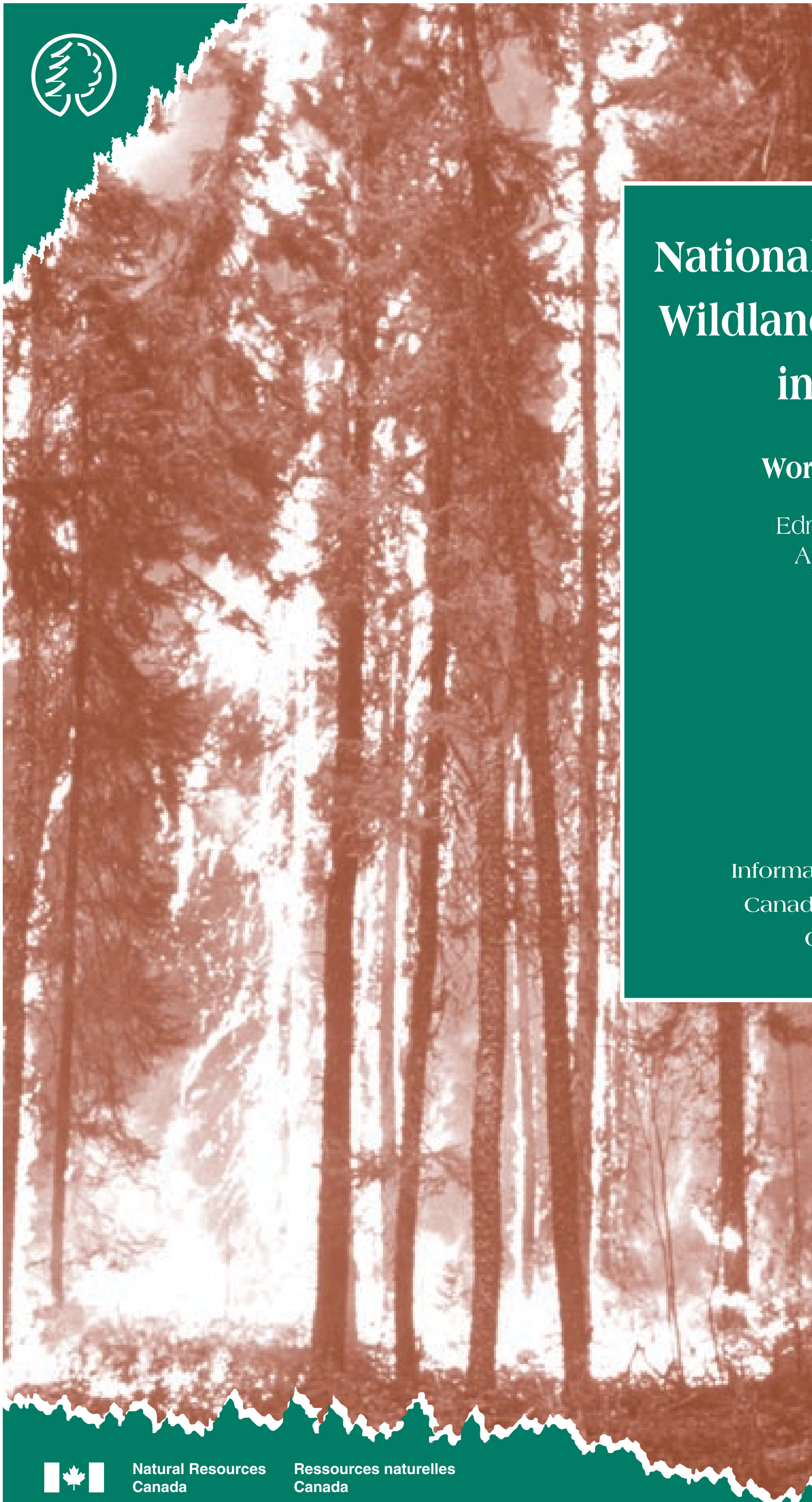

National Workshop on Wildland Fire Activity in Canada

Workshop Report

Edmonton, Alberta
April 1–4, 1996

Information Report ST-X-13
Canadian Forest Service
Ottawa, 1997

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Canada

National Workshop on Wildland Fire Activity in Canada

Workshop Report

A wake-up call for the sustainable development of Canada's Forests

Edmonton, Alberta
April 1–4, 1996

Albert J. Simard
Fire Coordinator
Canadian Forest Service

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Contents

Preface

This report accomplishes the fifth objective of the workshop on wildland fire activity in Canada which is to communicate its findings and recommendations. The report combines presentation notes taken by Paul Ward and discussion notes taken by the rapporteurs. It summarizes the workshop and makes no attempt to interpret the discussions, findings, or recommendations from any particular perspective. Thus, policy analysts, fire managers, research scientists, and various stakeholders will have to interpret the outcome in terms of their own interests.

Everything that was said at the workshop has been included in the report, although presentations and findings were reorganized so that related topics could be reported together. In addition, similar statements by the eight speakers and twelve discussion groups were combined under appropriate headings to avoid repetition. The report reflects different opinions and includes some conflicting statements. In contrast, different statements on various issues are included as they were put forward.

It is hoped that common ground will be found among the various perspectives and interests—that the issues raised by the workshop will be addressed and the recommendations will be adopted. If this happens, the status of wildland fire in Canada will be improved for those who follow, and the collective effort to organize and report on the workshop will have been worthwhile.

Workshop Steering Committee:

Bob Rosehart,
President, Lakehead University (chair)

Al Simard,
Fire Coordinator, Canadian Forest Service (secretariat)

Dennis Dubé,
Fire Network Program Manager, Canadian Forest Service (host)

Peter Fuglem,
Manager, Forest Protection Analysis, BC Forest Service

Jean-Pierre Martel,
Director, Forest Environment, Canadian Pulp and Paper Association

Remarks by the Honourable A. Anne McLellan

Minister, Natural Resources Canada

On behalf of the government of Canada, I welcome you to day two of the Workshop on Forest Fire Activity in Canada.

I asked the Canadian Forest Service to set up this colloquium because I believe it is essential to have some scientific clarity on what is happening with forest fires in Canada. I am pleased that we were able to serve as the catalyst for bringing together such an impressive group of experts on forest fires.

In my brief remarks today, I will talk about two matters:

- first, the importance of developing a consensus on the causes and potential effects of forest fires; and
- second, the importance of partnerships for effective research in this complex and multi-faceted issue.

Introduction

Increasing forest fire activity is of great concern to many Canadians. Forestry plays a key roll in the Canadian economy and the Canadian way of living. Forest fires are of particular concern to the 350 communities across Canada whose economies depend on forestry. Fires consume nearly as much wood as we harvest, and they can have a dramatic effect on the ecology of entire regions. Forest fire management accounts for nearly one-quarter of the cost of forest management in Canada and that doesn't count the very human cost of forest fires, particularly to those Canadians who are professional firefighters.

A Complex Issue

My department has the lead for forest fire research in Canada. We take our responsibility seriously. The Canadian Forest Service is reorganizing its research program so that it will have ten national science and technology networks—each devoted to a major field of national research. We have dedicated one network—the one located here in Edmonton—to research on forest fire management. And it is this Edmonton network that has taken the lead in organizing this conference so that we can take a comprehensive look at why forest fires are increasing.

Canadians cannot help but be confused about the causes. Some scientists say that increased fire activity results from global warming. However, many other scientists say that this is too simplistic—that there are a number of contributing factors that can help explain why we are seeing increased fire activity. Such factors include:

- an increasing population with easier and more frequent access to forests

- natural factors, such as variable climate and weather patterns, and
- new methods of data collection. For example, before 1980, we only counted the fires that we fought. As a result, these statistics did not account for many fires, or the large areas that were burned.

Importance of Consensus on the Issues

Increased fire activity may be due to a combination of some or all of these factors. In any case, given the potential effects of fires on the sustainable development of Canada's forests, it is important that we develop a consensus on the issues. Then, we can identify appropriate responses and implement them. That is why workshops like this one are so important. Here, we have an opportunity to lay the foundation for future policies, research, and management of forest fires in Canada.

Partnership Approach

Partnerships are key for research into an issue of such complexity as forest fires, and the Canadian Forest Service is committed to working with the entire fire community. We need to combine our resources to make significant progress. We need to strengthen existing partnerships and forge new ones among the federal government, provincial fire management agencies, and private industry in order to meet the challenges of a successful forest fire management program.

This workshop is an excellent example of ongoing federal–provincial partnerships in fire management. Another example is the partnership with Environment Canada that was demonstrated yesterday during the presentation of the joint paper on forest fire activity and climate. As well, I am proud of our participation in the Canadian Interagency Forest Fire Centre, which emphasizes our commitment to successful federal–provincial cooperation. In 1995, the Centre facilitated exchanges of more firefighters and resources among the provinces than in any previous year.

International Partnerships

The federal government is also working outside of Canada to promote sustainable development practices in the area of forestry. For example, I have just recently returned from Mexico, where I renewed a Memorandum of Understanding on forests with the Government of Mexico. The Canadian Wildland Fire Information System is an example of the type of technology that could lead to similar agreements with Mexico and other nations. The Natural Resources' Team Canada mission to Mexico emphasized the fact that forest nations have much to learn from each other—much expertise and experience that we can share.

Another demonstration of my department's commitment to international progress and cooperation is the leadership role by the Canadian Forest Service in a G-7 Information Society project to develop a global emergency management information network. The Canadian Fire Information System is making a major contribution to this initiative.

Conclusion

Canadians have an excellent international reputation for meeting international challenges. And we are working hard to build stronger domestic partnerships, because this is the key to meeting the challenges that we face. This workshop demonstrates the federal commitment to partnerships and consensus as we build on our progress toward sustainable development. Forest fires have a potential impact on sustainable forest management in Canada. These issues are complex, but I am confident that you have the expertise and the goodwill to meet the challenge of reaching a consensus on how we can best manage forest fire issues.

