of bio-energy and bio-products.	D. Draper	Board of Directors	Federal and provincial governments and industry
	Canadian Centre for Climate Change Modelling and Analysis and Canadian Institute for Climate Studies	Global atmospheric general circulation model, and analysis. Located at UVic. Links to Regional climate change model network . Provincial climate change scenarios. Latter promoting research "consortium"	D. Spittlehouse		MoE, NRCan Currently
Provincial	Deputy Minister's Climate Change Committee See BC's Plan : Weather Climate and the Future.	High level government action plan to reduce vulnerability, reduce emissions and increase energy efficiency. Includes strategies for carbon, MPB, and fire mgmt.	H. Benskin (D. Draper)	Development of strategies, plans to achieve action	Thiessen, L (MoE) MSBED, MEM, MSRM
	Carbon Management Project	BC analysis of Canada's potential ratification of Article 3.4 Kyoto Protocol technical issues (FM definition, A/R, carbon sinks and credits.	D. Draper	BC Government Representative	Federal Gov't, CFS, Provinces, CCCma
	Interagency climate change committee	Lead by WAP to promote communication between policy staff within BC government.	B. Barber D. Spittlehouse	Participation	J. Fraser (MoE), with connections to feds and provinces.
	BC Biorefining Initiative		H. Benskin		Larson, J. (MEM) Langridge, J (RTEB)
	BC Bioproducts	Gov't-industry group promoting use of bioproducts – feedstocks, fuel and industrial products. Linked to BioProducts Canada , (sponsored by Industry Canada)	H. Benskin J. Langridge	Participate as required.	Hallman, R. (MAFF) BioProducts Canada Industry Canada,

Level of Initiative	Topic/Organization	Description	MoFR Lead	Involvement	Collaborators
	Royal Provincial Museum	Climate Change Display Richard Hebda	D. Spittlehouse M. Eng	Input/advice	

Appendix 3: Current MoFR Climate Change Related Projects, Research and Initiatives

Branch/Office	Topic	Description	MoFR Lead	Deliverables	Initiate	Complete	Collaborators
MoFR	Mtn Pine Beetle 2005 Action Plan	Provincial response to the MPB infestation.	R. Schultz, R. Deboise	Several objectives. See: http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/#action	On-going		Feds, Industry, Communities, FNs, Others
Forest Stewardship Division	Future Forests Ecosystem of BC Initiative	Exploration of opportunities to adjust approaches to forest management in response to rapidly changing conditions in our forest ecosystems	J. Snetsinger K. Weese	Report on options, recommendations http://www.for.gov.bc.ca/hts/Future_Forests/	Dec 05	May 06	Various
Forest Practices Branch	Species Selection	Committee reviewing species selection in MPB impacted areas	P. Martin	Recommendations on policy options http://www.for.gov.bc.ca/hfp/fft/species/index.htm	May 2005	Nov 7, 05	TIB, Res.Br, Ops Div
Research	Forest genetics and seed transfer	Impacts of climate change on pine productivity using transfer curves	G. O'Neill	Using transfer curves, estimate and map changes to pine productivity for three future decades			Hamann, U of Alberta
		Impacts of climate change on pine productivity using population response functions	T. Wang, UBC	a) Using population response functions, estimate and map changes to pine productivity for three future decades; b) estimate how facilitated migration of seed may mitigate some of the negative impacts to productivity.			Greg O'Neill, Alvin Yanchuk, Sally Aitken and Andreas Hamann
		Seed Transfer Systems	G. O'Neill	Explore alternative seed transfer systems and examine their advantages and disadvantages in terms of productivity, accuracy, risk, ability to accommodate a changing climate, and ease of implementation and use.			
		Climate-based Seed Transfer Impact Calculator (STIC)	G. O'Neill	Objective: to make the STICs more accurate and sensitive to transfers involving precipitation, and to allow productivity of any seedlot to be predicted for future climates, the current STICs will be converted from a geographic-base to a climate-base			Tongli Wang, UBC

