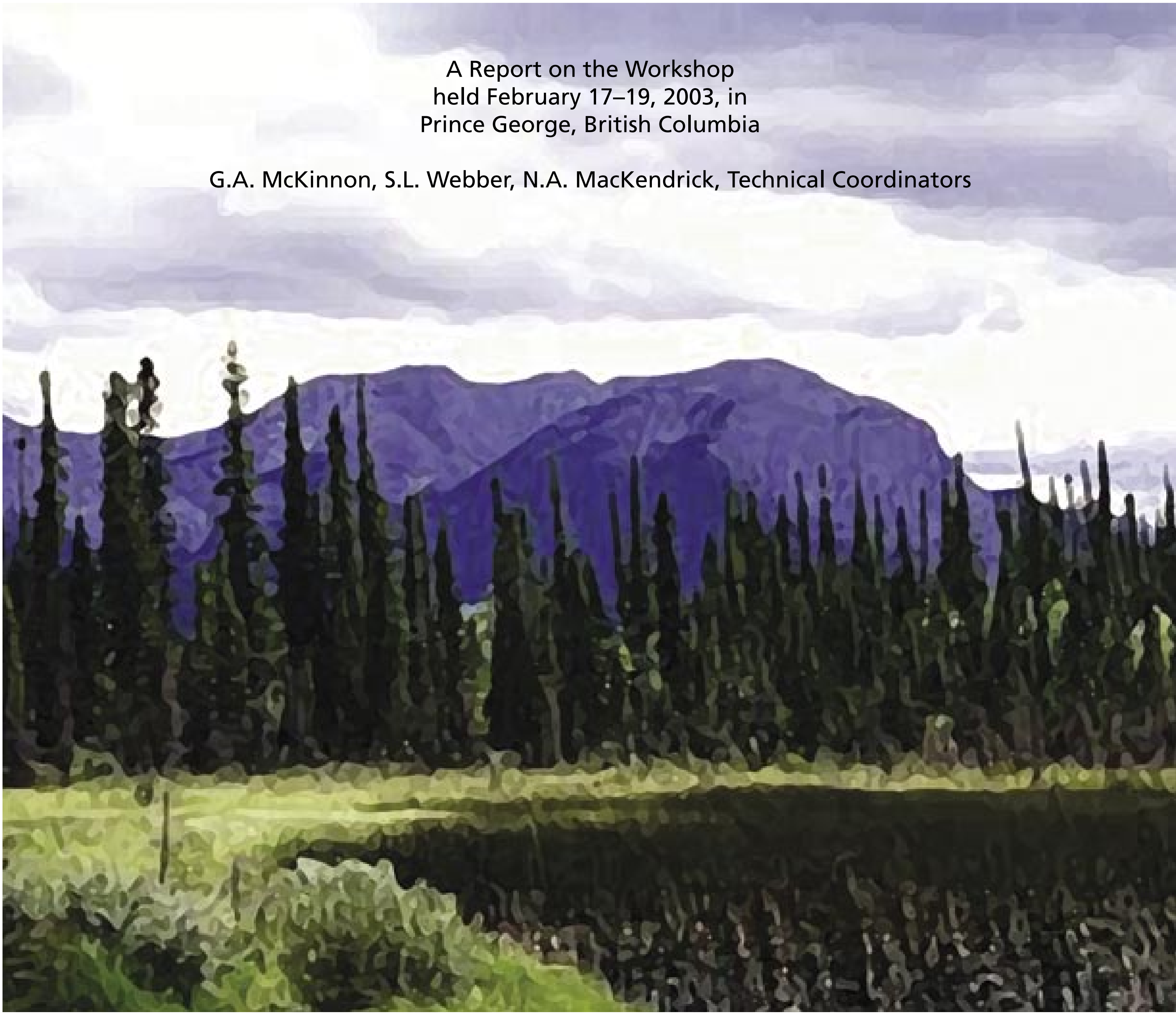
Climate Change in the Western and Northern Forests of Canada:

Impacts and Adaptations



A Report on the Workshop
held February 17–19, 2003, in
Prince George, British Columbia

G.A. McKinnon, S.L. Webber, N.A. MacKendrick, Technical Coordinators

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CLIMATE CHANGE IN THE WESTERN AND NORTHERN FORESTS OF CANADA: IMPACTS AND ADAPTATIONS

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ABSTRACT

The *Climate Change in the Western and Northern Forests of Canada: Impacts and Adaptations* workshop was held on February 17–19, 2003, in Prince George, British Columbia. The workshop provided a forum for the exchange of information on both the expected impacts of climate change on Canada's western and northern forests, and potential adaptive strategies. Presentations were given, and posters displayed, on climate change science and the implications of climate change on environmental, social, and economic values of the forest. Facilitated interactive sessions focused on knowledge gaps, policy, and institutional barriers to adaptation, followed by suggestions for moving the climate change impacts and adaptation agenda forward in the forest sector.

RÉSUMÉ

L'atelier intitulé Changements climatiques dans les forêts de l'Ouest et du Nord du Canada : Impacts et adaptations s'est tenu du 17 au 19 février 2003 à Prince George (Colombie-Britannique). Cet atelier a permis d'offrir un forum propice à l'échange d'informations concernant les impacts prévisibles des changements climatiques sur les forêts occidentales et nordiques du Canada et les possibles stratégies d'adaptation. Plusieurs présentations ont été faites, parallèlement à une exhibition d'affiches, sur la science des changements climatiques et sur les impacts de ces changements sur les valeurs environnementales, sociales et économiques de la forêt. Des séances interactives, sous la direction d'un animateur, ont permis d'axer les débats sur les lacunes en matière de connaissances, sur les politiques en vigueur et sur les barrières institutionnelles qui font obstacle à l'adaptation. Ces débats ont été suivis de suggestions visant à ce que soit discutées plus avant les questions relatives aux impacts des changements climatiques et à l'adaptation dans le secteur forestier.

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Note: The material in this publication originally appeared on the websites http://britishcolumbia.c-ciarn.ca/ and www.res.unbc.ca/climatechange. It is being reprinted in this form for the convenience of some users. The views, conclusions, and recommendations published in this proceedings are those of the authors and participants, and do not necessarily imply endorsement by the Canadian Forest Service.

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FOREWORD

From February 17 to 19, 2003, in Prince George, British Columbia, the Canadian Climate Impacts and Adaptation Research Network - Forest Sector (C-CIARN) and the University of Northern British Columbia (UNBC) co-hosted a workshop[1] on climate change impacts and adaptations in Canada's forest sector. Attendees included forest users, managers, policymakers and researchers. There were 129 participants in total, including 35 provincial government employees, 40 federal government employees, seven First Nations community representatives, 29 academic and research organization representatives, nine non-governmental and community organization representatives, five representatives from forestry consulting companies and four representatives from the forest industry. Participants came from across Canada including the western provinces, Ontario, Quebec, Yukon, and the Northwest Territories.

The workshop was designed to raise awareness of the expected impacts of climate change on Canada's western and northern forests and to facilitate communication between the research community and forest users on related forest management issues. Two separate interactive sessions engaged participants in the process of determining knowledge gaps, priority issues, and future research agendas.

The three-day agenda opened on the evening of February 17th with a public seminar, where four speakers presented various perspectives on the current state of climate change research and key considerations in adaptation planning. These presentations were followed by a panel discussion where audience members were given the opportunity to ask questions of the presenters. On February 18th, the first of two technical sessions was presented. The session featured six presentations on climate change science and the ecological implications for western and northern forests of Canada. The day concluded with a facilitated "Knowledge Café" session. On February 19th, the second technical session was presented. This session featured six presentations focusing primarily on climate change adaptation and the impact of climate change on human uses and values in the western and northern forests of Canada. The workshop concluded with a facilitated "Open Space" session and wrap-up.

This report summarizes the content of the workshop. The oral presentation abstracts are presented first, followed by a summary of the "Knowledge Café" and "Open Space" sessions. Asterisks by authors' names indicate individuals who gave presentations.

[1]In addition to C-CIARN Forest and UNBC, the workshop was sponsored by the following organizations: C-CIARN National Office; British Columbia Ministry of Water, Land and Air Protection; Model Forest Network; British Columbia Ministry of Forests; Natural Resources Canada, Canadian Forest Service; McGregor Model Forest; Prairie Adaptation Research Collaborative; and Sustainable Forest Management Network.

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The workshop *Climate Change in the Western and Northern Forests of Canada: Impacts and Adaptations* was hosted by the Canadian Climate Impacts and Adaptation Research Network Forest Sector and the University of Northern British Columbia.

C-CIARN Forest Sector and UNBC thank the sponsors:

- C-CIARN National,
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- Natural Resources Canada, Canadian Forest Service,
- McGregor Model Forest,
- Prairie Adaptation Research Collaborative, and
- Sustainable Forest Management Network.

The participants are acknowledged for their valuable contributions to the workshop. A list of workshop participants appears at the back of this book.

Special thanks are extended to Dr. Art Fredeen of the Faculty of Natural Resources and Environmental Studies for leading the development and organization of the workshop on behalf of the University of Northern British Columbia. Thanks also to Jennifer Studney, UNBC Conference Services, for logistical support. Our appreciation is also extended to Bob Chartier and Rob Hauch for their excellent facilitation skills during the "Knowledge Cafe" and "Open Space" sessions, and to Brenda Laishley and Sue Mayer of the Northern Forestry Centre Publications Unit for editing and formatting the report.

ABSTRACTS

Impacts on Ecosystems and Natural Processes

Climate Trends and Future Projections

B. Taylor*

According to the Intergovernmental Panel on Climate Change (IPCC), the globally averaged temperature has risen 0.6°C during the 20th Century. IPCC states that it is very likely that the 1990s was the warmest decade since 1861, and that the increase in 20th Century temperatures is likely to have been the largest of the past 1 000 years.

The regional pattern of climate change in Canada over the past 50 years has been unusual in that western and southern Canada have warmed while the northeastern part of Canada along the Labrador Sea has actually cooled. Most of the warming in the south and the west has occurred during winter, and daily minimum temperatures have increased much more than daily maximum temperatures. Thus, it is said that Canada is not getting warmer, it is getting "less cold." This trend in daily minimum temperatures is also evident throughout much of British Columbia.

It is not possible to predict the future climate with a high degree of confidence. In its Special Report on Emissions Scenarios (SRES), the IPCC describes six marker greenhouse gas emissions scenarios based on varying assumptions of population, economic growth and technological change. Based on the full range of SRES scenarios, the IPCC predicts global temperature increases in the range of 1.4–5.8°C by the end of the 21st century. A warming of this magnitude would be unprecedented in the past 10 000 years. Extreme events such as heat waves and more intense precipitation are expected to increase during the 21st Century. Conversely, there will be fewer cold spells.

There is good agreement among climate models that western North America will experience greater than average warming by the 2080s, both for the winter and summer periods. Precipitation projections are much less certain. The models agree on a small increase in winter precipitation by the 2080s for western North America, however, there is no agreement as to whether summers will be drier or wetter.

Climate Change Impacts and Adaptations: Global and Regional Perspectives

S. Cohen*

A warmer climate could result in a wide range of impacts for ecosystems and communities throughout the world. What kinds of impacts are expected? How might these affect the future of communities and nations? What are the options for adapting to such changes, as part of a combined effort with reduction of greenhouse gas emissions? What are the challenges and opportunities for impacts and adaptation research, particularly when considering inter-disciplinary efforts and partnerships between researchers and stakeholders? This presentation explores some of these impacts and adaptation challenges, drawing on the recent review by the Intergovernmental Panel on Climate Change (IPCC), as well as current research activities in Canada.

Climate Change and Forests: An Overview of the Expected Impacts

J. Innes*

Long-term temperature records clearly indicate that there has been a marked increase in surface temperatures since the last quarter of the 19th Century. These records are supplemented by large amounts of evidence from proxy sources revealing the changes in a number of phenomena. Glaciers in the northern Rocky Mountains have retreated extensively over the past 100 years, with photographic evidence providing clear indications of the extent of the changes. Additional evidence comes from tree cores, with larch trees near the Athabasca and Peyto Glaciers showing a period of increased growth during the 20th century. These trends are also present in tree cores and glaciers from many other parts of the world, ruling out the possibility that the trends are site specific.

The causes of the increase in temperature remain contested, but there is a broad consensus amongst scientists that emissions of greenhouse gases have played an important role. Average temperatures in the Pacific Northwest rose by between 0.6 and 1.7°C over most of the region during the 20th Century. Average precipitation has also been increasing throughout much of the Pacific Northwest, although there are local exceptions to this trend. The changes caused by anthropogenic activities are superimposed on natural variations in climate. There has been a warming trend in global surface temperatures since the peak of the Little Ice Age and there are also shorter variations associated with the El Niño – Southern Oscillation phenomenon and the Pacific Decadal Oscillation. The effects of the latter have only recently been recognized, although it is tree growth that has shown some of the clearest responses.

Models incorporating climatic forcing factors are becoming increasingly good at reproducing the observed temperature trend during the 20th Century, placing greater confidence in extrapolations into the future. Average temperatures in the Pacific Northwest are expected to increase by 1.7 °C by the 2020s and 2.8 °C by the 2050s. The greatest increases in temperature are likely to occur in the northeast of the region. Annual precipitation will be less predictable, with a change of between -7% and +13% expected. Essentially, warmer, wetter winters and warmer, drier summers are anticipated.

The potential effects of these changes on the forests of the Pacific Northwest are difficult to predict. The heavier winter rainfall is likely to increase soil saturation, leading to more landslides and winter flooding. The response of trees is very uncertain due to the lack of knowledge of how the water use efficiency of trees will change as a result of continuing carbon dioxide enrichment. There are also mixed signals concerning forest ecosystems. Warmer winters could result in increased over-winter survival of some pests because of the higher minimum temperatures. However, the survival of other pests may be decreased because of reduced snow cover. Clearly, knowledge of the ecology of individual species will be required before any impacts can be predicted.