I look forward to receiving the findings and recommendations from these discussions. Present and future generations are counting on you to succeed. You have my best wishes for a successful workshop. Thank you.

Executive Summary

Introduction

The number of wildland fires in Canada has been increasing steadily since 1960 and the area burned appears to have tripled since 1980. There are many possible reasons for the apparent trend. A workshop of Canadian fire experts was convened to "understand the causes and increase awareness of the impacts of escalating wildland fire activity in Canada and recommend appropriate responses." The workshop had five objectives:

1. Determine whether fire activity has increased.
2. Evaluate and prioritize the possible causes.
3. Summarize the potential impacts.
4. Recommend appropriate responses.
5. Communicate the findings and recommendations.

Findings

The findings are summarized according to the workshop objectives.

Fire-Activity Trends

Every place has an inherent fire regime—a natural pattern of fire activity. A fire regime is the product of many natural and cultural influences; none can be studied in isolation. A fire regime only changes when humans substantially change the fuel structure by converting forest to agriculture, grasslands to forest, or developing wildlands. Canadian fire regimes span two orders of magnitude—from 100 to 10 000 years between fires. There is an important knowledge gap; Canadian fire regimes are poorly defined, measured, or understood—there is no basis for comparisons over time or space.

Historical, current, and forecast fire statistics are essential to many purposes, constituencies, and organizational levels. Traditional statistics are not adequate to resolve complex land management issues; criteria and indicators for wildland fire are needed in the context of sustainable development. Three indicators should be measured—fire load (environmental inputs), fire-management effectiveness (work performed), and impacts of fire on other systems (system outputs). Modern information technology could significantly improve the acquisition, analysis, and dissemination of fire criteria and indicators.

Existing fire records cannot be used to draw firm conclusions about the relative contribution of climate change and other factors to apparent increased fire activity in recent decades. Before 1975, area burned in Canada appears to have been significantly under-reported. The current area burned may be within the range of natural conditions that were experienced before 1920.

There is no consensus that fire activity has actually increased in Canada. There is a strong consensus that fire activity will increase in response to global warming, and it is prudent to be prepared. Large systems do not respond quickly to changes. Action will be necessary before all the evidence is in—waiting for evidence virtually guarantees failure.

Explaining Fire-Activity Trends

The observed trend of fire activity most likely results from a complex combination of most, if not all, of the possible causes. However, some potential causes of increasing fire activity such as weather variability, climate change, and declining management budgets are consistently viewed as more important than others, such as increasing population, increasing occurrence, and harvesting activity.

Greenhouse gases have increased significantly in the past half-century. Part of the increase has been attributed to anthropogenic (human) activities. Without major human intervention, greenhouse gases will increase to several times their pre-industrial concentrations by 2100. Average temperatures in western Canada were warmer in the 1980s than in the previous 3 decades; this warming is consistent with projections of global climate-change models. If the climate does change as projected, average fire danger will be significantly higher than it is today. Preliminary research suggests longer fire seasons, more severe fire weather, and earlier season start-up, particularly in western Canada.

Fires outside of protection zones have historically received only limited suppression; however, the area burned by these fires has only been reported since the mid-1970s. Although pre-suppression budgets and consequent resource availability have been reduced in recent years, a cause-and-effect relationship to increased area burned or resource losses cannot be demonstrated at the present time. There is evidence that suppression success has increased fire-return intervals in Canada relative to natural fire regimes, but it cannot be demonstrated that unnatural fuel buildups are causing increased area burned.

Impacts of Increasing Fire Regimes

Ecosystems are expected to shift northward in response to climate change; grasslands and the boreal forest are expected to expand. Fire may be an important catalyst in speeding ecosystem migration and expansion. Canada's forests could shift from a net sink to a net source of carbon. Although not anthropogenic, this would affect the national carbon budget. The composition of forest communities will shift towards fire-tolerant pioneer species and an increasing fire regime will tend to benefit wildlife populations.

Particulates and trace gases emitted by forest fires into the atmosphere will probably increase and could reinforce global climate change. An increased fire regime could result in reduced water quality, increased soil erosion on hilly sites, and increased permafrost melting. These effects will tend to be site-specific and can be mitigated to some extent.

Declining fire-management resources, coupled with increasing fire activity, may lead to a sudden decrease of fire-management effectiveness and the point of onset is not known. The level of fire activity that the public is willing to accept is also not known. The cost of maintaining suppression capability to preserve artificially low levels of burned area may increase exponentially. Interagency resource sharing has proven invaluable during extreme fire situations; this will likely increase. Although fire-management efficiency can be increased, the potential improvement may not be sufficient to maintain current levels of management in the face of increasing fire regimes.

Canada's forests cannot be sustainably managed at the limits of growth. Some buffering is essential to ensure long-term sustainability. An increased fire regime will reduce the quantity and quality of wood available for harvest. The cost of harvesting will likely increase, but this may be offset by increased resource values. Forest growth and allowable cut calculations will have to be adjusted downwards as fire activity levels increase.

Wildland/urban interface fires will increase with consequent community evacuations, loss of homes, property, and infrastructure, threats to public health and safety, and media attention. Limited suppression resources will exacerbate conflicts between resource and property protection; sacrificing one to preserve the other will become increasingly necessary. Increased political scrutiny of fire management is likely, making rigorous quantitative analyses of selected alternatives necessary. Public education about fire issues and participation in developing fire-management policies will be needed for continued support of fire management. Stakeholders will increasingly scrutinize protection-zone boundaries and the selection of full or modified suppression.

Responses

Different levels of government (federal, provincial, agency) have different mandates, and responses vary accordingly. Government funding processes are not well suited to fire management. Income resulting from fire protection is usually not linked to suppression costs in general revenues. Carrying over unused funds from moderate years to severe years is generally not possible. The line between resource protection and emergency management is blurred. Fire regimes evolve very slowly over decades or centuries; fire policies should not change significantly with changing governments. Agencies will have to provide a socio-economic rationale for fire policies and demonstrate the quantitative values of fire management. Agencies should adopt an ecosystem management approach, which will have to be better defined and understood than is currently the case.

Levels of resource protection are generally (but not universally) decreasing while wood values are increasing. Industry and government should reevaluate their investment in fire protection and determine appropriate levels, based on the values of the resources protected. Forest managers should not invest in silviculture without protecting that investment. Industry may be expected to assume a greater share of the cost of protecting the wood resource. Industry will have to become increasingly involved in setting fire policies and in fire management which could, in turn, increase the pressure to protect industry interests.

Fire research will have to shift its focus from process models and tactical systems to policy issues and strategic systems. Combining landscape fire models with regional climate forecasts would yield probabilistic landscape models that could establish the range of future ecosystems. This would enable analyses of long-term fire-regime trends. Methods will have to be developed to measure criteria and indicators for wildland fire in a context of sustainable development. Large fires might be monitored and mapped automatically via satellite. Methods will have to be developed to link suppression expenditures with fire size and all values at risk.

Recommendations

Recommendations are numbered in order of priority, as ranked by the workshop participants. They have been organized into four groups of related recommendations. (Number 9 is related to group D).

A. Linkages to Higher-Level Processes

Strengthen the policy and planning linkages between wildland fire and higher-level processes. These linkages are critical to obtaining the long-term support necessary to implement fire management's mandate.

1. Incorporate fire regimes into sustainable forest-management policies and planning.
2. Develop methods to measure fire regimes and indicate changes.
3. Increase public understanding of and participation in developing fire policies.

B. Technical Support for Policy-Making

Discover knowledge and develop systems to provide technical support for establishing fire policies.

4. Develop methods for measuring and predicting the effects of wildland fire.
5. Develop a nationally applicable analytical system with a capability to determine the socio-economic implications of wildland fire.
6. Improve the historical fire record to permit analyses of long-term fire-activity trends.
7. Enhance setting and coordinating fire-research priorities, and establishing partnerships.

C. Fire-Management Information

Develop systems to improve the quality and timeliness of operational and archival fire-management information which is essential to successful fire management and to support fire policies. (Number 9 is related to group D.)

8. Maintain and enhance compilation and analyses of national fire statistics.

10. Develop a national wildland fire-information network to link all fire agencies.
11. Develop decision-support systems to increase fire-management efficiency.

D. Fire Management and Research

Address issues that are important to fire management and research.

9. Develop improved fuel-management strategies.
12. Improve strategies for delineating protection zones.
13. Use a multi-scale approach to develop fire-management systems.
14. Increase fire-management effectiveness.

Overview

Four overarching patterns of wildland fire and climate change emerge from the discussions, findings, and recommendations.

There are three sets of nested systems. Society, land management, and fire management; the physical environment, dynamic processes, and fire behavior; and landscapes, ecosystems, and forest stands. Little is understood about the multi-lateral, long-term, and hierarchical relationships among the systems. Each system is part of a higher-level system that provides essential inputs; in turn, outputs from each system affect the higher-level system. The balance between the inputs and outputs determines whether a system will grow or decline and, ultimately, whether or not it will survive.

Different values lead to conflict. Limited resources for supression make choices between protecting resources or property inevitable. Many agencies want research to solve current problems, but the culture of science primarily rewards fundamental breakthroughs. Governments are seeking partners to share the burden of fire management while industry wants government to better protect the wood resource. The interface between people and their environments is complex; disputes are likely because of conflicting values. Well-honed analytical and negotiating skills will be needed to resolve these conflicts.

No single perspective is adequate. Understanding the issues requires that they be viewed from different perspectives. Organizational level (e.g. policy, management, operations) is inappropriate because most issues involve more than one oganizational level. Sector (e.g. government, industry, research) is inadequate because partnerships will be essential to resolving most issues. Function (e.g. funding, planning, suppression) is also limited because most issues involve multiple functions. Aboriginal interests, preserving natural heritage, and biodiversity are of value and must be considered. Protecting communities, property, and individuals must be factored into the equation along with resource and non-resource values. Thus, wildland fire involves cross-cutting issues, which will require partnerships among groups of stakeholders for their resolution.