Branch/Office	Topic	Description	MoFR Lead	Deliverables	Initiate	Complete	Collaborators
		Sx genecology/climate change trials	O'Neill	Objective: to establish long-term genetic field trials of wide-ranging Sx provenances tested at wide-ranging sites. Data from these trials is fundamental for all seed transfer/climate change studies			Alvin Yanchuk, Barry Jaquish
		The role of climate change in Dothistroma infections	A. Woods	Objective: Using data from 25 Pli provenance test in northern BC, assess the role of site climate, provenance, seed transfer and climate change in recent Dothistroma infections			Greg O'Neill
		Pli provenance test remeasurement	G. O'Neill	Objective: to measure growth and wood quality traits in the 32-year-old Pli provenance tests			Michael Carlson, John Murphy, Alvin Yanchuk
		Role of seed transfer and climate change on Pli value	G. O'Neill	Objective: to use recent provenance data to develop transfer curves that will assist in estimating the effect of seed transfer and climate change on both volume and value of Pli			
	Biogeoclimatic zones	Modeling climate envelopes and BGC changes	D. Meidinger D. Spittlehouse	Updating BEC Zones	TBD		A. Hamann , T Wang - UBC
	Climate and air quality	General research and extension	D. Spittlehouse		On-going		MoE
	Adaptation and Forest Management	Adapting forest management to the impacts of climate change in Canada	D. Spittlehouse	Recent article in Forestry Chronicle Sept/Oct 2005 – also involved in BioCap funded project in collaboration lead by Mark Johnson, Sask. Res. Council.	Sept 05		Tim Williamson,(CFS) David Price(CFS), Adam Wellstead (CFS), Paul Gray (MNR), an Dan Scott (U. Waterloo)
	Growth and Yield	Climate change impacts on conifer productivity	G. Nigh		On-going		
Tree Improvement	Reforestation – policy	MA thesis on reforestation strategies for adapting BC's forests to climate change: Policy barriers and opportunities.	B. Barber	MA thesis & recommendations to MoFR	May 05	Aug 06	RRU
Forest Analysis	Timber supply analysis and risk assessment	Assessment of potential impact of climate change on forest resources, both timber and non-timber.	C. Fletcher, G. Lawrence	Inform policies and strategies	TBD		
Region	Forest Health	Dothistroma and climate change	A. Woods	Article in Bioscience, 2005.	2005		D. Coates, A. Hamann

Appendix 4: Possible Climate Change Impacts on Commercial Tree Species in British Columbia

The following predictions of tree species vulnerability to the indirect impacts of climate change on forest insect and diseases are based on the collective knowledge of the regional forest health staff of the Ministry of Forest and Range. This list is not complete. It is an attempt to address some of the more likely scenarios. In a few cases there is published scientific evidence that supports these predictions (e.g. Carroll et al. 2004, MacLachlan et al. 2006, Woods et al. 2005). For the majority of the relationships we must rely on educated guesses. All of these predictions follow the basic premise that short-lived insects and pests will likely be able to adapt more quickly to a rapidly changing environment than their long-lived hosts. Host tree species that are not as well adapted to sites as a result of a rapidly changing climate will be under greater stress and thus more susceptible to pests.

Lodgepole pine:

- Mountain pine beetle (MPB) is already attacking and killing trees as much as 60 years younger than what was previously thought possible,
- Warrens root collar weevil is already killing young lodgepole pine at significantly higher rates as a result of MPB killing most of the mature pine across the interior landscape,
- Changing pathosystems for western gall rust (DSG) and comandra blister rust (DSC) with possibility of increasing frequency of wave years with higher than normal spring and early summer precipitation. This phenomenon already appears to be happening in the central interior. Behaviour of pathogens that we thought we understood now changing, e.g., high risk period for rusts extending, so that pine stands are no longer safe after age 15,
- Atropellis canker benefiting from increased summer moisture higher incidence and severity of attack
- Dothistroma needle blight and other foliar diseases of lodgepole pine are on the increase in areas of the province that have been experiencing increased summer precipitation.