A major concern is the response of plant communities. This is hotly debated, and there is fairly widespread acceptance that entire ecosystems will not simply shift northwards (or upwards). Individual species respond in different ways, and it is quite possible that new plant communities will emerge, requiring major revisions to the biogeoclimatic classification that forms a cornerstone of forest management in British Columbia.

Some changes, which may or may not be a direct response to climate change, have already been seen. Boreal forest productivity is increasing, with faster growth rates of trees (and subsequent impacts on wood quality). Some insects have shown accelerated seasonal development, and there have been changes in the distributions of some insects. In provenance trials, provenances from slightly warmer areas are successfully out-competing local provenances.

An added complication is the effects of forest management on the ability of forests to respond to climate change. In some areas of the Pacific Northwest, fire suppression, selective removal of large trees and intensive grazing have created a dense mixed forest overstocked with sensitive pines and firs. This forest is susceptible to insect outbreaks, disease and catastrophic fire, as the recent bark beetle epidemic and the 2003 fire season have so clearly shown.

The provincial government in British Columbia and the forest industry have been slow to take climate change into account. The current annual allowable cut makes no provision for future changes in productivity associated with climate change. Long-term forest management plans look at timber supply over the next 200 years, but again ignore any possible changes associated with climate change. These are major shortcomings in the sustainable management of the forest resources of British Columbia.

There are a number of strategies that could be taken to reduce the potential problems for forestry that might be brought about by climate change. Seed transfers from warmer areas to cooler areas are currently permitted, but the distances involved could be increased. Long-term growth estimates could be adjusted. Forest structure and composition could be restored in intensively managed areas. Forest density could be managed to reduce drought stress. Pre-commercial thinning, prescribed burning and other techniques could be used to reduce the risk of large, high-intensity disturbances. These are all mechanisms of adaptation, largely based on the premise that healthy forests are more resilient than unhealthy ones.

Many of the issues that climate change poses for forestry in British Columbia could be solved through suitable research. However, much of the research funding in the province is driven by the short-term needs of industry, with very little thought being given to strategic issues. This leads to reactive and poorly coordinated research efforts that are often too late to solve the problem. The result is a provincial forest industry that will continue to be surprised by events, whether they be bark beetle outbreaks, large-scale forest fires, or other major disturbances.

Range Expansion by Mountain Pine Beetle Under Climate Change: Today's Reality or Tomorrow's Problem?

A. Carroll*

The current latitudinal and elevational range of mountain pine beetle (MPB) is not limited by available hosts. Instead, its potential to expand north and east has been restricted by climatic conditions unfavorable for brood development. We combined a model of the impact of climatic conditions on the establishment and persistence of MPB populations with a spatially explicit, climate-driven simulation tool to produce maps of past climatically suitable habitats for MPB in western Canada. Overlays of annual MPB occurrence on these maps were used to determine if the beetle has expanded its range in British Columbia in recent years due to climate change. An examination of the distribution of climatically suitable habitats in 10-year increments derived from climate normals (1921–1950 to 1971–2000) clearly shows an increase in the range of benign habitats. Furthermore, an increase (at an increasing rate) in the number of infestations since 1970 in formerly climatically unsuitable habitats indicates that MPB populations have expanded into these new areas.

Climate Change and Insect Disturbance Regimes in Canada's Boreal Forest

R.A. Fleming*, and J.N. Candau

Natural disturbances are integral processes in the succession, functioning, and carbon cycling that occurs in most of the world's boreal forests. Insects represent dominating disturbance factors in Canada's boreal forests and during outbreaks trees are often killed over vast areas. This extensive tree mortality shifts the forest toward younger age-classes, which contain less biomass and much of the residual carbon is later released to the atmosphere.

A fundamental question is how climate change will influence the frequency, duration, and intensity of natural disturbances and whether this will affect the rate of warming. The resulting uncertainties also directly affect depletion forecasts, pest hazard rating procedures, and long-term planning for harvest queues and pest control requirements. Because the potential for wildfire often increases in stands after insect attack, uncertainties in future insect damage patterns magnify uncertainties in fire regimes. In addition, changes in damage and disturbance patterns can indirectly alter competitive relationships between plants and hence successional pathways, species composition, and forest distribution.

The disturbance regime associated with the most important insect of Canada's forests, the spruce budworm, *Choristoneura fumiferana* Clem. (Lepidoptera: Tortricidae), is briefly described. I focus on our approach to developing scenarios suggesting how this disturbance regime might respond to climate change. The potential importance of threshold and scale effects, historical factors, phenological synchrony, rare but extreme weather events, and natural selection are outlined.

Projecting Climate Change-Induced Impacts on Future Canadian Fire Regimes

B. Stocks*, M.D. Flannigan, K.A. Logan, E.M. Bosch, B.M. Wotton, D.L. Martell, B.D. Amiro, J.B. Todd, and D.W. Skinner

Forest fire is the major and most visible disturbance regime in Canadian forests, burning over an average of ~3 million hectares annually, threatening human life, destroying property, and significantly affecting Canada's economically vital wood supply. Direct fire management costs total ~$500 million annually, with larger indirect costs. Forest fires have also been shown recently to exert a major impact on the sink/source strength of Canadian forests, a subject of ongoing international negotiations on atmospheric emissions and the global carbon budget. Current climate change projections suggest a strong increase in the frequency and severity of weather conditions conducive to forest fires across much of Canada, and there is a strong and urgent need to project the extent and impact of future Canadian fire regimes in order to devise and implement effective adaptation strategies. Climate Change Action Fund (CCAF) support has been used in recent years to address these needs.

A database of all large (>200 hectare) fires in Canada was developed using fire report data from all Canadian fire management agencies over the past 4 decades (1959–1999). This spatially explicit large fire database (LFDB) permitted the first national-scale assessment of forest fire impacts across Canada. Concurrently, national daily weather and fire danger databases were developed for the same time period, and used along with the LFDB, to develop scientifically sound relationships between fire activity and climate in Canada over the past 50 years. The movement and position of air masses in the upper atmosphere was quantitatively determined to be a major driver of large fire activity through this project. In addition, the amount of carbon released annually through forest fires over the past 4 decades was determined, using the LFDB in combination with outputs from the Canadian Forest Fire Behavior Prediction System.

Scenarios of future forest fire danger have been developed for western Canada, using the high-resolution Canadian Regional Climate Model, and these scenarios, in combination with the LFDB have been used to designate Canadian forest ecozones most vulnerable to increased fire activity with climate change. Preliminary adaptation strategies have been developed at local (community protection), landscape (forest fuel management options), and provincial (protection analyses) levels, based on future scenarios of fire danger across Canada, and adaptation research is continuing.

Impacts of Climate Change on Forest Productivity

M. Johnston*

Forest productivity is determined by a number of environmental factors, most of which will be affected by climate change. This presentation focuses on the most important of these: temperature, moisture availability, nutrient availability and atmospheric carbon dioxide (CO_2) concentration, and briefly reviews the ways in which climate is likely to change. Attempts to carry out more comprehensive analyses that combine the effects of climate change on productivity with down-stream economic impacts are also discussed. By and large, we expect a general increase in temperatures, with temperatures at night rising faster than those in the daytime, and winter temperatures increasing faster than summer temperatures. These changes will result in generally warmer soil temperatures, and fewer frost days, both of which will change growing conditions in the forest. Impacts of climate change are difficult to predict because of numerous interacting factors, which vary by species and site conditions. However, it appears that there is potential for increased productivity on sites with adequate nutrients (especially nitrogen) and water, due to higher temperatures and increased CO_2 levels. However, sites that are currently marginal with regard to water nutrients are likely to become less productive. We will probably see an increasing divergence between sites, in which the "good" sites get better and the "bad" sites get worse. This will provide added incentive for concentrating management inputs on the more productive sites and avoiding drought-prone, low nutrients sites.

Climate Change, Biodiversity and Population Migration

J. Malcolm*

Although global warming is recognized as a key threat to biodiversity, few studies have assessed the magnitude of this threat at a global scale. I used models of biome distributions under recent and doubled-CO_2 climates to examine warming-induced changes in biome areas (and attendant possibilities of species loss) and migration rates. Changes in biome areas were examined under two scenarios: (1) shifts in biomes kept pace with shifts in climatic conditions and (2) biomes fail to shift to new areas due to migration limitation. In addition, estimated future migration rates are compared with post-glacial rates, and also are used to locate areas that may be disproportionately important in facilitating future migration. Biome mapping was undertaken using 14 combinations of seven global climate models (GCMs) and two global vegetation models (GVMs). Under the first scenario, all models showed declines in the areas of tundra and tundra/taiga, respectively ranging between 41–67% and 33–89% of the total area depending on the particular combination of GCM and GVM. Corresponding estimates of species loss were between 8–15% and 6–28% of the biota using a conservative species-area exponent (0.15). Evidence of net declines in arid lands also were obtained. By contrast, temperate mixed forests showed consistent increases (49% on average) and tropical broadleaf forests and grasslands also tended to show increases in area. Under the second scenario, all biome types declined in area, especially those at high latitudes and altitudes such as tundra, taiga/tundra, boreal conifer forests, and temperate evergreen forests (55, 85, 46, 52% loss, respectively). Even tropical broadleaf forests showed an 8% loss in area, corresponding to the possible loss of tens of thousands of species. Although this second scenario is unrealistic in that it assumes zero migration, it does highlight the potential for impacts in a diverse array of ecosystems, and the potential importance of migration in mitigating these impacts.

In all models, migration rates much higher than those observed in the recent past (i.e., ~1 000 m/yr) were common, comprising 19% of global grid cells on average. These high rates were especially prevalent in boreal and temperate biomes. In the boreal biome, in order to obtain migration rates that were similar in magnitude to post-glacial rates, a radical increase in the period of warming was required, from 100 to >1 000 years. A spatially explicit example of projected tree migration is shown for Ontario, along with a technique to identify populations that may be especially important in facilitating future migration. Thus, coupled GCM/GVM projections suggest that global warming could result in considerable species loss, especially if migration fails to keep pace with the warming. Several poorly understood factors that are expected to influence the magnitude of any such losses are discussed, including intrinsic migrational capabilities, barriers to migration, the role of outlier populations in increasing migration rates, the role of climate in setting range limits, and variation in species range sizes.

The Role of Protected Areas Under Climate Change

D. Scott*

Both the Fourth World Congress on National Parks and Protected Areas (1993) and the United Nations Intergovernmental Panel on Climate Change Special Report on Climate Change and Biodiversity (2002) concluded that global climate change poses a critical threat to ecosystems, that existing protected areas may not provide adequate conservation safeguards, and that climate change adaptation must be a component of future protected area planning and management. The growing body of evidence documenting observed response of physical and biological systems to on-going climate change indicates that climate change also has immediate relevance for protected area managers. As the science community continues to advance its understanding of the potential biophysical impacts of climate change, discussions of the implications for conservation policy and management have for the most part remained outside of the institutional frameworks of the organizations responsible for the management of protected areas.

Using examples from Canada's national and provincial park systems, this paper examines the implications of a range of climate change biophysical impacts for conservation policy and planning (both at the system and individual park level). The steady-state protected area system plans adopted by most federal and provincial – territorial jurisdictions were developed with the assumptions of climatic and biogeographic stability; assumptions that an accumulating body of research indicates are no longer tenable. Individual park objective statements, wildfire management strategies, non-native species management programs, species reintroduction programs, and visitor management plans are also vulnerable to the impacts of climate change.

Climate change represents an unprecedented challenge for protected areas in Canada, as never before has there been an ecological stressor that has raised questions about the adequacy of our system of protected areas to conserve representative samples of Canadian ecosystems. The development of climate change adaptation strategies will be essential if the intergenerational conservation legacy of the Canada's protected areas is not to be diminished. The issues related to the strategic role of protected areas in an era of climate change are very complex and will require far greater analysis and significant input from conservation stakeholders.

ABSTRACTS
The Science of Adaptations

The Science of Adaptation: A Framework For Assessment

B. Smit*

Adaptation is one of the responses to climate change risks. There are several analytical approaches to estimate impacts and assess adaptation options in sectors such as forestry. Each approach provides insights on adaptation processes, types and effectiveness, with applications to climate change negotiations and adaptation planning. Lessons from adaptation research include the need to consider climate-related risks pertinent to the sector of interest, the need to learn from past experience, and the need to recognize that adaptation is essentially risk management. A framework is presented to guide adaptation assessment intended for policy and management applications.

Adaptation and Forest Management

D. Spittlehouse*

Sustainable forest management requires a long-term management strategy. This long-term view and the tools that have been developed to address it, give forest managers an opportunity to adapt to the effects of future climate change on forests. Adapting to climate change in the face of an unknown time of occurrence of impacts means we must have a suite of options ready to go whenever they are needed. Adaptive actions will involve intensifying the application of existing techniques, identifying barriers to their implementation and initiating monitoring. In many situations society will have to adapt to however the forest adjusts. A high priority will be coping with and adapting to forest disturbance while maintaining genetic diversity and resilience of forest ecosystems. For adaptation in forest management to take place, policymakers and forest managers must accept that climate change is probable and that its effects on forests can be addressed.

Examples of adaptive actions for genetic management, forest protection, forest regeneration, silvicultural management, forest operations, wildlife and maintaining parks and wilderness areas are presented. Adaptation in forestry is sustainable forest management with a climate change focus.