The issues are exceedingly complex. We have much in the way of experience, but little in terms of knowledge and understanding of large-scale and long-term fire issues. A marriage between science and experience is needed to grapple with real-world decisions that cannot be put off until we understand the problem. The cross-cutting nature of many issues will require similar broad studies among relatively unrelated disciplines (e.g. sociology, physics, biology). We are no longer addressing questions that can be easily or quickly answered.

Conclusions

From an environmental perspective, it cannot be concluded that current fire activity has actually increased in recent decades. However, the probable long-term scenario is that global warming will most likely result in escalating fire regimes in Canada. But it is not currently possible to demonstrate a cause-and-effect relationship between the two processes or quantify the change.

From an ecological perspective, most Canadian forests trace their origins to fire; many require fire to maintain their species composition. Fire may be an important catalyst for ecosystem migration and in shifting Canada's carbon budget. It will affect the level of sustainability of some of Canada's forests and play a major part in shaping the Canadian landscape.

From a socio-economic perspective, fiscal restraint prevails as governments attempt to balance their budgets while values at risk are simultaneously increasing. The costs and benefits of fire management must be weighed against those of other programs but the costs and benefits of fire management are not compared easily. However, declining budgets coupled with escalating fire regimes may lead to a sudden decrease of fire-management effectiveness and the point of onset is not known.

Wildland-fire management is a subset of two management domains—forestry and emergency. In Canada, fire accounts for one-quarter of the cost of forest management and consumes nearly as much wood as is harvested. Fire has a major impact on the sustainable development of Canada's forests. It also results in injury and loss of life, destruction of property and infrastructure, environmental degradation, and disruption of rural communities. Fire also affects the health and safety of Canadians living in rural areas. Fiscal realities are already forcing hard choices between protecting property and resources.

We are dealing with large systems, which like great ships will not easily alter their course. If we wait until all the questions are answered, it will probably be too late to influence the outcome. Prudence dictates that Canadian wildland fire policies should anticipate and reflect whatever context nature and society might provide. Substance must be given to policies that state that fire suppression should be proportional to values at risk and that fire should assume a more natural role in managing the landscape.

Introduction

Recent fire statistics paint a sobering picture that has attracted considerable media interest.

- 1995 was the second worst year on record (7.2 million ha burned).
- In 1995, two-thirds of Canada (seven provinces) experienced severe fire situations.
- In 1995, the extreme situation lasted longer (3 months) than any year in recent history.
- In 1995, CIFFC moved more resources among provinces than in any previous year.
- 1994/95 was the worst 2-year period on record (13 million ha burned).
- In 1994/95 an area equal to that in New Brunswick and Nova Scotia was burned.

"Official" statistics for Canada show that the number of fires has increased by 60% since 1960 and that area burned appears to have tripled since 1980 (Figure 1). The 10-year average area burned (3.0 million ha) is the largest on record. From another perspective, the 5 worst years on the official record (since 1918) have been in the past 15 years (Figure 2).

Although some interpret increased fire activity as an indicator of global warming, scientific proof remains elusive. Some scientific studies have concluded, however, that if the climate were to change as models currently forecast, forest-fire activity in North America will generally increase significantly. Given the potential impacts of an escalating fire regime on the sustainable development of Canada's forests, it is important that the underlying causes be identified and appropriate responses be implemented.

There are, in fact, many possible underlying causes of the apparent trend, including:

- increasing population and accessibility of forests results in more fires
- early statistics are incomplete—reporting of remote fires is much improved
- an early symptom of global climate change
- natural variation of climate and weather conditions
- allowing some fires to burn naturally and reporting their actual area
- budget reductions have reduced suppression resources
- decades of successful suppression have resulted in unnatural, heavy fuel accumulation
- older forests are more susceptible to stand-replacing fires.

Two essential points are that something appears to have changed and that there are many possible reasons. It is imperative for the sustainable development of Canada's forests that the reasons be identified and appropriate responses be implemented.

This imperative led the Canadian Forest Service to host a workshop on wildland fire activity in Canada. The purpose of the workshop was **to understand the causes and**

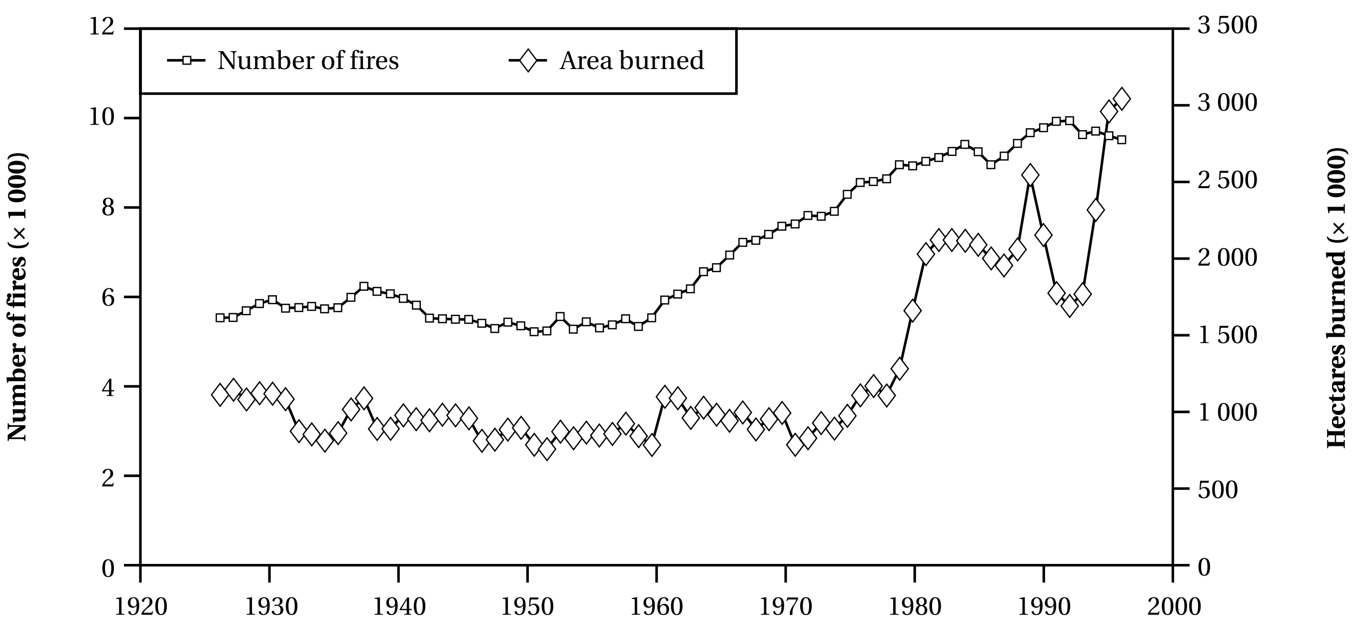

Figure 1. Canadian forest fire statistics (10-year running average). Data for 1995–1996 are estimates.

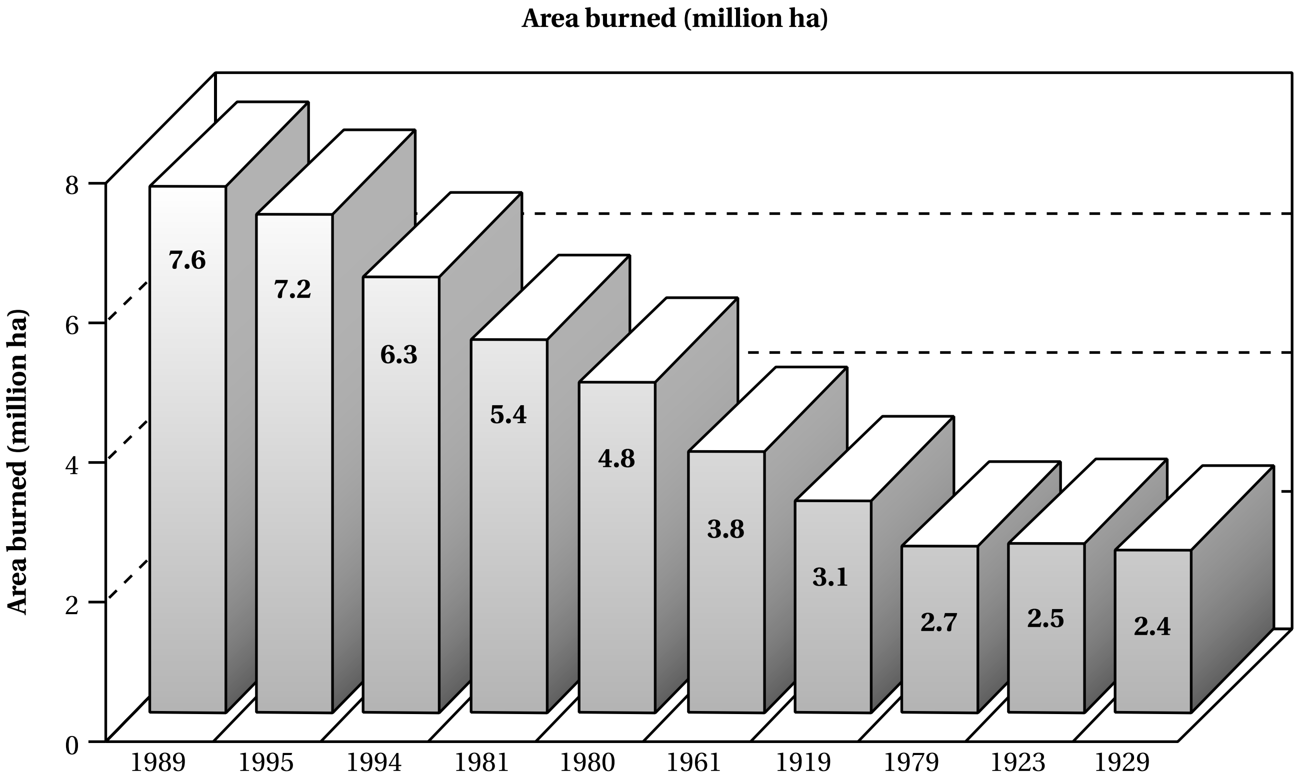

Figure 2. Top 10 fire years in Canada.

increase awareness of the impacts of an escalating fire regime in Canada and recommend appropriate responses. The workshop was held in Edmonton, Alberta, on 1–4 April 1996.