Douglas-fir:

- Growing season frosts in the Montaine Spruce (MS) and Sub Boreal Spruce (SBS) biogeoclimatic zones has historically been one of the range limiting factors for this species. Under climate change perhaps Douglas-fir will be able to replace or at least supplement lodgepole pine in SBS plantations as the latter species suffers increasingly from pests under climate change.
- Spruce budworm and other insect defoliators could be a bigger problem further north in the province if Douglas-fir was deployed to a greater extent.

- Spruce budworm incidence and severity of attack is already higher than the historical norm.
- Armillaria and Laminated root diseases could and probably will move north under CC. These pathogens will also cause greater damage in areas experiencing drought as trees will be stressed and more susceptible to disease.
- Foliar pathogens could be more of a concern in future under climate change in areas that experience increased summer precipitation.
- Douglas-fir will be drought stressed in drier ecosystems (summer drought), which can lead to bark beetle attack and mortality (stressed fir is both more attractive and less resistant to bark beetles) - this in turn will lead to ecosystem.

Western hemlock:

- Conditions for western hemlock should improve throughout current SBS under CC.
- Western hemlock is not drought-resistant but if mean summer precipitation will increase as most recent decade indicates in the northern SBS zone then this species could be deployed more extensively.
- Western hemlock within drier variants (and on shallow soils) within CWH have already shown effects of summer drought (die back and mortality)
- This species will likely suffer greater losses to insect defoliators under CC.

Larch, western and Siberian:

- These species tend to be better adapted for colder environments but possibly could cope with drought and possibly help supplement lodgepole pine in SBS under CC.
- Could suffer greater losses to foliar diseases in areas of increased summer precipitation.
- Insect defoliator damage to larch species will also likely increase.
- Research group in Kamloops has been cautioning about use of western larch in Lillooet area (very light demanding, have to watch species mixes)

Spruce:

- Increased losses due to leader weevils - increased range and hazard of spruce weevil
- Increased losses to foliar diseases (*Rhizosphaera kaukhoffii*) etc.
- spruce beetle lifecycle completed in one year = increased attack

Western redcedar:

- This species could be deployed to greater extent under climate change in Northern Interior Forest Region

- Western redcedar is less susceptible to Armillaria root disease and so is a valuable species for areas that are heavily infested with that pathogen.
- As Armillaria root disease spreads north over time under climate change need to move western redcedar as well.
- Increased foliar disease in current range of species under CC
- In Coastal Douglas Fir (CDF) biogeoclimatic zone this species is slowly dropping out of species mixes as a result of summer drought. This will likely occur in the Southern Interior ICH zone as well

True firs:

- Subalpine -fir range will shrink as tree line rises under influence of CC
- Foliar diseases and insect defoliators will increase under CC
- Increased risk of balsam woolly adelgid spreading into interior forests

Broadleaf species:

- Die-back issue for paper birch associated with drought in southern interior.
- Trembling aspen probably better adapted for drought than paper birch
- Foliar diseases have already been a concern in NW where increased summer precipitation has occurred.

Possible Climate Change Impacts on Pests

- Armillaria and Laminated root diseases will move N. Laminated root disease is particularly well adapted to take advantage of drought stressed trees.
- Budworms and other insect defoliators will flourish
- Leader weevils will flourish and spread
- Damage associated with rusts and foliar diseases will intensify if spring and fall moisture increases
- Pythiums and Phytophthoras in seedlings in spring will get worse in young stands
- Sudden Oak Death (SOD) *Phytophthorus ramorum* and other introduced diseases will become more prevalent
- Tomentosus root disease may be displaced by Armillaria and Laminated root rot, however, if we planted a greater component of spruce due to reductions in lodgepole pine deployment we could have more Tomentosus.
- General expansion of insect ranges northward and up in elevation
- BEC variant boundaries are probably already changing and will continue to change; trees within these margins will find that the conditions under which they established and grew are changing; these changing environmental conditions will stress them; stressed trees are generally more susceptible to pests.

Appendix 5 – Example of Decision-Focused Risk Assessment

A Decision-Focused Risk Assessment for Forest Health under Climate Change

(A.J. Woods, with input from A. Britneff, P. Hall, S. Hoyles, L. MacLauchlan, L. Rankin, K. White, D. Wilford, and S. Zeglen.)