FireSmart: An Example of a Climate Change Adaptation Strategy

K. Hirsch*

Forest fires are an important natural disturbance in many of Canada's forest ecosystems and can have both ecological benefits as well as detrimental socioeconomic impacts. Under a changing climate, forest fire activity is expected to increase, especially in the western and northern boreal forest. This is due to projected increases in lightning and human-caused ignitions, a longer fire season, and higher fire intensities, all of which will result in more escape fires and area burned. Recognizing the likelihood of a climate induced change in forest fires, proactive fire smart strategies and actions can be taken to minimize the negative impacts of wildfire.

FireSmart, in its simplest form, involves thinking about fire when conducting strategic and operational land and resource management activities. Originally focused on protecting life and property in the wildland-urban interface, fire-smart concepts are now being extended to larger landscapes (e.g., forest management units, parks, and protected areas) as part of adaptive and sustainable forest management programs. Being fire smart

- recognizes that fire is a natural process and that we are living and working in a flammable ecosystem;
- accepts that although wildfires can be a relatively rare occurrence at any particular location, there is a chance that "it could happen here";
- realizes that traditional approaches to fire suppression (e.g., airtankers, helicopter, fire-fighting crews) are reaching their limit of economic and physical effectiveness; therefore, a small percentage of wildfires will continue to escape initial attack and become large;
- promotes cooperation and appropriate sharing of responsibility among individuals, communities or municipalities, and land and resource management industries and agencies.

Based on a synthesis of available science and expertise, fire smart guidelines have been developed by the Partners in Protection (an association of federal, provincial, and municipal agencies and organizations) to help individuals and communities in the wildland-urban interface reduce the risk from wildfire. For example, three primary actions have been found to greatly reduce the ignition potential of a structure: installing a non-flammable roof (e.g., metal, tile, or asphalt shingles), breaking the chain of fuel by removing flammable material in the area immediately around your home (e.g., creating a 10- to 30-m ignition free zone), and reducing the flammability of the building's exterior (e.g., using non-combustible siding, closing gaps in eaves and decks, and installing tempered windows).

From a forest management perspective, activities such as harvest scheduling, cut block design, road layout, reforestation, and stand tending all provide opportunities to change the forest fuels and, therefore, the fire behavior potential at the stand and landscape levels. Fuels management activities include fuel reduction, conversion, and isolation and will affect the amount, configuration, and composition of forest fuels. One of many possible actions is to strategically intersperse fuel treatments among large continuous areas of highly flammable fuels. This could be accomplished through thinning, pruning, and surface fuel removal, and/or by converting crown fire prone coniferous stands to deciduous species that generally have a lower flammability. Although these types of actions will not eliminate the possibility of large fires, when used in combination with fire suppression they could significantly reduce the area burned by wildfires under current and future climatic conditions.

Climate Change and Industrial Use of the Forest

M. Bradley*

This presentation explores some of the ways in which climate change is expected to impact upon the forest sector in Canada. The effect that climate change may have, both on forest disturbance and on some key distinguishing attributes of Canadian wood and fiber is explored. The contribution of some of the sectors products in contributing to climate change and a cradle-to-grave carbon balance across a paper chain is illustrated. Finally the presentation will discuss some of the ways in which climate change concerns are driving government policy decisions and influencing civil society.

A Summary of Climate Change Effects on the Global Forest Sector

J. Perez-Garcia*, L.A. Joyce, A.D. McGuire, and X. Xiao

This study describes an integrated assessment of climate dynamics, ecosystem processes, and forest economics. We utilize three climate scenarios and two economic scenarios to represent a range of greenhouse gas emissions and economic behavior. At the end of the analysis period (2040), the potential responses in regional forest growing stock simulated by the global ecosystem model range from decreases and increases for the low emissions climate scenario to increases in all regions for the high emissions climate scenario. The changes in vegetation are used to adjust timber supply in the softwood and hardwood sectors of the economic model.

In general, the global changes in welfare are positive but small across all scenarios. At the regional level, the changes in welfare can be large and either negative or positive. Markets and trade in forest products play important roles in whether a region realizes any gains associated with climate change. In general, regions with the lowest wood fiber production cost are able to expand harvests. Trade in forest products leads to lower prices elsewhere. The low-cost regions expand market shares and force higher-cost regions to decrease their harvests. Trade produces different economic gains and losses across the globe even though, globally, economic welfare increases. The results of this study indicate that assumptions within alternative climate scenarios and about trade in forest products are important factors that strongly influence the effects of climate change on the global forest sector.

Social and Economic Considerations Pertaining to Climate Change Impacts and Adaptation in Forest-Based Communities

T. Williamson*

Forest-based communities have strong social, cultural, and economic ties with climate-sensitive forest environments. Also, the characteristics of forest-based communities define a particular social context for climate change that contributes to additional concerns about the forest's vulnerability to climate change effects. For example, capacity to adapt to climate change may be impaired somewhat by a) low investment in higher education, b) general declines in autonomy, c) potential tendency to underestimate climate risk, d) institutional inflexibilities, and e) a general lack of scientific information regarding climate change effects at local levels. At the same time the long-term and irreversible nature of forestry investments and forest management decisions increases the imperative for incorporating climate change into current policy and decision-making.

There is significant uncertainty about the magnitudes and timing of climate change effects in forest-based communities and the lack of information on local effects will limit the development of adaptation strategies. One approach for providing communities with a better information base upon which to evaluate the need for action is to undertake risk analysis. A risk analysis framework is described. The framework includes evaluation of adaptation capacity, scientific risk assessment, and understanding risk perceptions as its main components. Effective risk management and risk analysis, however, requires that each of the components are linked by a systematic and structured approach to risk communication.

KNOWLEDGE CAFÉ SESSIONS

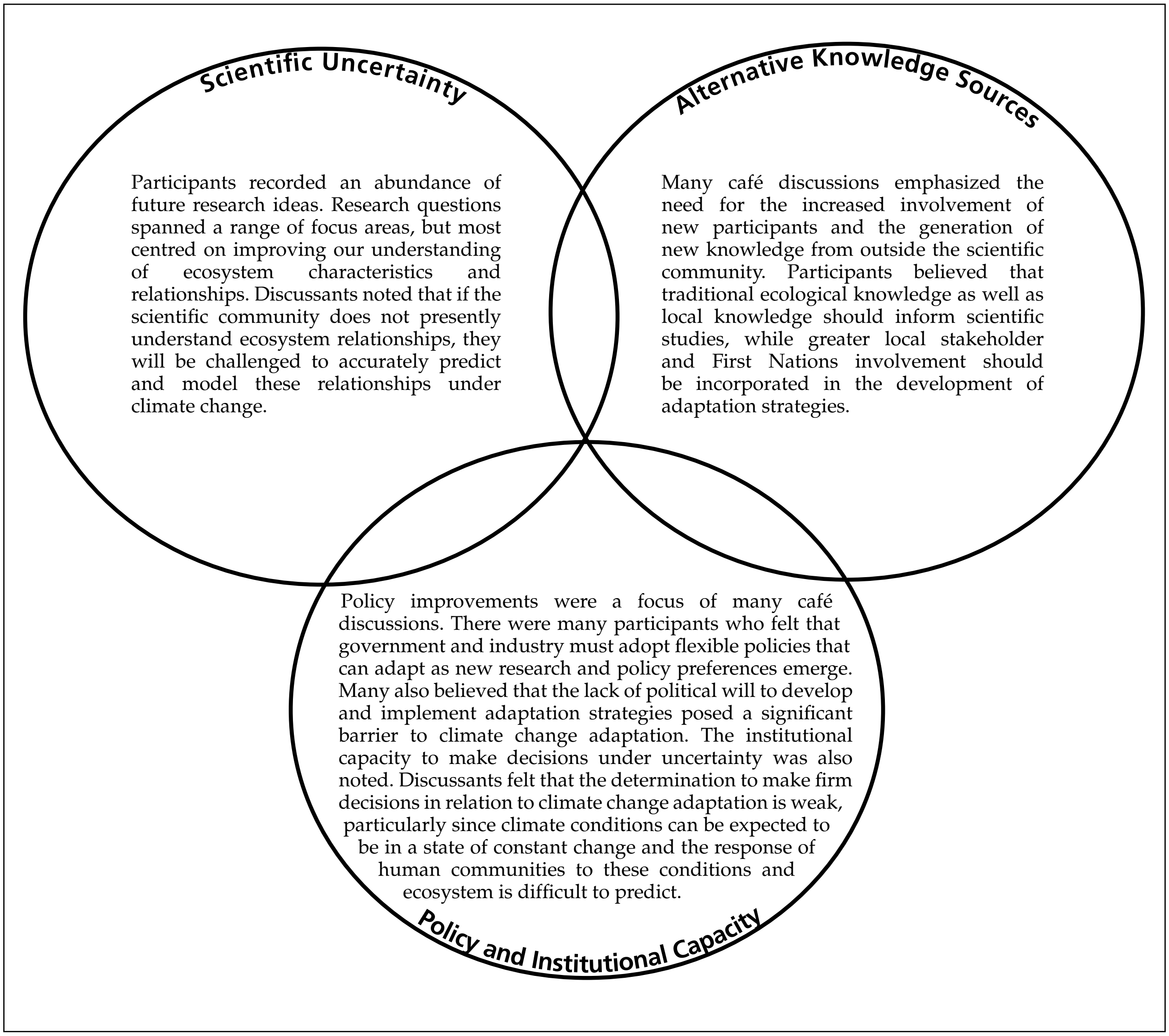
KNOWLEDGE CAFÉ SESSIONS

The first break-out session of the workshop was conducted using a framework called a "Knowledge Café." This requires participants to gather in small, rotating groups to engage in conversations regarding key climate change and forest-related issues. The Knowledge Café sessions addressed six key areas of interest: forest fires, insects and disease, forest productivity, forest practices, biodiversity, and non-timber forest values. Participants addressed three pre-formulated key questions in each session:

1) What are the primary knowledge gaps regarding climate change as it pertains to this issue?
2) What are the key policy changes/enhancements required to effectively respond to climate change for this issue?
3) What forest management practices will improve our ability to address this issue under a changing climate?

With the help of an observer[1], individuals had the opportunity to participate in three different café discussion groups. After the final rotation, café observers assembled to debrief all participants on the key points discussed during their sessions. The comments summarized in this section are adapted from notes taken at these sessions, including points noted both by participants and observers.

[1]Café observers acted as note takers and information synthesizers in the discussions that took place in each café.



Common themes from the Knowledge Café sessions.

Common Themes

- Basic science needs strengthening. In particular we need a better understanding of ecosystem relationships and how ecosystems will change under climate change.
- Multiple factors are acting in concert. We should not isolate these factors, but consider them together.
- How do we understand systems that are constantly changing? There is no baseline.
- Stakeholders need to be involved in science, policy, and adaptation strategies.
- Humankind has difficulty acting under conditions of great uncertainty. This reluctance will impede adaptation efforts.
- We have the knowledge and understanding to develop adaptation strategies. What is missing is the political will to design and implement these strategies.
- Public willingness to engage in climate change adaptation will require better education, in order to reduce the confusion about climate change.
- Take a broad and long-term approach to climate change research and adaptation planning.
- Develop flexible policy to feed new information and new understanding into constantly changing adaptation strategies. Take an interdisciplinary approach to climate change research and adaptation.
- Involve Aboriginal communities in climate change research and adaptation planning.
- Include traditional ecological knowledge in scientific studies and adaptation decision-making.
- Rethink how the annual allowable cut is allocated. Must protect forest integrity from potential losses due to climate change.
- Improve the predictive capacity of climate change and forest models. Reconsider their core assumptions.
- Improve and strengthen climate change monitoring.
- Maintain genetic diversity in order to maintain ecosystem resilience under climate change.
- Management strategies will have to consider whether to proactively facilitate species adaptation by a) utilizing genetically modified organisms, or b) helping species move north.

Note: Detailed comments recorded by participants, along with the extensive set of notes taken by observers, are summarized in the following pages. Comments have been organized into themes reflecting the substance of participants' observations. Similar remarks have been merged into one point or grouped together under the same theme.

Non-Timber Forest Values (NTVs) and Climate Change

Observer: S. Grainger

Knowledge gaps

1. Defining and Measuring NTVs
   - NTVs fall into several categories:
     - Intrinsic values
     - Existence values
     - Spiritual values
     - Cultural values
     - Heritage values
     - Subsistence values
     - Use values
   - Develop a catalogue of NTVs.
   - How do we reconcile conflicts between different NTVs?
   - Climate change will modify existing NTVs and likely create new ones.
   - What standard should we use when identifying, defining, and assessing NTVs?
   - We have considerable difficulties measuring NTVs.
   - A global climate science approach is inappropriate for defining NTVs.
   - How do we assign quantifiable and measurable values and reconcile cultural differences in the valuation of NTVs?
   - How will the perceived impact of climate change on NTVs vary with different cultures?
2. First Nations
   - What are some appropriate structures for allowing meaningful discussions between First Nations and stakeholders?
   - Incorporate traditional ecological knowledge with climate change adaptation studies.
3. Science
   - Do we know enough about ecosystems or their growth characteristics to manage them?
   - Identify environmental thresholds.
   - Are understory species and pioneer species more adaptable to climate change than commercial forest species?
   - How do the risks of climate change on forests vary with harvesting and non-harvesting scenarios?
4. Involving Stakeholders
   - How can we get consensus on NTVs and then incorporate these multiple values into climate change adaptation plans?
   - How can we communicate with each other about NTVs, their existence and spatial location?
   - Are long range management plans considered at management planning tables?

Policy changes and enhancements

1. Political Will
   - One way to influence policymakers is to increase public awareness of the possible impacts of climate change on NTVs.
2. Focus and Approach
   - Policy must be adapted to regional levels.
   - Policy should not be fixed on one area, region, or species.
   - Policy needs to look far ahead in time. Aboriginal people, for example, look ahead seven generations.
3. Flexibility
   - Policy should be adequately flexible and adaptable to allow for the likely discrepancies between predicted climate change impacts and actual outcomes.
4. Involving Stakeholders
   - Develop structures for meaningful conversations between First Nations and government, and between government, First Nations, and stakeholders.
   - Government needs to follow through on promises to stakeholders.
   - Improve policymakers' recognition of NTVs identified by stakeholders.
5. Funding
   - Funding sources such as the Climate Change Action Fund should support research examining impacts on NTVs.