The workshop had five objectives:

1. Determine the trend of wildland fire activity in Canada.
2. Evaluate and prioritize possible explanations of the trend.
3. Explore the potential impacts of increasing fire activity.
4. Recommend appropriate responses by governments, industry, and science.
5. Communicate the findings and recommendations.

Many organizations were invited to ensure broad Canada-wide representation of knowledge, experience, and views. Provincial government agencies, federal government departments, universities, private industry, forestry associations, environmental non-government organizations, and aboriginal groups were included. Participants were sought from executive and senior management.

The workshop was divided into four themes, based on the first four workshop objectives. Eight invited speakers presented background papers to stimulate thinking among the participants. They summarized existing knowledge and started focusing the discussions. Participants were divided into 12 discussion groups to develop a consensus of Canadian fire experts. The groups discussed the issues, listed and prioritized their findings, and drafted recommendations. Additional information about the workshop process can be found in Appendix II.

Sections I to IV of this report summarize the presentations and discussions for the first four workshop objectives. Each objective is divided into thematic issues and subdivided into specific aspects of each issue. A total of 15 issues were raised at the workshop. Section V lists the workshop findings, which are organized by workshop objective and issue. Section VI lists the workshop recommendations, which are organized into four groups of related recommendations and are listed in the order of priority as determined by the workshop participants.

I. Wildland Fire-Activity Trends

The first objective of the workshop was to determine the actual trend of wildland fire activity in Canada. This objective addresses a fundamental question—is there a problem? There are four issues: fire regimes, fire statistics, the historical record, and fire-activity trends.

Issues

A. Fire Regimes

Every place has an inherent fire regime—a pattern of fire activity that characterizes that place. Fire regimes are a product of nature and culture. The natural background is the short- and long-term cycles of wet and dry periods coupled with the accumulatizon and decomposition of biomass. Culturally, North American fire regimes hark back to European colonization and the industrial revolution. This issue is divided into two parts—natural fire regimes and cultural influences.

Table 1. Canadian fire regimes by ecozone.

Interval (yr)	Ecozone
10 000	Pacific and Atlantic Maritimes, Mixedwood Plains
5 000	Taiga Cordillera
2 500	Montane Cordillera
1 000	Prairie Plains
500	Boreal Cordillera, Hudson Plains
250	Taiga and Boreal Plains, Taiga and Boreal Shields (part)
100	Boreal Shield (part)

Natural Fire Regimes—A fire regime integrates wildland fire activity over time and space, that is, the climatology of fire behavior. Fire regimes are measured with indicators such as fire interval (years between fires on one site), fire cycle (years to burn an area equal to an area of interest), fire frequency (number of fires per unit time at one site), fire season (duration, distribution), and the number, type, and severity of fires. Two factors govern natural fire regimes—climate and biomass.

Canadian fire regimes are typical of northern latitudes. Fire occurrence per unit area is low due to low population densities, but average fire size is large due to the remoteness of many fires and consequent difficulty of suppression. For example, in Canada, about 9 500 fires per year burn an average of 3 million ha (average size of 315 ha). In contrast, in the United States, about 200 000 fires per year burn about 1 million ha (average size of 5 ha).

Large fires occur everywhere in Canada except in agricultural, Arctic, and urbanized regions. Canadian fire-return intervals span two orders of magnitude—from 100 to 10 000 years. This reflects considerable variability among three major factors—climate, ecosystem properties, and level of protection. Table 1 lists Canadian fire regimes by ecozone. Fire is the dominant ecological disturbance factor for short-return intervals and of relatively little consequence for long-return intervals. A fire-return interval of less than 100 years would seriously limit sustainable forest management. Little can be said, however, beyond these simple statements as research on fire regimes is relatively new. The recent availability of technology needed for large-scale and long-term studies will provide broader perspectives of wildland fire than have been available in the past.

Relatively short Canadian fire seasons are delineated by temperature. Most fire activity occurs between May and September in southern Canada and June to August in northern Canada. There is virtually no fire activity from November through March. Overall, Canada has a unimodal summer season with a peak in July, although this varies among regions. The Prairies may have a short burst of extreme activity in May, lightning-prone areas typically peak in August, and eastern Canada exhibits a bimodal (spring/fall) season typical of deciduous forests. Lengthening the relatively short fire season would notably escalate fire regimes.

Canadian fire regimes include both dry (<50 cm annual precipitation) and moist (>50 cm annual precipitation) climates. Short-duration droughts (1 month) can significantly affect dry regions through soil-moisture deficits that reduce foliar moisture; longer droughts are needed to achieve comparable results in moist regions. The drought effect also depends on plant phenology. Before "green-up" and during late-season curing stages, fire activity responds more readily to drought. During the green stage, all ecosystems are more resistant to wildland fire due to high foliar moisture.

Precipitation frequency is also a key element. Summer precipitation in Canada is typically well-distributed but punctuated with moisture deficits of varying severity and durations. Coincidence of a dry period with one or more "wind events" (40 to 50 km per hour for 1 to 2 days) results in short periods of extreme fire activity. Although brief, the entire fire season can be dominated by these extreme periods. Their frequency is, therefore, a critical attribute of Canadian fire regimes.

Lightning is important to Canadian fire regimes. It starts 42% of all fires, but these account for 85% of the total area burned, due to remoteness and a tendency to occur in clusters which can overwhelm an agency. Lightning is more important in central and western Canada than in eastern Canada; lightening is more likely to be associated with rain in the east.

In the domain of fire, biomass is fuel. The balance between accumulation and decomposition determines fuel quantity. The moisture balance controls the amount available for combustion, which in turn, determines the amount of energy released and consequent fire severity. Horizontal continuity and bulk density affect a fire's ability to spread; vertical continuity affects a fire's ability to jump into the crowns. Grass fires spread rapidly but consume only surface vegetation which resprouts quickly and vigorously, particularly after spring fires. In contrast, peat fires spread very slowly but burn deeply for long periods, even under snow cover, resulting in long-lasting effects. Fires in the boreal forest tend to jump readily into the crowns, resulting in intense stand-replacing fires whereas deciduous forests experience predominantly low-intensity surface fires.

Many Canadian ecosystems are inextricably linked to wildland fire. Fire maintains grasslands by retarding the encroachment of woody plants. Fire is the primary, natural-disturbance agent for establishing plant communities and tree species such as Douglas-fir and poplar that require open conditions for growth. For some tree species, such as jack pine and lodgepole pine, fire is generally fatal to existing trees yet critical to reproduction and survival of these species. These ecosystems have adapted to, and in some cases require, relatively short fire-return intervals to maintain themselves. In contrast, eastern deciduous ecosystems have evolved in regions with long fire-return intervals and tend to be highly susceptible to damage from fire.

Fuel properties can be affected by management practices. Successful fire suppression in fire-prone areas can result in unnaturally heavy fuel accumulations and consequent increased fire intensity. Forest harvesting reduces stand age and consequent susceptibility to fire, but it generates heavy fuel loads as part of the harvesting process. Prescribed burning can reduce fuel loading. Fuel breaks can afford some measure of protection for high-value areas. However, fuel management generally affects only localized areas; it is generally not applied on sufficient scales to affect regional fire regimes.

Cultural Influences—Human culture strongly influences the amount of wildland fire that can be expected. Human-caused fires compete for fuel with lightning fires. Human- and lightning-fire cycles are different. The former is relatively steady and manageable; the latter tends to come in large pulses that can overwhelm an organization. There is some evidence (e.g. Chernobyl, midwestern United States) that fire activity may increase when agricultural land is abandoned and reverts to a natural state. Natural fires have always occurred within a matrix of human-caused fire as on African savannas and American prairies.

During the peak of the British Empire, lands were set aside in many colonial areas for the preservation of forests and wildlands, because deforestation of those areas was believed to be leading to climate change and unhealthy conditions. This led to the creation of public forests around the world and state-sponsored fire control. State fire agencies have significantly influenced the fire regimes in the areas under their jurisdictions.

The peak of charcoal production in Mesoamerica occurred in the 50 years before the Spanish conquest. Lower charcoal levels are found during subsequent periods, when native populations collapsed, and slash and burn agriculture never achieved the same prominence again. In the expansionary phase of U.S. settlement, the fire regime looked very much like that in developing countries today—slash and burn agriculture and the major use of fire for cultural purposes.

Great fires in the late 19th and early 20th centuries in the United States killed hundreds of people. Those traumatic events led to the development of organized fire protection, similar to the Canadian experience. A major debate took place in the early 20th century in the United States—fire suppression vs. the need for prescribed fire. Gradually, the necessity of fire became increasingly evident and eventually the use of prescribed fire supplemented the traditional European fire-exclusion paradigm.

Worldwide, there are two geographies of combustion—areas of biomass burning (e.g. Mexico, northern South America, and central Africa) and areas of fossil fuel consumption, primarily in industrialized countries. There is relatively little overlap between the two. In recent centuries, the use of fossil fuels has reduced the human need for biomass burning. Fossil fuel burning is limited by the size of the carbon sink; biomass burning is limited by the biomass source.

The area burned in the United States has been relatively steady since the 1950s. In contrast, the cost of maintaining area burned at its current level is increasing exponentially. Despite modern technology, more people are in the woods fighting fire than ever—to keep the lid on fire losses. Fire-control success was relatively easy in the early stages of fire management, but it is becoming increasingly difficult over time.