“The overall risk varies...the primary determinants of risk are the potential for a high magnitude impact coupled with scientific uncertainties that prevent precise forecasting of the situations that will be highly risky.” Compass Resource Management Ltd. 2004

“Focus on the decision process.

Science serves decisions; it does not make them.

A better decision process will lead to more transparent and defensible decisions (withstand public, auditor, regulatory scrutiny).

Decision makers must commit to a more active role.” Compass Resource Management Ltd. 2004

“Risk assessment is the process of estimating the consequences of defined management options on defined management endpoints, with explicit expression of the uncertainties in these estimates.” Compass Resource Management Ltd. 2004

Introduction:

The scientific uncertainty surrounding the specific direction of climate change, particularly regarding precipitation, has significant consequences for forest pests, their hosts and forest management in BC. Climate change will directly affect the environment which will indirectly affect the host, the damaging agents (insects or fungi) and the resulting damage (Figure 1).



Figure 1. The disease triangle altered to account for both disease and insects.

Published scientific evidence of the unpredictability of the behaviour of forest pests under changing precipitation regimes (e.g. *Dothistroma* needle blight (Woods et al 2005)) illustrates this vulnerability. To date, other examples of the impacts of climate change on the forests of BC have been more predictable. One would expect trees in areas of the southern interior to eventually succumb to drought if the drought was severe and prolonged. Similarly, one would expect that mountain pine beetle populations could again reach epidemic levels in the absence of killing winter conditions given the

preponderance of over-mature lodgepole pine throughout much of the interior and the history of such occurrences (Safranyik 1988). That said, the extent and the duration of this epidemic are beyond almost everyone's expectations. In the case of *Dothistroma*, a relatively small increase in the frequency of warm-rain events coupled with a recent increase in mean summer precipitation tipped the scales in favour of the pest. That pest has in turn had devastating consequences for lodgepole pine dominated plantations in the ICH zone of northwest BC. This result was not so predictable. One would have expected that lodgepole pine would benefit from increased precipitation and warmth during the growing season (Rehfeldt et al. 1999). Our past experience with *Dothistroma* in BC would not have led us to predict the current situation.

The *Dothistroma* example highlights the uncertainty regarding forest pests and their hosts throughout much of the province. The combinations of hosts and their suite of pests will of course be different depending on location but the scientific fact remains that short-lived insects and fungi will be able to adapt to new environmental conditions under climate change much more quickly than their long-lived hosts. We don't know how these relationships will play out but we predict they will occur. In some cases these new relationships could be positive for some forest resources. In others there is a high probability that these new relationships will be negative, particularly in terms of timber productivity. This reality coupled with the inherent uncertainties associated with global climate change places forest management under a significant cloud of uncertainty.

The indirect impacts of climate change on BC's forests orchestrated by forest pests will present varying opportunities for management intervention. In mature unmanaged forests our options for interventions will be confined to being reactive rather than proactive as the forests, their species mixes and genetic diversity, are set. We will have to wait and see what the next pest outbreak or environmental stressor will be, and then react. In contrast, the establishment of new forests can be managed proactively. We can increase diversity both in terms of genetics and species, we can also adjust establishment densities to increase the resiliency of managed stands and to reduce the risk associated with climate change and its indirect affects on pest/host interactions. For this reason in this example we have chosen to focus the Decision-Focused Risk Assessment for Forest Health on young managed stands.

The Forests For Tomorrow (FFT) initiative provides an opportunity to implement forest management recommendations with a longer term focus. The stands established under FFT are predicted to experience significant environmental changes over their rotation due to climate change, see Hamann and Wang (in press). The FFT program could demonstrate measures that could be used to improve the resiliency and adaptive capacity of forests throughout BC.