Improving our ability to adapt to climate change

1. Focus and Approach
   - Climate science must try to identify local level impacts under climate change.
   - Use ecosystem approach to assess local NTVs.
   - Look at the whole system rather than individual elements.
2. Natural Resource and Landscape Management
   - Emulate natural disturbances in management practices.
   - Use an integrated resource management approach to management.
3. Involving Stakeholders
   - Incorporate greater stakeholder involvement when identifying and monitoring community NTVs.
   - Integrate local knowledge and traditional ecological knowledge when managing for NTVs.

Forest Productivity and Climate Change

Observer: G. Carlson

Knowledge gaps

1. Focus and Approach
   - Focus on non-timber productivity, non-timber values.
   - Account for social values.
2. Modeling and Representation
   - Forest level models should be driven by climate.
   - Scale models up in time and space.
   - Address several weaknesses of yield curve models
     - Ability to predict future environmental conditions
     - Ability to incorporate environmental knowledge
     - Unrealistic assumptions
     - Lack of understanding of forest growth, particularly if growing conditions change
     - Growth and yield curves and table do not incorporate climate drivers; therefore, unable to adjust or apply sensibly
   - Conduct sensitivity analysis to compare and test assumptions in models about risk.
3. Data Collection and Management
   - Increase investment in data collection.
   - Avoid costly research by using data proxies (using a variable in place of the actual variable of interest, when the latter is unavailable).
4. Science
   - How will ecosystem services change with climate change?
   - How will precipitation change?
   - How will certain tree species adapt to future climate conditions?
   - What will be the effects of the expected rate of climate change on forest productivity?
   - Improve understanding of carbon budget economics under climate change.
   - Conduct provenance tests to determine ecological variability.
   - Acquire better knowledge about the future growth of managed stands, multi-species stands, and multi-age stands under climate change. How to validate models to something that has not yet happened.
   - Increase monitoring and inventorying to identify problems of productivity and health.
   - What are the current limiting factors on forest productivity?
   - Can ecotypes and species be matched to predicted future conditions? This will require more tests and provenance trials.
   - How do natural disturbance losses affect landscape-level productivity?
   - Develop a better understanding of below-ground factors.
5. Natural Resource and Landscape Management
   - How do we decide what and where to cut? Do we keep naturally resilient stands?
   - What is the cost of being proactive versus doing nothing?

Policy changes and enhancements

1. Policy Goals
   - Policymakers should view the forest as more than a supply of fiber.
   - Decide whether markets or science drives policy.
   - Choose between accommodating desired fiber production and respecting what forests can actually produce.
2. Natural Resource and Landscape Management
   - Focus policy and management activities on productive land base, rather than everywhere.
   - Concentrate on maintaining high productivity.
   - Policymakers have the responsibility to justify and explain new management strategies to forest users.
   - Provide incentives to forest users for new management approaches.
   - Decide if there should be restrictions on the use of genetically modified organisms on crown land.
   - Allow changes to reforestation requirements to accommodate proactive alteration of forest composition.

3. Flexibility
   - Make policy flexible enough to allow for innovative adaptation efforts.
   - Be open to new knowledge and revise policy accordingly.
4. Land Tenure
   - Leave flexibility in the Annual Allowable Cut (AAC). Do not allocate fully the AAC.
   - Results-based code will allow for a more adaptable policy approach and local land management.
5. Involving Stakeholders
   - Involve more stakeholders and decision makers in policy reviews. Be more inclusive.
   - Widen definition of stakeholders and include them in policy processes.
   - Increase communication between policymakers and the public.

Improving our ability to adapt to climate change

1. Natural Resource and Landscape Management
   - Management activities should focus on ecosystem productivity instead of forest productivity.
   - Cookbook approach to forest management is too restrictive.
   - Develop more science-driven forest practices.
   - Planting decisions should be made based on what species will grow in current conditions and be most resilient to change.
   - Allow free breeding to develop species varieties with ability to sustain climate change.
   - Natural disturbance regime does not apply any more, change management approach to accommodate influence of climate.
   - Idea of replacing natural disturbances with anthropogenic disturbance has to be real, not a pretence.
   - Have the simultaneous management of natural and anthropogenic disturbance to return forests to “natural” range of variability in anticipation of climate change.
   - Plan new forests based on knowledge of ecological variability and species tolerance.
   - Choose practices to preserve natural variation.
   - Implement regular monitoring of management practices.
2. Land Tenure
   - Increase stumpage charges on salvage logging.
3. Practices
   - Invest in soil conservation practices. Do not invest management efforts in poorer soils, as they will only get poorer with predicted changes in climate.
   - Prioritize harvesting according to areas that are most vulnerable to climate change.
   - Match suitable species with planting site and use improved planting stock.
   - Plant by forecast, rather than by the calendar. This will require greater flexibility in planting.
   - Identify opportunities for cutting and thinning of stands infected with pests and pathogens.
   - Use commercial thinning to build resistance to drought.
   - Shorten harvest rotations. May have to provide incentives to companies.

Insects, Disease and Climate Change

Observer: J. Volney

Knowledge gaps

1. Science
   - Place a greater emphasis on improving basic science and generating a better understanding of ecosystem relationships. Less emphasis should be placed on modeling.
   - Lack of understanding of basic biology of insects, diseases, and hosts.
   - Improve taxonomic expertise.
   - Is there greater genetic variability within insect populations than in tree populations?
   - Lack of knowledge of foliar pathogens. Does forest management contribute to disease conditions?
   - We still do not know what effect insect populations have in vegetation assemblages, particularly under climate change.
   - Study changes in insect cycle periods and intensity, and relationships to host dynamics.
   - Determine how different species respond to climate change.
   - Study susceptibility of tree species to disease. What species are most vulnerable?
   - Study positive feedback and interactions between climate change, stress, and insects.
   - Changes in seasonality of precipitation need to be taken into account when interpreting species vulnerability.
   - How does climate change affect the ability of plants to defend themselves?
   - We do not fully understand stand response after defoliation.
   - Can pest management be used to increase carbon sinks? May take long-term planning to achieve this.
   - Genetic variability of *Dothistromo pini* (pathogen on pine). Is this disease epidemic in BC a different strain of the disease?
   - What are some stress-related increases in disease (e.g., drought and root disease)?
   - What exotics are increasing under a changing climate?
   - Combine current ecological understanding of forest insects with existing and future climate models to develop risk assessments.
   - What is the applicability of regional climate models to insect and disease population behavior?
   - Retain existing knowledge and learn from past experience and mistakes. Improve the archiving of records upon retirement of scientists. Data management infrastructure is leading to the erosion of data and expertise.
   - Increase the number of data sets, as existing data sets are too few for useful analysis.
   - Archiving of data needed.
   - Need longer-term data on insects and diseases.
2. Focus and Approach
   - Different scales of climate change adaptation planning needed (e.g., provincial, regional, landscape, stand).
   - Adopt a holistic perspective.
   - Twenty-five year planning perspective is too short term.
   - Take a longer-term and broader view of ecosystem and forest management practice relationships. A longer-term view is needed in several areas, such as the study of mountain pine beetle increases after fire suppression, and the study of insects on a geological scale.
3. Interdisciplinary Approach
   - Take an interdisciplinary approach to climate change research.
   - Traditional knowledge needs to be incorporated in the study of insect and disease cycles.
   - First Nations elders' knowledge and explanations might provide new information on change in frequency of disease outbreaks.
4. Involving Stakeholders
   - How do we convince people that they should adapt to climate change?
   - What are the impacts of mountain pine beetle on social systems, such as communities?

Policy changes and enhancements

1. Political Will
   - Governments must be convinced that climate change impacts and adaptation will pose enormous problems.
2. Political Communication
   - Need to improve the communication between scientists and policymakers. How well are studies being filtered up to policymakers?
   - Retain knowledge accrued by previous and existing scientific communities and build on this in policy formulation.
   - The transfer of responsibility for data collection from provincial agencies to industry results in fractured data sets, impeding scientists and policymakers' ability to make a coherent picture of the relationships of interest.
   - Knowledge of "what works" in climate change adaptation should be shared with policymakers.
   - Encourage governments and industry not to bury unpalatable messages.
3. Policy Suggestions
   - Timber supply should not be the sole priority of planning.
   - Unmanaged forests should be considered reservoirs of variation.
   - To prepare for adaptation, there should be a policy mandating plant diversity tests (provenance tests).
   - Target management strategies for areas most at risk.
   - Should we use genetically modified organisms to reduce forest susceptibility to climate change?
   - How will companies, that are currently operating under a sustainable even-flow premise, operate when faced with large-scale disturbances?
   - Determine how other resource industries (e.g., oil and gas) are shaping policy to deal with climate change and adaptation.
   - Forestry companies need incentives and flexibility to adapt practices to local and landscape needs.
   - Give companies enough flexibility to deal with changing conditions.

Improving our ability to adapt to climiate change

1. Focus and Approach
   - Change our management projections to at least 50 years.
   - Take a holistic view of the system. Do not focus on individual aspects of the system.
   - Develop locally specific management practices balanced by landscape perspective.
   - Target areas most at risk under climate change and develop risk assessment maps to integrate planning with other vulnerabilities.
2. Monitoring
   - Monitor past successes and failures.
   - Greater priority should be placed on evaluating the effectiveness of past strategies.
3. Natural Resource and Landscape Management
   - Manage forest with insects and disease in mind.
   - Suppression is not a long-term solution, but it can be used to manage resistance to disease and thereby minimize certain impacts from climate change.
   - Develop management plans to increase forest health and fight an increase in disease.
   - Create forests that can diversify. Manage species, patch size, and arrangement.
4. Land Tenure
   - Decouple tenure from mill capacity. Forest management units cannot operate continually as sustained field units, particularly if large-scale disturbances become more prevalent.
5. Practices
   - Maintain diverse populations of trees and avoid monoculture plantations.
   - Give planners a choice of reforestation species.
   - Improve climate change detection and monitoring.
   - Use remote sensing for detecting severe damage.
   - Conduct detailed pest surveys. Solve problems associated with downsizing and downloading insect and disease surveys.
   - Proactively manage the forest. Start planting stock for future conditions.
   - Use denim pine as an economic opportunity.

Biodiversity and Climate Change

Observer: N. Kingsbury

Knowledge gaps

1. Focus and Approach
   - Research focus is largely on charismatic megafauna and commercial species. Expand research to include other species (e.g., fish, lichen).
   - Expand research focus to species on northern limits since species on southern limits will be displaced.
   - Will our goal of conserving biodiversity be attainable as climate change proceeds, or must we explore new approaches?
   - Do we preserve entire ecosystems or specific species?
   - We have difficulty agreeing on the value of specific species. What is worth protecting and how do we decide?
2. Science
   - One challenge of climate change is that the rules of the game start to change.
   - We can never fully predict the impact of climate change on species biodiversity.
   - Improve understanding of how ecosystems really work.
   - Focus research on species interactions.
   - Identify and target scale variations in biodiversity.
   - Look at ecosystem processes (e.g., fire, insects, succession) at regional and tree scales to identify how species are changing under these processes.
   - Understand compound disturbances and recognize importance of disturbance as a change mechanism.
   - Obtain greater knowledge of species specific responses to climate change.
   - Loss of biodiversity rather than shifts in biodiversity will result from climate change.
   - Investigate further the historic vulnerability of species to different climate conditions.
   - How do we discuss and quantify biodiversity in the boreal forest?
   - How do we choose indicator species? Should they have the narrowest range of tolerance or be keystone species?
   - Identify existing gaps in taxonomic knowledge and increase taxonomic expertise.
   - Current species loss numbers presented by ecozone under different climate scenarios are not rigorous.
   - Improve field detection of outlier populations, especially for outlier populations in the north that disproportionately facilitate integration.
   - No baseline work has been done in intensely managed forests. Compare managed and non-managed forests.
   - How much natural forest versus managed forest is needed to support biodiversity?
   - How do managed forests adapt after harvesting? May adapt better than non-managed forests.
   - Species will migrate north and become exotics in northern regions. Is this increase in exotic species “good” for biodiversity? Where will existing species go? What are the implications for migration corridors (river valleys, plains) and conflicts between species?
   - Under facilitated/managed species migration, is it good to move everything including pests?
   - What will be the impact of forestry composition and location changes on biodiversity?
   - How will forest management increase or decrease vulnerability?

Policy changes and enhancements

1. Political Will
   - How do we convince the public and natural resource managers that biodiversity is worth saving (e.g., send the message that high diversity allows for greater resilience to pest outbreaks)?
2. Making Policy Choices
   - Goal of adaptation should be a dynamic, functioning ecosystem that will take care of itself.
   - Policy needs to accept that an increase in biodiversity is not always possible.
   - What is the repercussion for biodiversity conservation if we place an economic value on species?
   - Conservation may not be an option in a changing world. Need to accept that some species will just disappear (e.g., Vancouver Island Marmot).
   - Need to define biodiversity objectives in various forest systems.
   - Choose where we want to maintain biodiversity (e.g., protected areas, forest management units).
   - It may be a subjective decision.
3. Policy Suggestions
   - Need integrated and interdisciplinary approaches and solutions.
4. Interdisciplinary Research
   - Develop strategies for conservation, decide which species should survive and how to conserve them.
   - Conduct a knowledge gap analysis for North America (e.g., www.taiga.net).
   - Kyoto and conservation policies need to be considered together.
   - Policy should translate issues of concern into modified forest practices.
   - Policy needs to be applicable outside single management boundaries (e.g., Forest Management Areas, provincial boundaries). Some of the most vulnerable forests are in agricultural areas under separate jurisdictions.
   - Seed transfer guidelines may need to be reviewed and amended.