There is some evidence in Russia that aerial fire-protection is showing a pattern of exponentially increasing cost and area burned. This must be interpreted with caution, because the extent to which the shifting Russian economy may have influenced this pattern is not known. In Canada, fire-management costs do not appear to vary greatly from year to year (factor of two). The fire regime appears to be balanced through a large variability in the annual area burned (factor of seven).

In industrialized countries, rural areas are being recolonized, but recolonizers are not pursuing traditional rural activities (e.g. grazing, cultivating, burning). They are imposing ex-urban patterns (e.g. development, planting trees, and vegetation). In so doing, they are creating conditions suitable for fire ignition and spread, and the loss of socio-economic values in the wildland/urban interface.

One indicator of societal importance is the extent to which an issue is covered by the media. By this yardstick, wildland fire appears to be important primarily as a cause of community evacuations and personal tragedies. Vast remote areas often burn with little or no notice outside the affected regions. But, if a community is evacuated, even a modest-sized fire receives a week of nightly, national media coverage. Yellowstone in 1988 appears to have been an important exception to this rule. Perhaps the fame and emotional appeal of the park, the 2-month duration of the fires or the spectacular footage may have led to the extensive coverage. It was probably all of the above.

It is not known whether there is more or less fire in the world today than in the past because the global fire record is incomplete. Frequently, statistics for prescribed or observed fires are not included so that figures are typically incomplete for area burned.

B. Fire Statistics

This issue is concerned with the compilation and analyses of national data on wildland fire. This data, when validated and archived, is the basis of the Canadian fire record. This issue can be categorized into four questions. Why compile fire statistics? What should we measure? What tools should we use? Who should compile national statistics?

Why Compile Fire Statistics?—Wildland fire statistics serve many purposes, organizations, and constituencies, including:

- international commitments (global biomass burning inventory, carbon budgets, biodiversity convention)
- national interests (criteria and indicators, sustainable forest management, the national forest strategy, public health and safety, biodiversity, atmospheric emissions)
- land management agencies (fire and sustainable forestry, landscape management, ecosystem management, wildlife management, watershed management)
- fire-management agencies (fire planning, operations, suppression, prevention, prescribed fire, budgeting, audit and evaluation)
- fire science (fire history, the fire environment, fire management, fire ecology, fire economics, global climate change and fire)
- political leaders (fire-management policies, appropriate levels of fire management)
- forest industry (resource losses, timber supply, international trade)
- general public (health and safety, management of Canada's forests)
- media.

Fire statistics have several uses over time—recording what occurred (past), evaluating current conditions (present), and projecting expected trends (future).

What Should We Measure?—Currently, national fire statistics are limited to simple measures, such as the number of fires and area burned by cause, size class, month, and forest land-use classification for each province and Canada. An average of 9 600 fires has burned 2.9 million ha annually—0.6% of the total forested land in Canada. One-third of the total area burned is in commercial forest—0.4% of the commercial forest area. An average of 91.5% of all fires burn less than 10 ha whereas 1.5% of all fires that exceed 1 000 ha burn 93.1% of the total area. There are other contrasts. People start 58% of all fires in Canada, but these fires burn only 15% of the total area; lightning starts 42% of all fires but accounts for 85% of the total area burned. Full suppression accounts for 95.5% of fires and 42.7% of area burned, while modified suppression accounts for 4.5% of fires and 57.3% of area burned.

We should distinguish between national and agency statistics. Agencies tend to need detailed, localized, and short-duration information, such as in individual fire reports. National needs tend to be long-term and span large regions. National data should permit comparisons of current fire activity with natural (unmanaged) conditions. Statistics should indicate inter- and intra-seasonal spatial and temporal distributions of the data. There must be a national "buy-in" for compiling national statistics. If the statistics are to be used for evaluation purposes, benchmarks of successful fire management will have to be developed; the focus should not be only on indicators of failure. Fire statistics should be part of the national resource inventory.

The possibility of providing minimal standardized national information in every fire report was discussed. It has been attempted several times in the past, but it has never been possible to achieve consensus on the elements of a minimum set. Further, the idea of granting automatic access to individual fire-report data to entities external to fire-management agencies is even more problematic, other than on *ad hoc* bases.

Criteria and Indicators—It is becoming increasingly apparent that traditional fire statistics are not adequate to address the complex landmanagement questions that are currently being asked and that will be increasingly asked in the future. A higher-level concept of criteria and indicators for evaluating wildland fire is beginning to emerge. Three aspects of wildland fire should be measured—fire load (environmental inputs), fire-management effectiveness (work performed), and the impacts of fire on wildland systems (system outputs).

The fire environment (weather, fuels, topography) controls fire behavior (rate of spread, intensity) which, in turn, affects the difficulty of control. The number of fires, their relative remoteness, and the difficulty of control affect fire load—the amount of work that must be performed by fire-management agencies.

A true indicator of fire-management effectiveness would be the area saved divided by fire-management expenditures—and adjusting for values at risk and fire load. Area saved is currently unmeasurable. Fire suppression costs vary from $40 to $1 000 per ha burned with corresponding average fire sizes of 1 350 to 35 ha, respectively. Spending money can make a substantial difference in the average fire size. Yet, each agency is probably near its appropriate level. High costs per ha burned tend to be associated with high values at risk or high occurrence; low costs per ha burned are in regions with low values or low occurrence.

Area burned, by itself, is ambiguous; it may reflect fire-suppression effectiveness, peak fire load, or fire policies. Suppression effectiveness is governed by resource availability and the efficiency of use. Fire policies balance fire-management expenditures with socio-economic values at risk. One substitute for this balance is a classification of fires into “full” and “modified” suppression categories; the average fire size for the latter is 20 times that of the former.

Fire severity is the magnitude of significant and negative effects of fire on other systems. There are six systems of interest associated with fire-severity measures: ecosystems (disturbance characteristics), geosystems (soil erosion), the atmosphere (smoke emissions), fire management (fire business), forestry (wood supply), and society (community disruptions).

Environmental inputs, management effectiveness or system outputs for wildland fire cannot be directly measured. What can be measured indicates that fire is a major component of sustainable forest management in Canada. Fire activity is highly variable over time and space, which greatly complicates both management and measurement. Canadian fire management is effective, but deciding whether or not to fight a fire has major consequences. The return interval for large fires spans two orders of magnitude and requires a broad range of fire policies and appropriate levels of fire management.

What Tools Should We Use?—Current techniques use manual transmission of near-real-time operational data to rapidly disseminate information. Official statistics are carefully validated to remove errors and increase accuracy. The latter typically requires from 1 to 3 years to complete.

One possible improvement to current methods involves the use of a national fire-information network via the Internet. Agencies would be able to summarize data entered on individual fire-report forms and directly transmit their statistics, without having to reenter data. Adequate safeguards against unauthorized access would be essential to such a system.

Another potential improvement would be the use of satellites to map and monitor fires (greater than 200 ha) across Canada. Although this would not provide complete statistics, it would represent about 95% of the total area burned and would be able to pinpoint the time of each event, exact location, daily growth, and possibly, severity. It could be a key component of measuring criteria and indicators for fire.

Who Should Compile National Statistics?—Fire-management agencies are the original source of all fire statistics. National statistics should, however, be compiled by a national organization. National operational statistics are currently compiled by the Canadian Interagency Forest Fire Center (CIFFC) as part of the process of preparing a daily, national fire-situation report. Official national statistics were compiled by the fire-research group at the Petawawa National Forestry Institute (PNFI) of the Canadian Forest Service (CFS). Since the closure of PNFI, national fire statistics are being compilied by the national forest-inventory group of the CFS in Ottawa. The CIFFC and the CFS appear to be the appropriate agencies to compile national wildland fire statistics.

C. Historical Record

This issue focuses on the accuracy, validity, and completeness of the historical record of fires in Canada. The quality of the data must be evaluated before making pronouncements concerning long-term trends in wildland fire activity. This issue comprises three elements: the cultural context, case studies, and stand-age analyses.

Canadian Cultural Context—European settlers in Canada were not used to the level of natural fire experienced in North America. Early writings, art, and photographs often describe large fires. They imply high fire frequencies and short fire-return intervals. Settlers did not realize the key ecological role played by fire in the new world; fire was seen as negative, destructive, and undesirable.

Political and social influences shaped fire management in the first half of this century. From 1900 to 1930, the federal government managed Canada's forests with a focus on forest reserves, including parks and industrial forests. Although only rudimentary techniques were available for fire suppression early in this century, agencies were able to achieve some degree of success. The depression limited government funding in the 1930s. World War II followed and only limited resources were available for fire control. After World War II, mechanized equipment was adapted to fire suppression, which notably increased suppression effectiveness. During this period, the area protected from fire gradually moved northward.

Case Studies—Canada and the United States experienced similar social, technological, and economic developments during this century. In the United States, these developments resulted in high fire activity during the first third of the century, a substantial decrease durng the middle third, and relatively low levels during the last third. Notable changes in the fire activity can be related to important socio-economic events and developments. In Canada, the fire record indicates a slight decrease in area burned through the middle of the century and a significant increase since 1970; this trend cannot be related to socio-economic developments. The marked differences in what should be parallel fire-activity trends in Canada and the United States suggest that the Canadian record may be substantially incomplete. A handful of case studies imply the magnitude of what may be missing in the Canadian fire record:

- 1919—There is evidence of an 8 million ha fire straddling the Alberta–Saskatchewan border, north of Lloydminster; official statistics indicate that the total area burned for Canada in that year was 3 million ha.
- 1942—There is evidence of a single fire north of Fort Nelson, B.C., that burned 1 million ha.; 1 million ha burned was reported for Canada.
- 1950—A fire that started north of Fort St. John, B.C., and straddled the Alberta border was 245 km long (1.45 million ha) and is not in the official record.