Decision-Focused Risk Assessment for Forest Health

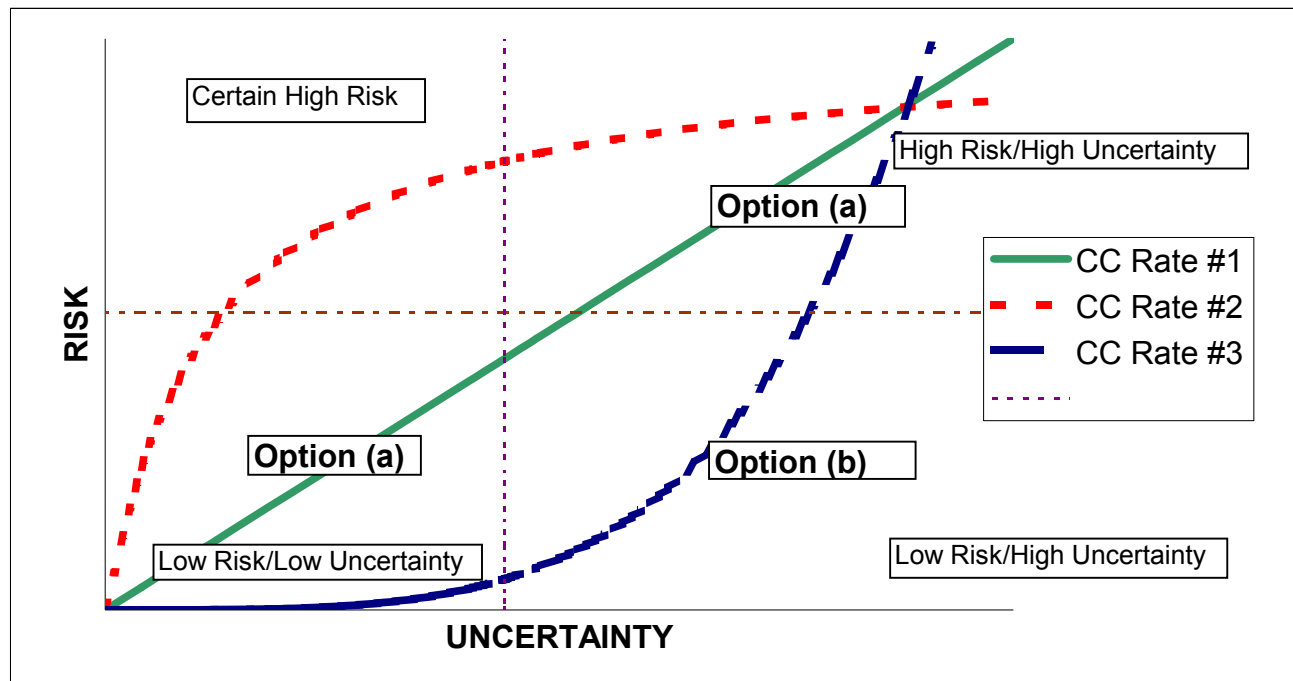
Question:	<p>What is the predicted impact of Climate Change on:</p> <ul style="list-style-type: none"> • managed stand resiliency, • forest management sustainability, • timber supply predictability, • managed stand productivity, • multiple use availability, and • community stability. <p>considering CC's relationships with Forest Health agents if we:</p> <p>(a) follow current practices regarding species selection and stocking standards until direction of climate change is more clear, or</p> <p>(b) increase species and genetic diversity at the stand and landscape level by ensuring that all currently preferred and acceptable tree species are incorporated into intimately mixed plantations AND application of the projections of changes to BEC boundaries predicted by Hamann and Wang (in press) to incorporate a proportion (up to 20%) of the dominant commercial tree species from the 2025 projected BEC zone distribution?</p>	
Objectives and Endpoints	<ul style="list-style-type: none"> • Resilient managed forests capable of coping with uncertainty of CC, • Sustainable forest management, • Stable, predictable Timber Supply, • Productive managed stands, • Maintenance of diversity of uses for forest land, • Stable forestry dependent communities • Minimal disruption/cost to forest industry. 	
Information on Impacts	<p>(1) Likely impacts of alternative (a): follow current practices regarding species selection and stocking standards until direction of climate change is more clear:</p> <p>Resilient managed forests: Our current practice regarding species selection and stocking standards is based on the philosophy that there is a “best” species or combination of species which in turn is based on years of experience under relatively stable climatic conditions and the assumption that environmental conditions including host/pest relationships are stable. Given our current understanding of Climate Change and our experience with host/pest interactions thus far, following (a) could delay the creation of resilient managed stands because we may well continue to choose the wrong “best” species or the wrong “best” provenance of a species until it is clear we have made a mistake.</p>	