Improving our ability to adapt to climate change

Increase Diversity

- Maximize species diversity at the landscape and operational level.
- Increase biodiversity to increase resilience of the ecosystem.
- Stock areas with certain species to manage some of the risk from climate change.
- Introduce exotics to proactively manage biodiversity.
- Do not isolate regions, including protected areas. Allow for the creation of corridors.
- Promote the Triad approach (looks at three aspects of forest management: extensive forestry, intensive forestry, and ecological benchmarks. These three components work together to guide us in managing a healthy, sustainable forest. Alberta-Pacific Forest Industries Inc. is currently using it).
- Because of their role in biogeochemical cycling, it is important to preserve soil microbes.
- Intensive forestry and its role in conservation: could allow for an increase in protection but not in frequent-fire boreal ecosystems.

Forest Practices and Climate Change

Observer: L. Van Damme

Knowledge gaps

1. Uncertainty
   - Uncertainty is a big problem. How do we choose the right actions without knowing future climate and forest conditions? Makes planning difficult.
   - How much future growth will we have under climate change?
   - Considerable uncertainty around future growth should lead to cautious Annual Allowable Cut allocation.
   - Identify potential catastrophes resulting from climate change.
   - How will fire season change under climate change?
   - How will water availability and quality change regionally? Will there be droughts or too much precipitation?
   - How will hydrology change with climate change?
   - Conditions of roads, ice roads: will they have delayed or rapid response to changes in precipitation from changes in climate?
   - Climate change will impact soil compaction and increase avalanche hazards.
2. Interdisciplinary Approach
   - Fill in some knowledge gaps using local knowledge and traditional ecological knowledge.
3. Science
   - Conduct fundamental research by species and genotype.
   - Increase understanding of:
     - growth and yield relationships
     - succession pathways
     - water relationships
     - relationship of forest management practices to landslide events and climate change
   - To determine what to reforest, must determine the adaptability of tree species. How much change can they tolerate under predicted local and regional climate change effects?
   - Does the natural disturbance paradigm fit anymore?
4. Modeling
   - Need regional climate models.
   - Better weather prediction and details.
5. Natural Landscape and Resource Management
   - What are the implications of planting even-aged crops? What is their susceptibility to attack from forest pathogens given ideal conditions?
   - How do carbon credits fit with forest practices? Need an economic analysis of various management scenarios, one managing for carbon credits and one without.

Policy changes and enhancements

1. Focus and Approach
   - Bottom up policy preferred over top down. The people who live in communities have to live with decisions made by government, industry, and foresters.
   - Policy should be localized.
   - Decentralize and de-globalize policy. Resentment of policy being driven by American trade interests rather than homegrown concerns focusing on issues like climate change adaptation.
2. Political Will
   - Concern expressed over the lack of resources and political will to meet current policy requirements and develop new adaptive strategies to climate change.
3. Flexibility
   - Need adaptable forest management policy and regulation (e.g., reforestation requirements generally are inflexible, and would not facilitate significant changes that could be required under adaptive strategies).
   - Current policy instruments are restrictive and not conducive to adaptation.
4. Policy Suggestions
   - Certification systems and management systems must redefine what sustainability means. Rather than resist change these systems must encourage change in the right direction.
   - Address future gaps in knowledge from the current cut back in weather monitoring networks.

- The long tradition of monitoring weather—that has demonstrated utility—has been cut back.
- Primary forest sustainability must be ensured. Land not reforested contributes to global warming.
- Need to take a value-added approach.
- Encourage value-added processing to improve flexibility.
- Protect genetic diversity.
- Recognize forester expertise; give them the freedom to manage forests.
- Silviculture prescriptions should provide guidelines for adaptation.
- Need seed transfer guidelines.

5. Land Tenure
   - Need tenure reform.
   - Re-evaluate Annual Allowable Cut every 5 years.
   - Will a results-based code work? No one is making sure licensees are following the rules.

Improving our ability to adapt to climate change

1. Focus and Approach
   - Ecosystem management approach.
   - Abandon 'cookie cutter' approach to forest management and renewal.
   - Do what is good for the local area, rather than what external entities (e.g., USA) say we should do.
2. Genetic Resources
   - Manage genetic resources to increase species adaptability. Alter species selection depending on planting, seed collection, and breeding strategies.
   - Diversify species, particularly in tree plantations.
   - Take advantage of species and genetic diversity.
   - Use tree improvement family tests to monitor impacts of climate change over time on family rankings, in particular the shifting of southern families north.
3. Monitoring
   - Need monitoring of growth and yield.
4. Practices
   - Cut to Length (CTL) systems that fell and process logs at the stump could help reduce emissions from fuel consumption and slash burning. CTL can continue operating on soft ground because the forwarders for logs have lower ground pressure than do skidders. The conversion costs from current Full Tree systems that fell, skid, and then process roadside are a big obstacle.
   - Sanitation thinning to increase tree vigor might help improve resilience to climate change stressors.
   - Selective harvest—leave something for future generations.
   - Should we stop roadside burning and promote de-limbing at the stump?
   - More pre-harvest planning.
   - Start planning and building year-round access structures.
5. Data
   - Information retention poor because of technical changes and job losses.
6. Natural Resource and Landscape Management
   - In a risk management context, current practices aimed at emulating natural processes are questionable.

Forest Fires and Climate Change

Observer: V. Peters

Knowledge gaps

1. Interdisciplinary Approach
   - How do we integrate First Nations knowledge with fire management?
2. Involving Stakeholders
   - How do public values about fire management vary regionally?
3. Prediction
   - What is the pattern of fire in historical drought periods?
   - What will future fire regimes be like considering projected precipitation changes?
4. Risk
   - How do we manage risk from prescribed burning or mechanical site preparation?
   - Conduct risk assessments at regional and local levels of forests and fire frequencies, and intensities under a changing climate.
5. Science
   - Assess the scale of ecosystem responses to fire.
   - What organisms and ecosystems depend on fire?
   - Have a better understanding of the effects of fire management on wildlife (e.g., natural fire regimes and caribou; effect of fragmentation on wildlife).
   - What is the plant response to increasing frequency and severity of forest fires?
   - Determine the effectiveness of fire mitigation on fire intervals and severity.
   - Determine changes by region in disturbance regimes.
   - What is the effect of skewed forest age class distribution toward younger stand age classes? What is the ensuing effect on species diversity?
   - What is the impact of the elimination of fire-sensitive species and the dominance of fire adapted species on ecosystem function and processes?
   - What are the interactions among multiple disturbances, such as logging, density, and flammability?
   - How does fire behave in pine stands killed by mountain pine beetle?
   - Obtain more information regarding fire history in forests (e.g., use of paleo data, historical records to reconstruct past and relate to precipitation).

Policy changes and enhancements

1. Focus and Approach
   - At what scale should policy be changed?
   - Should planning and development policy in managed areas try to stop or reduce the risk of forest fires and the vulnerability of people and property to fire?
2. Involving Stakeholders
   - Combine responsibility for fire management between people living in fire-prone areas with people who are currently responsible for fire management.
   - There is a fundamental conflict between fire-smart management in an interface community and what people value aesthetically.
   - Need to assess and manage public concern about fire management (e.g., prescribed burning) and smoke, and pollutants from fire retardants.
   - Everybody has a value associated with the forest that may be at risk if fires and forests are managed to facilitate adaptation to climate change (e.g., First Nations communities, cottage owners, naturalists, industry).
   - Need better public education on the ecological role of fire.
3. Interdisciplinary Approach
   - Traditional knowledge of First Nations is not entering fire/climate change policy or research.
4. Policy Suggestions
   - Need to identify whether government or industry will take responsibility for climate change adaptation and fire management.
   - Try to stop, limit, or reduce fires.
   - Do not allocate the entire Annual Allowable Cut. There needs to be room for timber lost to fires.

Improving our ability to adapt to climate change

1. Goals
   - Recognize and deal with conflict between fire management for climate change and management for biodiversity.
2. Natural Resource and Landscape Management
   - Should prescribed burning be brought back?
   - Identify areas we want to re-burn.
   - Issues in forest fire management:
     - Trade-offs between personal health and ecology
     - Trend toward increasing burn prevention
     - Urban wildfire interface and fire proofing communities

OPEN SPACE SESSIONS

OPEN SPACE SESSIONS

During the second breakout session, attendees participated in an "open space" discussion. With the help of a facilitator, participants were invited to develop a list of potential discussion topics focused on the question,

> **"In order for the community of forest users to adapt to the reality of climate change, we should pay attention to…"**

These topics then guided a series of small group discussions. Participants recorded the important points arising from the discussions. These points have been summarized and organized into five theme areas. The key points arising from these discussions are presented below.

In general, the open space discussions centered very little on improving climate change science, but focused instead on managing the various mechanisms, organizations, and stakeholders involved in climate change research and adaptation strategies. Participants felt that the appropriate structures, tools, and capacity to adapt to climate change currently exist; however, the ability and the political willingness to employ these are limited.

Changing our approach to climate change adaptation

What We're Doing Well:

- Canada's approach to climate change adaptation currently involves some collaboration of multiple institutions with various jurisdictions over natural resource management (e.g., federal and provincial governments, industry, research organizations).
- Ties between institutions and stakeholders will be strengthened with Canada's ratification of the Kyoto Protocol.
- Kyoto will create a stronger impetus for developing climate change adaptation strategies.
- We have a sound and rigorous body of science that can support the design and implementation of adaptation strategies.

How We Can Improve:

- Governments and other land-use planners need to be proactive in adaptation planning.
- We want proactive adaptation and proactive mitigation. Rather than focusing efforts on 'end of the pipe' solutions, suspected contributors to climate change should be targeted at the source.
- Proactive planning must be supported by sound science allowing planners to predict future conditions under climate change and understand how natural and managed environments, as well as urban and rural communities, will respond.
- If we delay planning, the costs of adaptation will only increase.
- Proactive planning will be motivated by an assessment of the costs and benefits of early, rather than delayed, adaptation to climate change.
- Climate change adaptation will involve the reconfiguration of traditional roles undertaken by industry, government, and the public.
- More partnerships between industry and researchers are required.
- Adaptation plans will need to be applicable at local, as well as regional levels.
- Adaptation efforts must be interdisciplinary, requiring collaboration among various disciplines in the natural and social sciences.
- Use traditional ecological knowledge to inform adaptation strategies.
- The community of climate change scientists, policymakers, and natural resource managers have a responsibility to communicate what they know to government institutions and the public.
- Communication will involve education programs that "make climate change real," emphasizing that climate change is occurring, and natural and human systems must adapt.

Improving climate change policy and government involvement in climate change adaptation

What We're Doing Well:

- We have support from two important groups with key roles in climate change adaptation. Government institutions and forest companies appear to be interested in adapting to climate change.
- The expertise and knowledge surrounding climate change impacts and adaptation exists.

How We Can Improve:

- Must engage industry further by making use of incentives (e.g., taxes, education, certification) and partnerships between industry and government.
- Although governments, industry, and the scientific community set reasonable goals relating to climate change adaptation, following through on these goals is generally weak.
- Our time and energy should not be invested in further research, but on creating the will to adapt.
- Regulation and policy must be more flexible to deal with the requirements of adaptation.
- Need a long-term commitment from a central organization to fund and monitor our progress toward adaptation and build support for adaptation.
- Forest certification schemes must be flexible enough to accommodate adaptive strategies.
- Government should help climate change scientists and forest managers work around policy obstacles to climate change monitoring and collection of baseline/benchmark data (e.g., restrictions in protected areas that complicate these goals).
- Data sharing between political jurisdictions and organizations is poor.
- Data formats need to be standardized and data collection better coordinated.

Working with stakeholders and Aboriginal communities

What We're Doing Well:

- There are individuals, groups, and institutions that are willing to discuss climate change adaptation.
- We have some multidisciplinary organizations (e.g., C-CIARN and the Model Forest Program) that are designed to bring together forest users, industry decision makers and governments to talk about forestry and climate change issues.
- Some education programs are designed to build public awareness of climate change issues.

How We Can Improve:

- Governments and forest users must be able to accept the great deal of uncertainty surrounding climate change impacts.
- To influence the political will to adapt to climate change, the public, government, and industry must be made more aware of the benefits of adaptation and the long-term costs of avoiding adaptation.
- Once key groups and individuals are interested, their progress should not be impeded.
- Forest tenure needs to accommodate and promote long-term stewardship.
- Allocation of Annual Allowable Cuts should take into account climate change risks, such as catastrophic fire events.
- Improve public education and extension by decreasing confusion over climate change and avoiding scientific jargon in education programs.
- The public, forest dependent communities, and industry must be involved in climate change science.
- Improve the transfer of information between knowledge sectors and workers. There will be information gaps owing to the large retirement cohort and recruitment of new personnel.
- Climate change adaptation strategies must recognize aboriginal rights and territories.
- Create a mechanism for meaningful consultation in forest management among government agencies, industries, and aboriginal communities.
- Train more Aboriginal foresters.

Improving research and monitoring

What We're Doing Well:

- We currently have some citizen involvement in research and monitoring.

How We Can Improve:

- Increase the scientific community's trust in participatory research, and provide long-term funding for participatory research programs.
- Reduce the prohibitive costs of data collecting by pooling data from different sources. Must establish common data collection standards.
- Need time scaling between models of forest dynamics.
- Invest in climate change monitoring.
- Research is required to understand how landscape hazards will change with climate change.
- Improve our understanding of species migration, behavior, and extinction under different climate change scenarios.
- Climate change research programs will require a landscape level, rather than stand level focus.