In recent years, limited-suppression fires comprise 30% to 70% of the total area burned in Canada.

- 1981—the fourth worst fire-year on record—Many large fires were recorded that were deliberately not suppressed; one fire in the Northwest Territories was larger than 1 million ha.
- 1989—the worst year on record—In Manitoba, an outbreak of fire overwhelmed the capability of fire organization to respond; 3.5 million ha burned.

Stand-Age Analysis—An analysis of stand ages in the Alberta forest inventory shows that during the 200 years before 1900, Alberta forests were subjected to 3.2% of the area burned annually—roughly a 30-year fire cycle. Although this provides a limited basis for comparison, area burned during the last 2 decades falls within this range. The long-term average area burned in Canada may be on the order of 1.0% to 1.3% per year, or a 75- to 100-year fire-return cycle.

D. Fire-Activity Trends

One objective of the workshop is to determine actual fire-activity trends in Canada. All else flows from the answer to this question. Previous discussions have demonstrated that the historical record will be of little assistance.

Evidence for the actual trend of fire activity in Canada is ambiguous and inconclusive. The historical record is fatally compromised by the absence of data on unsuppressed fires before the mid-1970s. It is not clear that current fire activity levels actually differ from natural background levels. One could argue that given current technology, we should be doing much better than natural background levels and, therefore, fire-management effectiveness must be getting worse. Although intuitively appealing, no quantitative basis exists for defending such an argument.

Should the climate change as projected, however, the potential impact of increasing fire activity is considerable. We must begin thinking about the issue in its early stages. We should establish indicators of the point at which we will have crossed the invisible threshold of changing climate and fire regimes as we progress along the imperceptible slope. The long-term effects of continuing on or changing our present course of action, must be determined. For, like a great ship, the systems in question will not respond quickly to our commands. If we must wait until the evidence is irrefutable, we will probably fail in our efforts to set things right.

Looking in a rear-view mirror is not the best way to drive a car around a curve, but such is the situation confronting us. The science and underlying processes relating climate and fire regimes must be understood because in a changing environment projections based on hindsight are not very useful. Further, with 100-year cycles, the time to begin planning sustainable forestry is now. How we establish and manage forest ecosystems today will affect their ultimate success under a changed fire regime. This is truly a new challenge for foresters; climate can no longer be considered constant. Innovative ways of managing ecosystems under variable climatic conditions must be developed.

The fundamental importance of determining the fire-activity trend remains. We should, therefore, consider how it will be resolved. A national steering committee will be needed to organize the effort, prioritize tasks, establish milestones, and evaluate progress. This group will need a mandate to acquire and manage the funds necessary to carry out the work. The issue is scientifically challenging and logistically daunting. We will have to form partnerships among stakeholders, dissolve institutional barriers, pool resources, and coordinate efforts to resolve this nationally-important question.

II. Explaining Fire-Activity Trends

Before considering appropriate responses to fire-activity trends, the probable causes must be known. There are three issues: weather and climate, social context, and fire management.

Issues

E. Weather and Climate

Although a warming trend has been observed in western Canada in the 1980s, is this the result of weather variability, climate variability, or an early symptom of climate change? It is important to distinguish between science and speculation. Because the concept of climate variability is ambiguous and difficult to define, this report focuses on the ends of the spectrum—weather variability and climate change.

Weather Variability—Canadian annual average temperature data for this century show an extended cooling trend from about 1940 to the early 1970s, followed by a period of increasing temperature. Data for the Canadian boreal forest shows a small increase in average annual temperature for the northeastern boreal region and a larger average increase in the northwestern boreal region. Boreal temperature increases have been highest in the winter and spring, moderate in the summer, and lowest in the fall.

Annual surface temperature trends in North America show the largest temperature increases in the centre of the continent, extending to the Yukon and the Northwest Territories. The largest departures from long-term normals occur in the winter and spring. From 1961 to 1990, summer warming was modest in the center of the continent. In autumn, average temperatures in Canada were slightly cooler than the long-term average.

Summer (May to September) warming has become more pronounced during each successive decade since the 1950s. The increases are concentrated in the early summer months—May, June, and early July. In the 1990s, the late summer was actually cooler than the long-term average in central Canada, although the 1980s were slightly warmer than average.

There have been no significant precipitation trends during the past 50 years for Canada as a whole, although the data suggest a slight increase. It has been suggested, however, that the increased temperature has more than offset the precipitation increase—through increased evapotranspiration which reduced soil moisture.

The Canadian Forest Fire Danger Rating System correlates reasonably well with various aspects of daily fire activity. However, correlating fire weather with longer-term fire business has proven more elusive. One approach might be detailed time-series analyses. Another would be to develop a fire-severity model for longer-term fire-severity processes.

There is a good correlation between entrenched stable high-pressure systems over central North America and severe fire activity. An analysis shows an increasing occurrence of these ridges in the central continent. An analysis of five recent extreme fire years and five benign years showed a strong relationship with the existence of a 50 kPa-height anomaly during extreme fire years. An analysis of data between 1945 and 1995 shows a steady increase in the occurrence of the 50 kPa-height anomaly.

A preliminary analysis of occurrences of lightning fires in Ontario suggests that apparently the number has not increased since 1960.

Climate Change—Nine mass extinctions have taken place in global history—roughly every 33 million years. Humans first appeared during the Pliocene era (2 to 6 million years BP), when most of the planet was unglaciated and temperatures were 3 to 4°C warmer than at present. During the Pleistocene era (2 million years BP to now), 16 glaciation events have taken place. These may be related to other periodicities of the earth's orbit, such as axis tilt and the ecliptic. All of these events were also related to significant changes in global climate. The paleoclimatological record shows a wide variability in average global temperature during the last million years.

During the Younger Dryas period (10 500 years BP), there was a very rapid cooling over a relatively short period of time (500 years). The rate of climate change during this period is believed to have been equivalent to the currently observed rate of global temperature change. Temperatures during the Holocene Maximum (7 000 to 3 500 years BP) were notably higher than those in earlier and subsequent periods. During the Medieval Optimum warming period (AD 1 000 to 1 300), Greenland was colonized, the Arctic ice sheet retreated, and there was a major expansion of European agriculture. During the “Little Ice Age” (AD 1 400 to 1 900), annual temperature over large regions of the northern hemisphere were less than 1°C cooler than today. During the 20th century, the global temperature shows a steady increase from the historic mean.

In general, many major climatic shifts have occurred throughout history—all have had significant impacts on vegetation and humans. Long-term climate change is a fact—not a subject for debate. There is great uncertainty, however, about cause and effect.

Trace gases in the atmosphere are necessary to maintain life on earth. From a climate perspective, without these gases, the average earth temperature would be –18°C, instead of the current 15°C. Data from Antarctic ice cores extending back more than 200 000 years show that concentrations of methane (CH_4) and carbon dioxide (CO_2) are always strongly and positively correlated with average temperature. This extends through periods unaffected by anthropogenic greenhouse gas emissions.

During the past half century, atmospheric greenhouse gases have increased significantly. Although most of the increase is due to burning fossil fuels, biomass burning and changing land uses are now believed to account for 40% of total global CO_2 emissions. CH_4, CO_2, nitrous oxides (NO_x) and chlorinated fluorocarbons (CFCs) have all shown large increases in concentrations since the 1950s.

Unless limited by major human intervention, CO_2 will increase one to two times and CH_4 will increase three to six times over pre-industrial levels by 2100. Warming will be non-uniform—greatest at higher latitudes and most pronounced in winter and spring. Some models suggest an increase in intense precipitation, but greater frequency of dry days and longer dry periods. This has implications for increased forest fire severity and area burned.

An important difficulty of climate-change research is that variables produced by Global Circulation Models (GCMs), such as temperature, have limited use for wildland-fire research. There is also a fundamental mismatch between the scale of climate change (continental, annual) and fire behavior (site-specific, hourly). Synoptic-scale (regional, weekly) fire-severity processors are needed to significantly advance this line of research. They would allow analyses to focus on extreme situations that are pivotal to overall wildland fire activity. They would also be useful to examine the frequency of extreme events.

Peatlands may become a key issue relative to changing fire regimes. Today, they are carbon sinks that burn only infrequently. However, peatlands might burn more frequently and deeply if ground water levels drop and release their carbon stores. Peatlands could move from a net sink to a net source of carbon, thereby shifting the national carbon budget.

The social context may affect our ability to respond to increasing fire regimes. Agencies rely heavily on student labour during the summer fire season. If the fire season advances by a few weeks, this labour force will not be available. Agencies will have to find some other way to manage early-season fires.

Recently observed warming in western Canada is consistent with the projections of GCMs. The current research emphasis is on developing regional climate models that are nested within GCMs and that provide many more detailed spatial outputs for specific regions than existing GCMs. These are an essential precursor to reducing the error range for climate-change projections.

In one study, projected temperature increases were assigned to weather stations. These were used to calculate seasonal severity ratings for Canada and Siberia (based on a simple mathematical transformation of the daily Fire-Weather Index; not a true fire-severity processor). Significant increases were found in western Canada; increases in Siberia were even more pronounced. However, the total increase in fire activity predited by climate-change projections is smaller than the apparent recent fireactivity increase, indicating that climate change—which is in an initial phase—is unlikely to be the sole cause of the apparent trend.

Although forests and fire regimes respond to climate, the response mechanisms are not understood. At what point will climate change favor one species over another? Ecosystem components respond to climate signals with different time lags which are poorly understood. It will be difficult to convert knowledge in this area to management guidelines.

F. Social Context

The social context considers the conditions imposed on fire management by Canadian society. There are three aspects to this issue: population and forest activity, government financing, and social costs and benefits.

Population and Forest Activity—Fifty-five percent of all wildland fires in Canada are caused by human activity. If the population of Canada and the number of wildland fires are compared, the two trends seem to parallel each other during the past 4 decades. This suggests the possibility but does not support a conclusion that the two are related. Several rationales can be applied to this issue.