<p>Information on Impacts</p>	<p>Sustainable Forest Management: We have seen what can occur when a change in the climate favours a pest (Woods et al 2005). We also have published science (Hamann and Wang 2005) that predicts the climatic conditions that resulted in managed stand failures in the ICH could occur in large portions of the SBS by 2025. We do not know precisely what will happen under climate change but we do know that large-scale plantation failures are possible in the ICH because we have already seen it happen. Other areas of the province are predicted to become drier. It is possible that if we continue to follow option (a) in those areas, less drought resistant species may continue to be planted until it is obvious that moisture deficits will threaten their survival. Under option (a) we would wait until a predicted result becomes a reality and then change. This option may hamper our ability to achieve the objective of Sustainable Forest Management if the climate continues to change at current rates.</p> <p>Stable, predictable Timber Supply: If rotation periods for our commercial tree species were much shorter (25 years?) we could follow option (a) and achieve the objective of a predictable Timber Supply, adjusting species preferences to maintain stability as new evidence of CC/Forest Health impacts became apparent. In general we do not currently manage for short rotation species nor are most of our current commercial species suited to such management, with the exception of some deciduous species. If, however, the climate does not change as quickly as predicted we will have sufficient time to adapt to new conditions under option (a).</p> <p>Productive managed stands: Evidence that suggests that FH/climate change interactions are already leading to less productive managed stands is mounting. Lodgepole pine is no longer a preferred species in the NW ICH because of Dothistroma needle blight (Woods et al 2005). Young lodgepole pine mortality due to Warren's root collar weevil has increased, to the point that stand rehabilitation is required in some stands (MPB epidemic is forcing the weevils out of mature forests into managed stands, MPB epidemic has been linked to climate change (Carroll et al. 2004)). The incidence of hard pine rusts in pine stands of central BC has increased significantly over the past two decades based on a review of published articles (van der Kamp and Spence 1987, Woods et al. 2000). Foliar diseases that historically have been so insignificant that identification guide books do not include them as pests in BC are frequently being reported in Free Growing surveys in central BC (e.g. <i>Phaeoseptoria contortae</i>, <i>Rhizoshaera kaukhoffii</i>). If we continue under option (a) until it is even more evident that climate change may be affecting our ability to maintain productive managed stands, we forego potential increases in productivity that we might have been able to obtain through the use of</p>
-------------------------------	---

<p>Information on Impacts</p>	<p>a mix of potentially pest and climate change resistant species.</p> <p>Maintenance of diversity of uses for forest land: Our ability to achieve this objective is likely similar under both option (a) and (b). If timber productivity is the priority for an area option (a) is the most vulnerable option to the indirect impacts of Climate Change on host/pest interactions. Other resource values such as range, recreation and biodiversity may benefit under option (a) or at least be neutral.</p> <p>Stable forestry dependent communities: Forest pests are just one of many factors influencing community stability. Following option (a) perpetuates the reactive management approach which can lead to boom-bust situations such as the current MPB epidemic. If we wait until there is another obvious problem before we adjust practices we inevitably experience greater instability in terms of timber supply which in turn affects community stability. If Climate Change does not occur as quickly as predicted the difference between option (a) and (b) diminishes as does the respective affect on community stability.</p> <p>Minimal disruption/cost to forest industry: Option (a) results in no disruptions to current practice and no increase in cost to industry in the short term. In the short term option (a) is lowest risk because current species selection guidelines are based on past experience regarding tree species and their favoured environmental conditions, conditions that are assumed to be relatively stable. If the trajectory of current climate change projections and indirect impacts on forest health agents become reality, costs to industry could rise sharply as efforts required to reforest areas increase due to plantation failures and poorly adapted provenances. The increased uncertainty associated with climate change could lead to an extension of the Free Growing obligation period, as high-risk species become less acceptable to grow. If climate change does not occur as quickly as predicted option (a) is least cost.</p> <p>(2) Likely impacts of option (b) increase species and genetic diversity at the stand and landscape level by ensuring that all currently preferred and acceptable tree species are incorporated into intimately mixed plantations AND application of the projections of changes to BEC boundaries predicted by Hamann and Wang (Ecology, in press) to incorporate a proportion (up to 20%) of the dominant commercial tree species from the 2025 projected BEC zone distribution</p> <p>Resilient managed forests: Increasing the diversity of species deployed in plantations through the use of intimately mixed</p>
-------------------------------	---