Enhancing C-CIARN (Canadian Climate Impacts and Adaptation Research Network)

What We're Doing Well:

- C-CIARN is successfully building a network of researchers, who are discussing existing research with practitioners and the forest industry.
- C-CIARN is making impacts and adaptation issues more visible.

How We Can Improve:

- Although C-CIARN is bringing together existing research, investment in new research is still required.
- C-CIARN must work toward increasing public awareness of climate change impacts and adaptation. One option would be to hold workshops and meetings that are easy to attend and are tailored to issues that are of interest to specific communities (e.g., industry, naturalists, etc.).
- C-CIARN forest should organize panels to develop ideas and policy options for adaptation to climate change for conservation, sustainability, and forest certification.

MOVING FORWARD: Next Steps

G. McKinnon

Canadians place heavy reliance on the forest for their economic, environmental and social well-being and expect that their governments and industries will manage this resource in perpetuity for the benefit of future Canadians. Forests are truly one of Canada's natural treasures. At the same time it is clear that climate change poses a significant risk to the health, vitality, and long-term sustainability of the forests and the many communities that depend on them.

The need for climate change impacts research has been recognized for some 20 years or more in Canada. However, it is clear that the results of this research have not yet generally moved into the arena of forest operations or forest-based community planning. Research has typically ended at the point of describing predicted impacts while the implementation of adaptive strategies has been hampered by the uncertainties inherent in the science of climate change modeling and scenario development, and institutional inertia. As well climate change adaptive strategies will be, by their very nature, controversial as they strive to balance a large number of overlapping, and in some cases competing, public policy and resource management objectives.

To move forward, forest science, policy and practices must collectively address the impacts of climate change on the forests and forest sector in order to build adaptive strategies that

- ensure the continued flow of environmental, economic, and social benefits from our forests (i.e., sustainable forest management);
- build resiliency to climate change into forest management and community planning decisions; and
- evaluate the risks associated with Canada's international obligations pertaining to biodiversity and climate change.

Canada's ability to establish effective policies to respond and adapt to climate change will require a better understanding of (a) vulnerabilities to current climate, (b) adaptive capacity, (c) the impact of climate change at local or regional levels to a range of forest values, (d) critical thresholds for change, and (e) a general understanding of the linkages between science, policy, and operational management of forest resources. My hope is that the C-CIARN Forest can play an important role in improving linkages and information exchange between forest science, policy, and management at the national, provincial, and regional levels so that climate change adaptive strategies are woven in the very fabric of sustainable forest, and forest-based community management.

WORKSHOP SURVEY

Climate Change Perceptions Survey

B. McFarlane, J. Parkins, and T. Williamson

Background

A research group from the Northern Forestry Centre, Canadian Forest Service approached C-CIARN Forest Sector about conducting a survey at the workshop, Climate Change in the Western and Northern Forests of Canada: Impacts and Adaptations. The purpose of the survey was to study of the opinions and perceptions of the workshop participants regarding climate change or how the particular characteristics of climate change as a risk issue might affect or influence their perceptions.

Introduction

During the past decade climate change has evolved from a mere concern to an international policy issue. Rising global temperatures are expected to significantly impact the environment, and as a result society and the economy. Canada's mean annual temperature is expected to increase more than three times the global average; therefore, it is an especially pertinent issue for Canadians. Among the nations' concerns with climate change is the fact that Canada's forest ecosystems are sensitive to climate and therefore it has the potential for significant impacts on the forest sector. "Scientists predict that climate change will occur at a rate that is rapid relative to the speed at which forest species grow, reproduce, and reestablish themselves and will have pronounced effects on Canada's forests" (CFS 1999, p. 4). However, there exists the opportunity to attempt to reduce impacts through adaptation. Willingness to adapt depends on (a) having information and knowledge about the magnitude and timing of local level impacts, and on (b) the degree to which individuals feel that climate change poses significant risks. Therefore, in order to develop policies to effectively respond to climate change impacts, it is important to understand people's opinions and perceptions about climate change effects at a local level. To date, however, there has been no direct study of either the opinions and perceptions of forest stakeholders regarding climate change, or the particular characteristics of climate change as a risk issue might affect or influence perceptions.

In order to begin to understand how forest stakeholders perceive climate change, a questionnaire was provided to attendees of a workshop that addressed climate change and forests. The Canadian Climate Impacts and Adaptation Research Network – Forest Sector (C-CIARN Forest) hosted a workshop in Prince George, BC on February 17–19, 2003. The purpose of the workshop was to bring scientists, resource practitioners, and stakeholders together to share information and identify and discuss climate change issues from a forest sector perspective. Scientists, resource managers, policymakers and other stakeholders representing a diverse range of organizations attended the workshop. Attendees were asked to complete two questionnaires – the first before the workshop began (pre-workshop survey) and the second with similar questions after the workshop concluded (post-workshop survey). The purpose of the survey was to evaluate the perceptions of a particular group of forest stakeholders about climate change and to differentiate those perceptions based on specific interests (such as human communities and forest ecosystems) and particular risk features (such as views about predictability, controllability and adaptive capacity). Also, the pre- and post-workshop survey questionnaire provided an opportunity to evaluate the extent to which the workshop may have influenced perceptions. This paper provides a brief summary and discussion of the survey results.

The Canadian Climate Impacts and Adaptation Research Network is a national network established by Natural Resources Canada that facilitates the generation of climate change knowledge, identifies information gaps, and defines research priorities. The C-CIARN Forest Sector focuses on issues relevant to forest users including the forest industry and forest-based communities.

General characteristics of survey respondents

The total number of individuals registered for the workshop was about 140 persons. Fifty-one individuals completed the pre-workshop survey questionnaire, and 41 individuals completed the post-workshop survey questionnaire. The survey respondents do not represent a random sample of the Canadian forest stakeholder community. Rather the respondents represent a sample of well-informed climate researchers and policymakers from Canadian universities, provincial and federal governments. Therefore, the results of the survey can be interpreted as an aggregation of expert perceptions of climate change impacts and adaptation in the northern boreal forest. Table 1 provides a socioeconomic profile of the survey respondents. There were no statistically significant differences in the socioeconomic characteristics of those that responded to the pre- and post-workshop questionnaires. In general, survey respondents can be characterized as follows: male, age: early 40s, highly educated.

Table 1. Socioeconomic characteristics of participants

	Number of participants (%)	
Characteristic	Pre-workshop	Post-workshop
Sex		
Men	31 (59.6)	30 (69.8)
Women	21 (40.4)	13 (30.2)
Education		
Some university	1 (1.9)	1 (2.3)
University degree (Bachelors)	21 (39.6)	12 (27.9)
Some graduate study	5 (9.4)	4 (9.3)
Graduate degree (Masters, PhD)	26 (49.1)	26 (60.5)
Mean age (years)	42.35	41.36

General perceptions of climate change

Table 2 provides a summary of responses to a series of general questions regarding climate change. Respondents neither strongly agree nor disagree with the statement that climate change poses a significant threat to them personally. This suggests the possibility that there is some degree of uncertainty in people's minds regarding the levels of personal exposure that they may have. They also disagree with the statement that there is ample time to adapt and with the statement that they are personally well prepared for the impacts of climate change. Although these respondents are ambivalent regarding personal exposure, they disagree with the statement that climate change impacts are exaggerated. Respondents recognize that climate change is an issue; however, they do not seem to perceive that it is an issue that threatens them personally and/or for which there is a compelling need for personal actions to prepare for climate change.

Table 2. Pre- and post-workshop means[a] (standard deviations) of general perceptions of climate change

General perception	Pre-workshop	Post-workshop
Human activities (such as the burning of fossil fuels) are a major cause of climate change	5.54 (1.66)	5.83 (1.58)
Climate change impacts are all negative	2.71 (1.33)	2.64 (1.51)
Climate change impacts are exaggerated	2.81 (1.40)	2.65 (1.46)
Generally, the science of climate change is inconclusive	3.47 (1.73)	2.82 (1.72)
Climate change is a serious threat to my family and me	3.92 (1.59)	4.20 (1.66)
I do not understand the impacts of climate change	3.22 (1.62)	2.61 (1.67)
I feel that my family and I are well prepared for climate change impacts	3.22 (1.43)	3.35 (1.45)
There is ample time to adapt to climate change	2.85 (1.45)	2.80 (1.64)

[a] Rated on a scale of 1 to 7, where 1 = strongly disagree and 7 = strongly agree.

Table 3 provides a summary of responses regarding peoples perceptions of risks to forest ecosystems related to climate change. Irrespective of climate change, pre- and post-survey respondents indicated strong concerns for the health of forest ecosystems and see climate change as an additional factor that is both having significant impacts on forest ecosystems now and in the future. In the view of the respondents, the impacts of climate change on forest ecosystems tend to be uncontrollable and unpredictable and will likely be noticeable. Respondents felt that the general public and forest managers do not have a good understanding of the effects of climate change on forest ecosystems.

Table 3. Pre- and post-workshop means and variances of perceptions of risk to forest ecosystems

		Pre-workshop		Post-workshop	
Indicate the degree to which		Mean	Var.	Mean	Var.
Regardless of climate change you are concerned about forest ecosystems	Not at all – Significant (1–7)	6.21	1.44	6.02	0.95
You agree that climate change is currently having a significant impact on forest ecosystems	Strongly disagree – strongly agree (1–7)	5.32	1.87	5.83	1.44
You agree that within the next 50 years climate change is going to have a significant impact on forest ecosystems	Strongly disagree – strongly agree (1–7)	5.96	1.42	6.13	0.96
There is certainty about the effects of climate change on the sustainability of forest ecosystems	Low certainty – significant certainty (1–7)	3.41	2.24	3.40	2.93
You feel that forest managers have the ability to control climate change impacts on forest ecosystems	Not controllable – very controllable (1–7)	2.64	1.54	2.69	1.76
Climate change effects on forest ecosystems are predictable	Not predictable – very predictable (1–7)	2.94	1.82	3.04	1.86
You agree with the statement Canada's forests will evolve and adapt in pace with climate change	Strongly disagree – strongly agree (1–7)	3.64	3.04	3.07	2.52
You expect that the effects of climate change on forest ecosystem will be noticeable	Not noticeable – very noticeable (1–7)	5.79	0.64	6.02	0.91
Climate change impacts on forest ecosystems are acceptable to you personally	Not acceptable – very acceptable (1–7)	3.25	2.70	3.11	2.10
You feel the effects of climate change on forest ecosystem are understood by the general public	Not well understood – good understanding (1–7)	1.54	0.99	1.37	0.37
You feel the effects of climate change on forest ecosystem are understood by forest managers	Not well understood – good understanding (1–7)	2.40	1.05	2.07	0.86

Note: Var = variances.

Table 4 provides a summary of pre- and post-survey respondent perceptions regarding risks and threats to forest-based communities. In general, respondents felt that climate change poses a serious threat to forest-based communities, but at the same time they found that the level of controllability of climate change effects on communities is in the mid range between very controllable and not controllable. They also felt that forest-based communities have a moderate capacity to adapt to climate change impacts. Similar to views regarding forest ecosystems, respondents felt that the impacts of climate change on forest-based communities were poorly understood by both the public and by policymakers. The respondents saw the potential for some benefits at a community level but also felt that climate change would likely lead to moderately higher levels of uncertainty for business and firms in forest-based communities.

Table 4. Pre- and post-workshop means and variances of perceptions of risk to forest-based communities

		Pre-workshop		Post-workshop	
Indicate the degree to which		Mean	Var.	Mean	Var.
You agree with the statement "climate change is a serious threat to forest-based communities"	Strongly agree – strongly disagree (1–7)	3.23	2.72	2.73	2.34
Climate change will significantly impact community well-being	Not significant – significant (1–7)	4.78	2.01	4.60	2.38
You feel that climate change impacts to forest-based communities are controllable through planning and preparation	Not controllable – very controllable (1–7)	3.94	1.63	3.78	1.68
You feel that forest-based communities have the capacity to adapt to climate change impacts	Low capacity – significant capacity (1–7)	3.62	2.16	3.61	1.71
Climate change effects on well-being of communities are predictable	Not predictable – very predictable (1–7)	3.17	1.80	3.26	1.44
You expect that the effects of climate change on forest-based communities will be noticeable	Not noticeable – very noticeable (1–7)	5.35	0.94	5.54	1.19
Climate change impacts on forest-based communities are acceptable to you personally	Not acceptable – very acceptable (1–7)	3.18	1.95	3.11	1.57
You feel there is scientific uncertainty about the effects of climate change on communities	No uncertainty – significant uncertainty (1–7)	5.10	1.85	4.86	2.41
You feel the effects of climate change on forest-based communities are understood by the general public	Not well understood – good understanding (1–7)	1.55	0.48	1.53	0.54
You feel the effects of climate change on forest-based communities are understood by policymakers	Not well understood – good understanding (1–7)	2.00	0.65	1.67	0.80
You feel that climate change will present opportunities to improve well-being in forest-based communities	No benefits – significant benefits (1–7)	3.75	1.52	3.58	0.97
You feel that climate change will lead to higher levels of economic uncertainty for businesses and firms in forest-based communities	No effects on uncertainty – significant increase in uncertainty (1–7)	4.87	1.37	5.26	1.67

Note: Var = variances.

Comparisons of pre- and post-workshop perceptions

Generally differences in the average responses provided in the pre-workshop survey and the post-workshop survey were statistically insignificant. There were, however, six questions where the post-workshop questionnaire means responses were significantly different at the 10% significance level.

1. There was stronger disagreement that climate change science is inconclusive in the post-workshop survey (Table 2).
2. There was stronger disagreement with the statement "I do not understand the impacts of climate change" in the post-workshop survey (Table 2).
3. There was stronger agreement with the statement "climate change is having a significant impact on forest ecosystems" in the post-workshop survey (Table 3).
4. There was stronger disagreement with the statement "forests will adapt and evolve in response to climate change" in the post-workshop survey (Table 3).
5. The degree to which respondents felt that the effects of climate change on forest ecosystems were not well understood by forest managers was stronger in the post-workshop survey (Table 3).
6. The degree to which respondent felt that the effects of climate change on forest-based communities were not well understood by policymakers was stronger in the post-workshop survey (Table 4).