- As population increases, more people spend time in forested areas, thereby increasing the risk of ignition.
- If leisure time and disposable income increase, people have more time and means for recreational activities.
- As more areas are opened, harvested or developed, more roads are built and the public has greater access to remote areas.
- Migration to suburban and rural housing increases the risk of wildland/urban interface fires.
- The risk of accidental fires increases as forest harvesting increases.

However, the actual impact of the human factor on the trend of fire activity is ambiguous. Since human-caused fires account for only 15% of the total area burned in Canada, changing patterns of human activity should not have a major influence on the total area burned. In fact, there are several counter-arguments to the preceding list.

- More people in the forest increases the chance of detecting a fire earlier, thereby reducing the final area burned.
- The number of forest workers is decreasing with increasing mechanization.
- Current harvest methods tend to leave less slash (residue) in the forest, thereby reducing the fire hazard in logged areas.
- Improvements to mechanized equipment have significantly reduced the number of fires caused by sparks from equipment exhaust.

Government Financing—Throughout Canada, governments are attempting to reduce budget deficits. Simultaneously, there is a consensus among Canadians that the tax burden is already high enough so that tax increases are generally not considered a viable option. Thus, competition among agencies for a share of a dwindling public purse is increasing. Fire management must compete with other essential functions of government such as education, welfare, and health care to obtain the funds necessary to carry out its mandate. The prospect of a potential fire disaster at an unknown and distant place at some undefined future time is less compelling than a real present-day urban hospital or school closure that has to be explained to voters. These are difficult social choices.

Meanwhile, values at risk from wildland fire are increasing. More homes are being built in the wildland/urban interface, placing extra burdens on fire management agencies. The value of standing- and growing-wood fibre continues to increase, leading the forest industry to demand increased protection of the resource. This is coupled with the need to ensure continuity of wood supplies to industries that form the basis of the economies of many rural Canadian communities. In some regions, there is little or no slack left in the wood supply. It is totally committed for the indefinite future; current losses cannot be allowed to increase.

In addition, the cost of people and equipment needed to manage fire is also rising. Computers are being increasingly used to optimize resource allocation—in essence, to do more with less. Mechanized equipment greatly increases suppression productivity. Aircraft and helicopters move people more rapidly and fight fire more effectively. However, full automation in the fire industry is not possible because, in the final analysis, a fire can only be extinguished by a crew of people on the site. More importantly, modern technology is expensive. An air-tanker costs thousands of dollars per hour to operate; a helicopter to transport initial attack crews is not far behind.

How should fire management respond? Recognizing the current climate of government finances, fire management must develop analytical methods that will demonstrate the consequences of alternative budgets. This cannot be done satisfactorily today. An economic-analysis system could be used to develop factually-based, realistic scenarios that would form the basis of discussion and negotiation with finance ministries. Financial decisions will continue to be part of a broader social mosaic, but fire management would be better able to quantitatively measure its usefulness to Canadian society. Until this is possible, fire management will continue to be disadvantaged by arguments founded on little more than the vague fear of potential, future fire disasters.

Social Costs and Benefits—The preceding discussion leads to a broader issue of social costs and benefits. In the tradition of government-sponsored management of Canada's forests, some questions have seldom been asked. What segments of Canadian society benefit from fire management? Who pays and who should pay? These questions address the fundamental reasons for the existence of fire management.

In the pre-suppression era, whole communities were destroyed by fire, with considerable loss of life. Clearly, community protection, and public health and safety are key contributions of fire management to the social mosaic. From another perspective, previous discussions suggest that natural fire-return intervals are so short as to preclude sustainable forest management in some Canadian forests. This certainly would affect the $20-billion forest industry that employs 1.2 million Canadians and supports many communities. The forest sector contributes more to the balance of trade than any other sector of the economy. Canada clearly receives substantial economic benefits from fire management.

The case for non-economic values is ambiguous and difficult to quantify. Fires emit particulates and trace gases to the atmosphere but as a natural source, they are not included in international conventions. Fires affect wildlife populations, but the effects tend to be positive except for vast fires. Fires are a natural part of most ecosystems in Canada; its ecological effects tend to be viewed as positive. Fire also benefits forest management by preparing logged-over sites for planting. Most noneconomic perspectives view fire as more beneficial than harmful. Generally, fire management generates benefits by using prescribed fires to accomplish various land-management objectives efficiently .

Traditionally, the cost of fire management has been borne by Canadian taxpayers. Funding typically comes from general revenues. Often, there is no link to the value of resources and infrastructures that are being protected or to land-management objectives. Sometimes, fire management is closely integrated within the ministry charged with managing the forest. In some cases, however, fire management is provided by an autonomous agency. All too often, one group may add value to the forest resource without considering the need to protect that value from fire.

G. Fire Management

Has fire management affected the apparent fire-activity trend? There are three aspects to this issue: fire-management policies, budgets and resources, and suppression success.

Fire-Management Policies—Have changing fire-management policies affected the trend of fire activity in Canada? In Canada, the debate between excluding fire and allowing it to assume a more natural role in managing the landscape has never reached the intensity encountered in the United States. In northern Canada, enormous expenditures for fire control were not made because of limited values at risk. Limited infrastructure and supplies to support fire control reinforced this decision. Further, the available people and equipment were simply inadequate to deal with a problem of such magnitude. Regardless of the reasons, some fires in northern Canada have always been allowed to run their natural courses. The fire policies of many agencies now formally recognize this reality. Suppression costs should be proportional to the values at risk and fire should play a more natural role in ecosystem management.

Two other elements of fire policy have changed over the decades. First, protection-zone boundaries have gradually migrated northward. This should have had the effect of reducing the total area burned in Canada. Second, since the mid-1970s it has been politically acceptable to report the actual area burned for fires in the "modified suppression" category. Before this time, they were not reported or were reported as "spots." This should have resulted in a significant increase in the reported area burned, but not the actual area.

Budgets and Resources—Has fire-management effectiveness been reduced by reductions to pre-suppression budgets? Most agencies are experiencing budget reductions, which are substantial in some cases. Agencies have reduced crew sizes and numbers of crews, closed bases, reduced equipment caches, shortened aircraft contracts, and centralized operations to operate more efficiently with fewer resources. Organizational flexibility has been reduced somewhat and there are fewer reserves for extreme situations, multiple-fire starts, or system breakdown. Much organizational experience and expertise has been lost due to widespread downsizing of work forces. High turnover rates lead to loss of corporate knowledge and memory, reduced crew fitness and motivation, and ultimately reduced productivity. However, there is no unambiguous, publicly documented evidence that the reductions have resulted in increased area burned.

It is generally believed that there is an inverse relationship between pre-suppression and suppression budgets—reductions to the former inevitably lead to increases in the latter. There have been bold political pronouncements that fire management will operate in the same manner as other government functions—on a fixed budget. Such decisions have proven untenable, however, when a community or a large corporation's timber supply is threatened. Conversely, when the fire budgets of Canadian agencies are collectively examined, some allocate 90% of their total expenditures to pre-suppression whereas others allocate 90% to suppression. Is this simply an accounting problem or do agencies differ fundamentally with respect to classifying expenditures? Given this level of variation, it will prove difficult to establish a relationship between pre-suppression and suppression expenditures.

Using Ontario as a case study, area burned shows great year-to-year variation since 1973—some severe years and many quiet years. In Ontario, the annual number of fires in the Intensive Protection Zone is high and variable, but the percent of the total area of the zone burned is consistently low. The opposite is true for the Extensive Protection Zone—few fires and large area burned. Using initial-attack response time as an indicator of the level of protection, Ontario data for 1976 to 1994 shows no change to a slight improvement.

Suppression Success—Has successful fire suppression in the past contributed to increased forest fuel levels and/or aging forests and consequent increased fire severity? This would be consistent with the theory that a fire regime is destined to have a given amount of fire and that keeping fire artificially low only postpones the day until a balance is reestablished. However, hard evidence to support this theory is difficult to extract from the available data. Certainly, specific instances can be found, such as the great 1988 fires in Yellowstone National Park, which were partially fuelled by large areas of over-mature lodgepole pine. Similarly, over-mature brush in southern California is known to burn with higher intensities than younger material. The pattern of fire-size distributions along the California (intensive suppression)–Mexico (extensive suppression) border is striking.

In Canada, evidence of the suppression effect can be inferred from an increasing forest age-class distribution in Canada's western national parks. Yet outside the parks, in commercial forests, the forest industry harvests somewhat more area than is burned on average. This would decrease the age-class distribution by more than the fire-suppression increase. Some studies show that current fire-return intervals in Canada are longer than those before active fire suppression. But these are insufficient to support the conclusion that fuels, on average, have built up to higher-than-normal levels, resulting in more intense fires and more area burned.

Analyses of Canadian fire regimes face fundamental difficulties—they have yet to be defined and measured. No generally accepted yardstick is available as a basis for comparison. To date, there have been site-specific fire-history studies, analyses of fire- return intervals, stand-age distribution studies, and lake-core sediment sampling studies. However, only one study has been undertaken on a national scale—production of a GIS-based map of all fires greater than 200 ha in Canada during the 1980s. This is a key knowledge gap in our quest to analyze and compare fire regimes over time and space.

III. Potential Impacts of Increasing Fire Regimes

The third step in responding to increasing fire regimes in Canada is a review of the nature and importance of the likely impacts. This can be viewed as the magnitude of the external impacts of wildland fire on other systems. This section is divided into five issues: ecosystems, the environment, the forest sector, fire management, and society.

Issues

H. Ecosystems

There are many potential ecological impacts of escalating fire regimes, including ecosystem migration and expansion, altered landscape patterns, shifts in species composition, changed wildlife populations, and modified ecosystem processes. Understanding the many relations between wildland fire, ecosystem processes, and land management is critical.