	<p>plantations will inherently increase the resiliency of managed stands. The probability of a single forest pest having the ability to severely impact the productivity of a stand is virtually zero if that stand is made up of intimate mixes of a variety of host and non-host species. Under option (b) managed stands would be more resilient and more capable of coping with the indirect affects of climate change whatever the next pest outbreak may be. Following option (b) also reduces the probability of creating non-productive areas.</p> <p>Sustainable Forest Management: Increasing diversity in plantations through the use of intimately mixed species and families within species (option b) will improve our chances of achieving the objective of sustainable forest management. The current MPB epidemic has emphasised the importance of diversity in the landscape and the role of diversity in the achievement of sustainability. A diversity of age classes within a single host species dominated landscape would have resulted in a forest that can be managed more sustainably. In the post MPB situation, under the cloud of uncertainty attached to Climate Change, a diversity of species, intimately mixed, and a diversity of stand structures offers a better chance of achieving sustainability.</p> <p>Stable, predictable Timber Supply: Experience thus far with the affects of Climate change on host/pest interactions suggests that the stability and predictability of timber supply will be challenged regardless of the option chosen. Though timber supply modelling may be more difficult under option (b), stability and predictability may improve under this option as the probability of plantation success improves despite the myriad combinations of host/ pest interactions under climate change. Some productivity loss is implied by including acceptable species as well as preferred in option (b).</p> <p>Productive managed stands: The speed at which the climate is predicted to change over the next rotation will compromise the productivity of managed stands regardless of the option chosen. Currently preferred species will be challenged by novel host/pest and climate interactions. Some species will cope better than others but we do not know how these new interactions will play out. If we follow option (b) we have a higher probability of having some trees that do cope better. As we see the new host/pest interactions develop we can adapt species mixes to maintain productivity of managed stands on the land-base. Having the variety of species already deployed in intimately mixed plantations buys time and provides an opportunity to have a scientific basis for management decisions (adaptive management).</p> <p>Maintenance of diversity of uses for forest land: Our ability to</p>
--	--

	<p>achieve this objective is likely similar under both option (a) and (b). If timber productivity is the priority for an area option (b) is the least vulnerable option to the indirect impacts of Climate Change on host/pest interactions although there are some implications for timber supply due to increased use of alternate species.</p> <p>Stable forestry dependent communities: Following option (b) allows for greater adaptability and promotes a more proactive forest management approach which should lead to more stability in timber supply and related community stability over the mid to long term. Overall volume will most likely drop due to climate change under either option but option (b) may limit the extent of the drop.</p> <p>Minimal disruption/cost to forest industry: Option (b) would require change to current forest practices which would result in increased costs to industry in the short-term. It is likely that a new silviculture survey approach would be required - one that would consider the diversity of species and genetics within species as the primary goal rather than achieving a minimum height in a minimal period of time. The short-term increase in costs associated with option (b) would result in less disruption/cost to industry over the mid- long term provided climate change and the indirect impacts of climate change on forest health agents occur as predicted (Logan et al. 2003).</p>	
Decision Guidance	<p>There are inherent risks associated with both options due to the degree of uncertainty associated with climate change. The magnitude of the risks depends a great deal on the rate at which the climate changes (Figure 2). If the climate changes more quickly than predicted there is a high degree of certainty that forests will be at very high risk not only from forest health agents but from fire, floods and many other factors regardless of the option chosen. If the climate changes more slowly than predicted there should be sufficient time to alter species selection and stand management practices to adapt to the new environments under option (a). Hansen et al. (2005) suggest that the climate is already changing and that given the inertia within the system, this change will continue even if we were able to immediately cut greenhouse gas emissions entirely. The predicted changes to BEC zone boundaries of Hamann and Wang (in press) are based on several “middle of the road” projections of the rate of climate change. These predicted changes have significant implications for forest health and forestry management in general. Option (b) may not go far enough to provide sufficient managed stand resiliency if the climate changes too quickly but it does provide a less risky option than (a). The Forest Health group recommend option (b) be implemented through FFT.</p>	