There are two possible reasons for statistically significant differences in the pre-workshop survey and the post-workshop survey. First, differences could be the result of the fact that individual perceptions were influenced by the workshop deliberations. Second, differences could be due to the fact that the samples were different and that, therefore, a bias was introduced resulting in incomparable results. Tables 5 and 6 show differences in origin and in organizations represented between the pre- and post-workshop respondents. The most significant differences between the samples were (a) BC representation was lower in the post workshop survey, (b) relative representation of provincial governments declined and federal government representation increased in the post-workshop survey, and (c) a higher percentage of participants had graduate degrees in the post-workshop survey.

Table 5. Origins of participants

Province or Territory	Number of participants (%)	
	Pre-workshop	Post-workshop
British Columbia	37 (71.2)	26 (63.4)
Alberta	6 (11.5)	6 (14.6)
Ontario	4 (7.7)	4 (9.8)
Manitoba	2 (3.8)	1 (2.4)
Northwest Territories	2 (3.8)	1 (2.4)
Saskatchewan	1 (1.9)	1 (2.4)
Quebec	0 (0.0)	1 (2.4)
Yukon	0 (0.0)	1 (2.4)

Table 6. Types of organizations represented

Organization	Number of participants (%)	
	Pre-workshop	Post-workshop
Provincial government	22 (42.3)	15 (36.6)
Federal government	7 (13.5)	11 (26.8)
University	10 (19.2)	8 (19.5)
Non-government organizations	4 (7.7)	3 (7.3)
Municipal government	1 (1.9)	0 (0.0)
First Nations	1 (1.9)	1 (2.4)
Forest industry	3 (5.8)	0 (0.0)
Other	4 (7.7)	3 (7.3)

Literature Cited

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WORKSHOP POSTER SESSION
ABSTRACTS

Lichen and Bryophyte contributions to the diversity, biomass and carbon pools and fluxes of a sub-boreal Spruce forest

R. Botting, and A.L. Fredeen

Bryophyte and lichen species are important components of forest biodiversity, biomass, and carbon pools. However, lichen and bryophyte diversity, biomass, and photosynthetic contributions to sub-boreal spruce forests are poorly understood. A better understanding of all components of the forest ecosystem is becoming ever more important as forested landscapes are increasingly modified through forest management.

This poster outlines proposed research for a MSc Natural Resources and Environmental Studies thesis. Research will occur during the summers of 2003/2004 in the Sub-Boreal Spruce biogeoclimatic zone, at the Aleza Lake Research Forest near Prince George, BC. This research will survey the terrestrial and lower canopy lichen and bryophyte communities in sub-boreal forest stands of three ages (old, mature, and young).

The research has three primary aims. The first is to assess the diversity and biomass of lichen and bryophyte species occurring in a sub-boreal spruce forest. The second aim is to use bryophyte and lichen diversity and biomass data to indicate the impact of forest management on the non-vascular components of a Sub-Boreal Spruce ecosystem. The third aim of this research will be the focus of the poster presentation. The contribution of the lichen and bryophyte communities to the overall forest carbon pool and carbon flux will be examined. Lichen and bryophyte biomass data for the three ages of stands will be used to quantify any difference in the carbon pool contributions of these communities based on forest stand age.

The project will also contribute to the Regional Carbon Balance and GIS Model for a Sub-Boreal Research Forest in central British Columbia project, occurring in the Aleza Lake Research Forest.

History of Mountain Pine Beetle outbreaks in the central interior of British Columbia

R. Campbell, R. Alfaro, B. Hawkes, and T. Shore

Mountain pine beetle (MPB) is a major natural disturbance agent for lodgepole pine in the central interior of British Columbia. In this study lodgepole pine (*Pinus contorta* var. *latifolia* Dougl.) tree-ring chronologies were developed for eighteen sites in the central interior of British Columbia. These ring-width chronologies were used to (i) determine the recurrence rate of mountain pine beetle (*Dendroctonus ponderosae* Hopkins) outbreaks in the 20th century, and (ii) establish the response of lodgepole pine ring-width growth after a MPB outbreak. Three synchronous periods of growth release attributable to MPB were observed, giving a recurrence rate of approximately 40 years for this disturbance. Outbreaks occurred in sampled stands starting in 1890, 1937, and 1981. Surviving lodgepole pine and other species (Douglas-fir) experienced increased growth for approximately 8 years following outbreaks. These studies serve to establish baselines useful to compare potential changes in MPB disturbance regimes under climate change scenarios.

Climate change implications in British Columbia: assessing past, current and future fire occurrence and fire severity in British Columbia

M. Flannigan, B.M. Wotton, K. Logan, J.B. Todd, and H. Cameron

Given the relationship of weather and climate to fire activity, the fire regimes of western Canada, particularly in British Columbia, are expected to be highly impacted by a changing climate. This study's purpose is twofold. First, it attempts to define the relationships between fire weather and fire activity (fire occurrence and area burned) in British Columbia based on historical data and how they will respond to climate change. Then, using this information, as well as the Pacific Ocean sea surface temperatures, a variable to which fire activity is linked in western Canada, a seasonal fire occurrence prediction model (SEAFOP) was produced. Climate change projections are available from a Regional Climate Model (RCM) for three scenarios based on carbon dioxide levels: $1\times CO_2$, $2\times CO_2$, and $3\times CO_2$. In BC, highly variable topography required a correction to be applied to the RCM. Daily fire weather (weather observations and Fire Weather Index (FWI) System codes and indexes) maps were produced using the historical (weather station) and RCM fire weather and compiled in bimonthly and seasonal (fire season) maps to undergo spatial analysis.

The change in fire weather between climate scenarios was quantified and then used to assess future fire occurrence and area burned. Results show a gradual, but not marked, increase in fire weather and fire activity. However, this increase is highly variable from one biogeoclimatic zone to the next. The SEAFOP model, although not yet tested operationally, holds promise in that it provides the first seasonal predictive model for fire season severity. Further work is required in order to reduce the uncertainty of climate change predictions and its effects on forest fires. However this work establishes predictive relationships that could be used to support long-term seasonal fire management planning in British Columbia.

Assessing the potential for policy responses to climate change

A.M. Wellstead, D.J. Davidson, and R.C. Stedman

Our research examines the role of knowledge and policy oriented belief systems in climate change decision-making within Canadian Prairie policy regimes. An online survey of over 700 policy elites in agricultural, forestry, and water sectors examined policy relevant belief systems and considered the probable policy responses to climate change and related scientific information. Several bodies of scholarship were employed to develop this research. In particular, the policy community/network analysis and the advocacy coalition framework models, as well as risk perception research were utilized. Policy networks that identify knowledge and power exchanges were identified using similar methods employed by Knoke, Laumann, and other European social scientists.

This network analysis was combined with another body of research, the advocacy coalition framework (ACF). The ACF examined policy change according to a set of well-defined research hypotheses that described the role and relevance of policy-oriented beliefs. In this study both the results of the research were presented as well as commentary on the role of methods required to understand the interrelationships between regional, national, and international policy actors in influencing the decision-making process in other contexts.

Quantifying the response of disparate tree species to climatic variation across primary environmental gradients

S. Green

There remains considerable uncertainty about the capacity of different tree species to adapt to rapid changes in climate. Among co-occurring species, the response to changes in local climate may be mediated by different environmental cues (e.g., photoperiod, air/soil temperature, soil moisture), and distinct responses can alter the survival and/or competitive ability of a species. Low phenological plasticity in the timing of budbreak and/or budset, for example, could limit competitive ability in warming climates by constricting the potential growth period. Additionally, within-species responses to changes in local climate may vary across primary environmental gradients (e.g., latitude, altitude, continentality) and/or at different tree developmental stages. Consequently, models that seek to predict climate-driven changes in tree distributions based primarily on estimated shifts in physiological ranges and paleo-ecological estimates of migration rates remain highly speculative.

There is a clear need, therefore, to quantify important interactions between key environmental factors and the life-history, physiology and growth of co-occurring trees across a wide range of species, conditions and developmental stages. I propose to measure the phenological, physiological and growth responses of disparate tree species and ecotypes (which here refers to populations adapted to narrow ranges of environmental conditions) to climatic conditions within and beyond their natural ranges by outplanting seedlings across primary environmental gradients (e.g., elevation/aspect, latitude and continentality).

The opportunity to directly examine tree species/ecotype response to environmental conditions beyond their natural limits overcomes a serious constraint in many field studies that seek to investigate tree response to climate change. Additionally, by incrementally extending the range of environmental gradients and species functional niches (e.g., early successional vs. late successional, deciduous vs. coniferous, wide ecological range vs. narrow ecological range), new questions can be adaptively explored about tree response to climate change. Further, long-term examination of phenology, physiology and growth in these common-garden studies would allow me to quantify primary limitations for disparate species/ecotypes at different developmental stages.

The identification of fire characteristics in the Eastern South Slave Region, Northwest Territories, in relation to pacific decadel and arctic oscillations

T.L. Hillis, S. Carriere, R. Case, and B. Croft

Disturbances operate in a heterogeneous manner in the landscape. The physical or vegetative features of the landscape often control gradients of disturbance frequency and severity. Correlation analysis between landscape structure metrics and variables indicate that climate change has a strong influence on landscape structure. An understanding of the influence of climate change on the occurrence and severity of forest fires is therefore crucial to understanding the impacts of climate change on the Boreal forest.

Data on fire activity were represented for the past 5 years within the eastern portion of the South Slave Region in the Northwest Territories. Data were presented in polygon format with attributes including area, perimeter, year, and decade interval for fire. All fires fewer than 250 hectares were removed. Vegetation data was tabulated for each of the fire polygons for each specific year (1995–2001) from a classified LANDSAT Thematic Mapper 5 image created by the Forest Management Unit in Fort Smith, NWT. Vegetation represented in square meters was converted to percentage of a habitat type within the fire polygon for analysis. Categorical map patterns used for defining fire polygons were obtained using a class level analysis in FRAGSTATS for ARCVIEW 3.2. All parameters (class level metrics and vegetation) were placed in a Principal Component Analysis (PCA) with a varimax rotation. In order to assess preliminary affects of climate on fire characteristics the parameters identified as being potentially influenced by change were correlated using non-parametric biavariate analysis with both changes in Pacific Decadel and Arctic Oscillations between 1995 and 2001.

In order to determine if season had an influence, both Pacific Decadel and Arctic Oscillations were represented as yearly means, mean winter fluctuations (November–March) and mean spring fluctuations (March–June).

The results of the PCA analysis of fire polygons between 1995 and 2001 identified five components that explained 97.2 % of the variance. Factor 1 is made up of parameters associated with configuration of the fire polygons and vegetation; fire area, largest patch index, total edge, edge density, percentage of mixed conifer, deciduous and fire regenerated low shrubland vegetation types. Factor 2 is made up of parameters that further define the configuration of fire polygons and include mean patch shape, patch density, and mean patch edge. Only one vegetation component was associated with Factor 2, Black Spruce. Factor 3 is made up of vegetation characteristics that include fire regenerated mixed forest and wetlands. Factors 4 and 5 include white spruce, scattered conifer and percentage of herbaceous layer and jack pine, respectively.

Determination of climatic change on the components identified in the PCA indicated that annual fluctuations in both Pacific Decadel and Arctic Oscillations had the strongest relationship with Factor 2 ($r^2 = -0.929$, $p = 0.003$; $r^2 = -0.775$, $p = 0.041$) respectively. The results of this study suggest that fluctuations in Pacific Decadel and Arctic Oscillations influence the class components associated with mean patch shape, patch density and mean patch edge of fire polygons. Fire has been a natural, regularly occurring part of plant succession that permits the rejuvenation of some populations (i.e., black spruce) and creates a mosaic of plant communities that develop over time and vary with location. Changes in the responses of black spruce to climate may change the structural properties of vegetation, thus increasing the potential flammability of the vegetation, which may change the degree of heterogeneity occurring across the South Slave Region.

Using forest management techniques to alter forest fuels and reduce wildfire size: a potential climate change adaptation strategy

K. Hirsch, J.B. Todd, M.A. Parisien, and V. Kafka

Climate change is expected to increase forest fire activity in many parts of western and northern Canada over the next few decades. At the same time a considerable portion of the productive boreal forest will be harvested, and there is an excellent opportunity to use forest management activities (e.g., harvesting, regeneration, stand tending) to alter the forest fuels. Such actions, termed fire-smart forest management, could reduce both the potential for catastrophic wildfires and the risk associated with the use of prescribed fire under current and future fire climates. This paper provides an analysis of one of many possible fire smart forest management techniques. It describes a process for incorporating strategically located, landscape-level fuel treatments, primarily species conversion, into a long-term forest management plan for an area in west-central Alberta.

To analyze the effectiveness of the fuel treatments, wildfires were independently simulated on the existing land base, a hypothetical fuel treatment landscape, and four potential future landscapes. Ignition points were randomly located with a systematic grid and fire spread was modeled using a cellular propagation, hourly time-step, mechanistic fire growth model. Inputs consisted of a 100-m x 100-m fuels grid and different sets of constant extreme fire weather conditions derived from an analysis of historic fire weather and fire spread data. The results showed the fuel treatments could have a considerable impact on average fire size and benefit timber supply without adversely affecting biodiversity. Future research needs and the implications for forest management in crown fire-dominated forest ecosystems under a changing climate are discussed.

Hybrid poplar clonal transect trial: preparing for the future—picking the winners

R. Hurdle, T. Keddy, and D. Sidders

Afforestation of marginal agricultural land has been identified as a viable strategy under the terms of the Kyoto Protocol. While initially seen as a mitigation measure that sequesters atmospheric carbon while preserving and augmenting soil carbon, other adaptive economic, environmental and social benefits of the practice were soon recognized.

Future programs intended to facilitate conversion of land to agroforestry will most likely require a large investment. Establishment of pilot-scale plantations to evaluate available stock, planting techniques, growing conditions and infrastructure readiness seemed a prudent step before initiation of a full-scale program.

In the summer of 2002, the Canadian Forest Service established 15 plantations of 500 units each of candidate hybrid poplar clones, recommended by various experts in the field, on private land along on a transect from southeastern Manitoba to the Alberta Peace River country. The transect included a number of soil types, along a climate gradient from moderate maritime influence to mid-continental. Consistent site preparation, stock handling, planting and vegetation management were employed on all sites.

Air and soil temperature and soil moisture were monitored at representative sites. Survival and growth were evaluated at the end of the season. Predictably, in a drought year, performance was better where there was more moisture in the early part of the season. No instances of excess water were evident.

Climate change impacts on productivity and health of aspen (CIPHA)

E.H. Hogg, J.P. Brandt, and B. Kochtubajda

Trembling aspen (*Populus tremuloides* Michx.) is the most important deciduous tree species in the Canadian boreal forest. In the early 1990s, dieback and reduced growth of aspen was noted in some areas of Saskatchewan and Alberta. Early studies suggested that drought, in combination with insect defoliation and fungal pathogens, played a major role. This led to concerns about the current status of aspen health, including the question of how aspen may be responding to climatic warming that is already evident in western Canada. To address these concerns, we established a regional study (CIPHA) that includes annual forest health monitoring of 75 aspen stands in climatically sensitive areas of western Canada, extending from the southwestern Northwest Territories and northeastern British Columbia to western Manitoba.

Field measurements on these stands showed that the aspen in the climatically dry parkland zone are significantly stunted in height, and have a smaller basal area compared to aspen of similar age (mean of 60 years) in the boreal forest. As a result, average aboveground biomass was 37% smaller in the parkland stands (105 T/ha) compared to the boreal stands (166 T/ha).

Tree-ring analysis was conducted on disks collected at three heights from 432 aspen stems at these sites. The results showed that regional aspen growth from 1950–2000 has undergone several periods of reduced growth and recovery. Growth was dramatically reduced during 1961–1964, 1979–1984, and 1988–1995, corresponding to periods with regional drought and large-scale outbreaks by forest tent caterpillar (*Malacosoma disstria* Hbn.). The last peak in aspen growth was in 1997, following a cool, moist period with little defoliation. Regional aspen growth started to decline during the unusually warm, dry "El Nino" year of 1998, and had decreased by a total of 30% between 1997 and 2000.

During 2001–2002, the region was affected by one of the most severe droughts on record. The 2002 forest health assessments showed that the drought had not yet caused widespread aspen dieback within these stands. However, a preliminary analysis indicated an increase in the incidence of poplar borers in some parts of the drought-affected region. Continued monitoring will provide an early indication of any long-term impacts of this drought on the health of the aspen forests in this region. Future directions include the "scaling up" of tree-ring analyses for annual estimates of net primary production, and the validation of models for projecting future impacts on the aspen forests of western Canada

Potential impacts of climate change on growth and regeneration of drought-prone forests near Whitehorse, Yukon

E.H. Hogg, and R.W. Wein

Climate change has already led to significant warming of the western Canadian boreal forest, where mean temperatures have increased by nearly 2ºC over the last 50 years. One of the major concerns is that as global warming continues, the future climate of this region will become significantly drier. This could have a major impact on forest ecosystem functioning, especially in semi-arid regions such as the aspen parkland located along the northern edge of the Canadian prairies. Some areas north of 60º N are also vulnerable, notably the low-elevation forests of the southwestern Yukon where mean annual precipitation is less than 300 mm per year.

In 1958, fires burned more than 400 000 ha of old, white spruce-dominated forest in the valleys west and north of Whitehorse, Yukon. Since then, these burns have shown very poor spruce regeneration, but have been colonized by scattered clones of aspen interspersed by grassland. One possible explanation is that climatic change, in combination with fire, is transforming the landscape from a closed, boreal coniferous forest to a more open vegetation resembling the aspen parkland of the Prairie Provinces.

The objective of this study was to conduct tree-ring analysis to examine the influence of climatic variation on growth and regeneration of aspen and white spruce in the 1958 burns and in the older, adjacent unburned forests. Tree-ring analysis on the unburned forests showed that despite the cold climatic conditions of this region, moisture has been the most important factor controlling growth of both species. Growth was greatly reduced during dry years, especially in the extreme fire years of 1958, 1995, and 1998.

Based on the examination of tree rings from 147 regenerating aspen stems on the 1958 Takhini burn, there have been two major waves of aspen colonization. The first wave, extending from 1959–1975, includes aspen that apparently colonized the burn as seedlings. The second wave, starting in 1980, primarily consists of aspen that suckered from the roots of the older aspen from the first wave. Despite the open conditions, very few additional aspen established on the burn during 1994–2002, which was generally drier than normal.

These results provide further evidence that low-elevation forests of the southwestern Yukon will be highly vulnerable, if the climate of this region becomes drier under future global change.

Assessing the impact of climate change on landscape-level fire behavior potential in central Saskatchewan, Canada

V. Kafka, M.A. Parisien, K. Hirsch, J.B. Todd, and M. Flannigan

This study describes and applies a procedure to assess the effects of climate change on fire behavior potential in central Saskatchewan (135 000 km^2), an area that characterizes the transition from mixedwoods to pure coniferous forest types. Head fire intensity (HFI) was used to quantify fire behavior potential because it can be related to fire behavior characteristics, suppression effectiveness, and fire effects. HFI maps were created from percentile fire weather, topography, and fuels data for three simulated climate scenarios representing present (1×CO_2), double (2×CO_2), and triple (3×CO_2) levels of carbon dioxide. Fire weather was obtained from the Canadian Regional Climate Model (CRCM) to simulate the projected climate. HFI maps were built for a range of climate conditions (e.g., 90th, 95th, 99th percentile values) and for various periods of the fire season (i.e., spring, summer, and fall).

Our results show a marked increase in fire behavior potential from 1×CO_2 to 2×CO_2: the area that could sustain intense crown fires (HFI > 10 000 ha) almost doubled, thereby dramatically reducing future suppression effectiveness. The greatest absolute change in HFI occurred in the central part of the study area; however, the effects of climate change may be more important in the northern part, as it experienced the largest proportional increase in fire behavior potential. Analyses also revealed that deciduous stands have a significantly milder response to climate change than other fuel types. Conversion to less flammable fuels could therefore be used as an adaptation strategy to mitigate an increase in landscape-level fire behavior potential. Unexpectedly, little change was observed from 2×CO_2 to 3×CO_2.

Disturbance of the boreal forest of British Columbia by the spruce budworm

A. Shand, and R.I. Alfaro

The study of the historical extent, intensity, and frequency of forest disturbances provides a baseline against which we can measure the effects of climate change on disturbance dynamics.

The spruce budworm, *Choristoneura fumiferana* (Clem.) (Lepidoptera: Tortricidae), is a defoliator of white spruce (*Picea glauca* (Moench) Voss) and a major disturbance agent of the boreal forests of British Columbia. The spruce budworm has caused concern to forest managers because of growth loss, stem defects, and tree mortality resulting from defoliation. Over 1 000 000 ha have been recently affected in the Fort Nelson Forest District in northern British Columbia.

A network of 39 ground plots established by the Canadian Forest Service between 1992 and 2002 have provided data on top-kill, mortality and stand level changes occurring as a consequence of budworm defoliation. Dendrochronological studies indicate a variable recurrence frequency for this disturbance over the landscape. The northern part of the district experienced four outbreaks during the 20th century, while the southern part of the district has only experienced two.

Little is known of the effects of climate on the range, severity, or frequency of budworm outbreaks. Understanding the historical and the current extent, intensity, and frequency of the budworm disturbance will give a basis for predicting the future impacts of this insect under changing climate and allow for adaptive forest management.

The carbon balance of pastureland and regenerating clearcuts in sub-boreal British Columbia

J.D. Waughtal, and A.L. Fredeen

As concentrations of greenhouse gases continue to increase in Earth's atmosphere, strategies to mitigate these increases are intensifying. One strategy currently being examined for CO_2 is the possibility of enhancing belowground carbon sequestration in terrestrial ecosystems. However, considerable uncertainties in how belowground carbon is or will be affected by climate change variables (e.g., warming) and land-use (e.g., conversion of forests to pasture) still exist.

Thus, we have undertaken a study to examine the relationships between soil carbon, belowground and ecosystem CO_2 flux, and temperature. In addition, because root activity can represent a substantial fraction of belowground respiration, we have also made measurements of volume-based root surface area. The study was conducted in pastureland near Hixon, BC; this was of particular interest because it was originally derived from sub-boreal forest and its management history was well documented. Measurements of ecosystem CO_2 flux were also taken in a sub-boreal regenerating clearcut east of Prince George, BC, for comparison with values obtained from the pasture.

Ecosystem CO_2 flux was measured with an Eddy Covariance system, verified with a Bowen-ratio system run in tandem for part of the growing season in the pasture during the 2001 field season (Campbell Scientific). The Eddy Covariance system was used in the 2002 field season for measurement of ecosystem CO_2 flux in the regenerating clearcut. Belowground respiration was measured using an LI-6200 portable photosynthesis system with an LI-6000-09 soil respiration chamber in the 2001 and 2002 field seasons throughout the pasture and in adjacent regenerating and mature forests (LI-COR Inc.). At all grid points in the pasture used for belowground respiration measurements, soil samples were taken for determination of root surface area and for soil carbon.

Based on the examination of tree rings from 147 regenerating aspen stems on the 1958 Takhini burn, there have been two major waves of aspen colonization. The first wave, extending from 1959–1975, includes aspen that apparently colonized the burn as seedlings. The second wave, starting in 1980, primarily consists of aspen that suckered from the roots of the older aspen from the first wave. Despite the open conditions, very few additional aspen established on the burn during 1994–2002, which was generally drier than normal.

These results provide further evidence that low-elevation forests of the southwestern Yukon are highly vulnerable, if the climate of this region becomes drier under future global change. At the points used for belowground respiration measurements in the adjacent forested areas samples were taken for soil carbon measurement. Root-containing soil samples were washed and isolated roots scanned digitally for surface area determination (Delta – T Devices Ltd.). Soil carbon was analyzed using stable isotope radio mass spectrometry. Samples of aboveground plant biomass and coarse woody debris were obtained at each of the belowground respiration measurement points to determine aboveground carbon stocks for each of the sample areas.

Soil respiration decreased slightly with increased root surface area and increased with soil temperature. Ecosystem CO_2 uptake and belowground CO_2 efflux both exhibited positive correlations with air and belowground temperature, respectively. Belowground carbon stocks were also affected by conversion of the native sub-boreal forest to pasture. The ecosystem CO_2 flux measurements indicated that both the pasture and regenerating clearcut were small sinks for CO_2.

The measurements of soil carbon, aboveground carbon, and belowground respiration will be used to create a map of carbon pools and fluxes at a local scale using a land type classification program developed to use orthophotos to map land types. Thus, the combined effects and interactions between management and the relative influences of global warming on net photosynthesis versus soil respiration will likely determine how land-use in sub-boreal Canada will ultimately influence atmospheric CO_2 concentrations.

Ecosystem CO_2 flux for a 5 and 6 year-old sub-boreal clear-cut in central British Columbia using two independent approaches

T.G. Pypker, and A.L. Fredeen

We measured ecosystem-level growing season CO_2 fluxes for a vegetated sub-boreal clearcut from 27 June to 3 September 1999 and 24 May to 20 September 2000. Two independent approaches were used to measure ecosystem CO_2 flux for both years. A Bowen ratio energy balance (BREB) method was contrasted with a second approach using component fluxes. The Component model approach was based on scaling up from regressions relating in situ CO_2 flux measurements for conifer seedlings (*Picea glauca* x *engelmannii*), as well as representative herbaceous (*Chamerion angustifolium*), woody (*Lonicera involucrata*) plant species and soil surface CO_2 efflux to microclimate conditions. Over the two measurement periods, the BREB method and the Component model predicted the site to be a sink in 1999 (–22.4 g C m^{-2} and –85 g C m^{-2}, respectively) and a source in 2000 (142 g C m^{-2} and 103 g C m^{-2}, respectively).

Over a comparable period of measurement (27 June to 3 September), the estimates for 1999 differ with those from 2000. The stand was a sink for carbon in 1999 (–22.4 g C m^{-2} using the BREB method and –85 g C m^{-2} using the Component model) and a source in 2000 (+65 g C m^{-2} using the BREB method and +44 g C m^{-2} using the Component model). The growing seasons of 1999 and 2000 experienced similar photosynthetic uptake over this same interval (–423 and –422 g C m^{-2}, respectively). The bulk of the carbon uptake was from the deciduous plants (86%). The main difference between the two field seasons was an increase in the soil surface CO_2 efflux from 1999 to 2000. In 1999, the soil surface CO_2 efflux was 338 g C m^{-2} and in 2000 the flux was 38% higher (466 g C m^{-2}) for the same period. The results indicate that while there was notable inter-annual variation in CO_2 fluxes, particularly the soil surface CO_2 effluxes, this young regenerating sub-boreal forest (≤6 years after harvesting) is a net source of CO_2 when the entire growing season is considered. Therefore, from a carbon 'sink' perspective, management of plantations should as much as possible promote rather than remove 'non-crop' species if the losses of CO_2 in the years immediately following harvest are to be minimized.

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