(c) **Figure 2.** Conceptual framework for assessing risk associated with option (a) follow current practices regarding species selection and stocking standards until direction of climate change is more clear, or option (b) increase species and genetic diversity at the stand and landscape level by ensuring that all currently preferred and acceptable tree species are incorporated into intimately mixed plantations **AND** application of the projections of changes to BEC boundaries predicted by Hamann and Wang (in press) to incorporate a proportion (up to 20%) of the dominant commercial tree species from the 2025 projected BEC zone distribution. (graph by Stefan Zeglen and Erin Hall)

Appendix 6 – Options for Reducing Emissions from MoFR Operations

Procurement

- Work with partners inside and outside government to access GHG friendly products, achieve economies of scale, and benefit from their recommendations; This would include keeping informed of, and helping to guide central government's procurement policy and practices regarding environmentally responsible actions;
- Raise our familiarity with environmental performance of equipment such as photocopiers and printers;

Buildings

- Moving toward energy-efficiency in our buildings, and investigating opportunities to reduce energy costs,

Transportation

- Transportation: working with staff and partners to minimize greenhouse gas emissions from vehicles.

Other

- Working with MoE, other agencies, partners, clients and staff on mitigation strategies for the forest sector
- Developing and supporting planned activities that would lead to reduction of GHGs during the course of MoFR business;

Operations

- Explicitly considering climate change mitigation in planning and operations as part of the way we do business, for example, encouraging the paperless office or providing avenues for increased composting to reduce methane from landfill sites.

Awareness

Increasing staff awareness of mitigation opportunities, for example:

- encouraging staff and offices to take on Canada's One-Tonne Challenge, which aims to reduce per-capita GHG emissions by one tonne annually. This program aims to use less energy, save money, improve air quality, and protect our environment.

- developing a staff involvement program to raise awareness of mitigation opportunities. Some of this work could be through workshops, info materials, presentations to senior managers, staff, cross-sectoral partners, etc.;

Monitoring

- working with staff and partners to develop monitoring mechanisms to assess MoFR's progress in reducing greenhouse gas and increasing energy efficiency;
- initiating and supporting a sustained program that would encourage interested staff and offices to assess and improve upon their GHG output and energy efficiency over time.
- providing reports to forest managers to assist in environmentally responsible decision-making at the local level;

Appendix 7 - Glossary of Terms

Adaptation

The actions that people take in response to, or in anticipation of, projected or actual changes in climate, to reduce adverse impacts or take advantage of the opportunities posed by climate change (Tompkins and Adger 2003).

Adaptive capacity

Adaptive capacity is the ability of a system to adjust to climate change, including climate variability and extremes, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC 2001).

Mitigation

Actions to cut net emissions of greenhouse gases and so reduce climate change. Examples are using fossil fuels more efficiently for industrial processes or electricity generation, switching to solar energy or wind power, improving the insulation of buildings and expanding forests and other “sinks” to remove greater amounts of carbon dioxide from the atmosphere (UNFCCC 2005).

Resilience

The capacity of a system to absorb disturbance, undergo change and still retain essentially the same function, structure, identity and feedbacks (Resilience Alliance: <http://www.resalliance.org>).

Vulnerability

The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of “exposure” and “adaptive capacity” (IPCC 2001).