Plant Communities—Projection of vegetation trends in a doubled CO_2 environment varies, depending on which global climate-change model is used. The general trend is for the northward migration and expansion in total area of prairies and grasslands. Most forest ecosystems will also migrate northward; the boreal forest will also likely expand in total area. But global models do not represent medium- to fine-scale vegetative processes, such as changes in photosynthesis, respiration, and water uptake, that may have feedback linkages to climate. These less-understood factors greatly complicate analyses which generate scientific debate and confuse policy choices that must be made.

The natural rate of migration of most ecosystems is much slower than the projected transition period of 100 years. Thus, natural ecosystems are likely to be out of balance with changed climatic environments for considerable time. Fire may be a catalyst on a grand scale by speeding ecosystem reaction, migration, and adaptation to climate change. This would be most noticeable in the expansion of grasslands.

The Canadian landscape is a mosaic of fire scars. A natural regime yields a higher proportion of larger fires that tend to blend into each other with few unburned patches. Fire management results in a higher proportion of smaller fires with areas that have not burned for a long time where fire-intolerant species become established. An increasing fire regime would shift the burned-area pattern towards a larger size-class distribution.

Most Canadian forests originated from fire and their species composition depends on the fire-return interval. An increasing fire regime will tend to shift the composition of forest communities towards pioneer species that are tolerant of and adapted to or dependant on fire. Fire-sensitive species or those that grow beneath the canopy of a pioneer species will tend to be disadvantaged under a regime of increased fire frequency.

Wildlife—Fire tends to benefit wildlife populations. It opens the forest canopy, creates edges that are favourable habitats, and rejuvenates the production of nutritious browse. More fire will generally have a positive impact on wildlife. There are two exceptions. First, species that are dependent on old growth will be negatively affected as more fire will tend to reduce old growth, except where overstory trees are large enough to resist damage from all but the most intense fires. Second, larger and more intense fires will create less edge and fewer unburnt islands thereby reducing the amount of favourable habitat.

Insects are a major disturbance in Canadian forests. The spruce budworm and mountain pine beetle can defoliate large areas in just a few years. For 10 to 20 years afterwards, these dead trees constitute an extreme hazard—primed to burn intensely under the right weather conditions. Conversely, sub-lethal surface fires can weaken overstory trees, thereby increasing their susceptibility to insect attack. It is probable that climate change will result in more and different types of forest insect damage in Canada. This could create a positive feedback loop between the two disturbances so that increasing fire and insects may result in a greater combined effect than would be generated by either alone. Although interactions between ecosystems, insects, and fire have been studied, little is known about the combined response of all three factors.

Ecosystem Processes—Fire is one of many influences on forest health. On one hand, an increased fire regime will tend to result in younger, more vigorous forests. On the other, fire will tend to reduce total growth and yield, which is maximized in mature forests, and damage or weaken overstory trees that are not killed outright. Little is known about relations between fire and forest health so that the overall balance between positive and negative effects cannot be determined at the present time.

Fire tends to foster average levels of biodiversity. Preliminary research suggests that fire increases the diversity of simple ecosystems and reduces the diversity of complex ecosystems. It is not known whether or not this holds true at all scales of biodiversity from genes, to individuals and communities, to ecosystems and landscapes.

The carbon budget is an emerging field of research. Canada's forests represent a vast carbon sink. The magnitude of this sink is sufficient to yield an overall surplus of carbon storage over emissions for Canada. However, during extreme fire years such as 1989 and 1995, forest fires emit sufficient carbon to the atmosphere to reverse the national balance to a net source. Thus, wildland fire can be a major national source of atmospheric carbon and trace gases. As a non-anthropogenic source, however, wildland fire is not currently factored into the carbon budget. It is ironic that current levels of fire activity are probably less than those before European settlement. The problem is that emissions from wildland fires increase high levels from anthropogenic sources.

I. Environment

The focus of this issue is on the impacts of wildland fire on the physical environment. These can range from local, through regional, to global scales. There are two aspects to this issue: the atmosphere and geosystems.

Atmosphere—The emission and dispersion of smoke is a highly visible by-product of wildland fires. It affects atmospheric visibility, with impacts ranging from obscuring vistas to causing highway fatalities. In several cases, smoke has forced international airports to close. Smoke adversely affects public health—particularly the health of the elderly and persons with breathing difficulties. Smoke from wildland fires contains extremely minute quantities of dioxins and furans. Although not problematic on a fire-by-fire basis, fires contribute to the total national atmospheric loading.

Smoke management to mitigate the adverse impacts of fire emissions has been a high-profile issue in the United States for more than 2 decades. The issue has received some attention in Canada, primarily on the west coast. Smoke management intervenes at several stages. Optimum burning conditions can reduce smoke production by up to one-third. Rapidly igniting large areas enhances plume development, which dilutes smoke. Sufficient surface wind avoids inversions which trap smoke in valleys. Appropriate wind directions disperse smoke over unpopulated areas. Finally, information systems that monitor multiple, simultaneous fires can be used to limit the total daily production of smoke in an airshed. All of these techniques relate only to prescribed fires which can be controlled by management. Little can be done to manage smoke from wildfires.

On a larger scale, fire is part of a positive feedback loop to the atmosphere of sufficient magnitude to potentially raise the final temperature of the warmer climate. In addition to particulates which intercept solar radiation, fires also produce significant quantities of trace gases which augment climate change. Although highly visible, particulates are not the primary problem. Smoke plumes rarely reach the stratosphere and rain readily washes particulates out of the atmosphere. Trace gases, which ultimately mix with the atmosphere at all levels, are much more problematic.

Geosystems—The effects of fire on water quality are generally deleterious. Fires reduce or eliminate the overstory which, in turn, reduces interception and storage in a watershed. This increases peak runoff but decreases total yield.

Soil may be washed into reservoirs which reduces their capacities to store water. Silted water must also be treated for domestic and industrial uses.

Wildland fires that remove the protective canopy and litter generally lead to soil erosion on sloping sites. Therefore, grass is often seeded on hilly sites immediately after a fire to mitigate potential erosion.

There is another important potential feedback loop between climate change and wildland fire. If peat fires become more severe, permafrost layers could melt with attendant negative effects during the climatic transition period.

J. Fire Management

This issue deals with the extent to which increasing fire regimes will affect fire management and its ability to fulfil its dual mandate to protect the wood resource and communities. There are two aspects of this issue: system behavior and management strategies.

System Behavior—An emerging theory of complex systems provides insights into the potential future behavior of fire management systems. Complex systems exist along the boundary between order and chaos. The characteristics of such systems include thousands to millions of components, abrupt transitions and state changes, and self-ordering.

In engineering and systems, some changes are sudden and irreversible (e.g. a hydraulic line fails, a bridge collapses, a computer network malfunctions). In physics, phase transition (e.g. the change from ice to water to steam) describes a similar process. The mathematics of catastrophe theory focuses on non-linear, irreversible responses. Biological systems often exhibit similar behavior—the collapse of a fishery or dominance by one species over another. The same applies to socio-economic systems—an economy swings from boom to bust or a single product dominates a market (e.g. VHS vs. Beta). In each case, a small input at an early stage causes a greatly disproportionate change in subsequent output and the system comes to equilibrium in a different state.

This behavior applies directly to fire management. Lightning is accompanied by rain or it is not; a surface fire jumps into or drops out of the crowns; a fire is either extinguished at initial attack or it escapes. Of the escapes, the 1.5% of all fires that exceed 1 000 ha in size account for 93% of the total area burned in Canada. Each escaped fire is a non-linear consequence of suppression failure; a grouping of many suppression failures can cause the fire-management system to fail.

A budget can be reduced a bit and fire management will allocate its resources more efficiently with few noticeable effects. Further reductions eliminate system redundancy and reserves; again, probably without major effects. The budget can be trimmed a bit more and the number of crews and their size will be reduced. The toll from scrambling and constant pressure to maintain traditional levels of effectiveness tends to be on employees rather than on organizational outputs. Cut a bit more, and an agency will rely more on external resources (e.g. 80% self-sufficiency rather than 90%). However, a day eventually comes when an extreme fire load causes an exceptional number of fires to escape initial attack; these make all the difference.

Agencies cannot operate in a crisis mode indefinitely without risking some type of organizational breakdown. Some agencies may be operating too close to the edge. As agencies slide down the slippery slope of decreasing resources, they are approaching a cliff blindly; the cost of finding the edge may be very high.

The level of fire activity that is acceptable to the general public is not known. Fire-management budgets may be forced upward if society decides the consequences of increased fire regimes are unacceptable. Compounding the problem, the cost of maintaining artificially low fire activity may increase exponentially over time—as natural processes exert increasing pressure to return a fire regime to a natural balance. This exacerbates the situation.

Fire-Management Strategies—Perhaps the most important fire-management strategy likely to emerge in the coming decades will be a pro-active approach to issues. In today's social context, reacting to issues rather than anticipating and planning for them usually results in others controlling the agenda and dictating the outcome. Fire management will have to prove its worth when competing for a share of the public purse. Stakeholders will have to be involved in developing fire-management policies. Fire management will have to be incorporated into sustainable forest management. The onus is on the fire profession, which understands the consequences of inaction and reductions better than anyone else, to make a convincing case. The cost of discovering, after the fact, that more should have been done might be terribly high.

In the search for ways to maintain current levels of protection with reduced resources, fire-management agencies are looking increasingly to pre-suppression activities, such as prevention, detection, fuel management, and prescribed burning for possible solutions. This may result from a growing realization that these functions have historically tended to be less important. Perhaps a solution may be found in something that has not been fully explored.

Increased prevention could reduce the number of human-caused fires, but collectively these account for only 15% of the total area burned in Canada, leaving relatively little room for improvement. Also, no work has been done in Canada to determine the economically efficient level of prevention; only one such study has been published in the United States. Increased detection capability is also considered from time to time, but today's detection standards are already high enough. It is hard to see how improvements in that function could make a substantial contribution. Increased fuel management is being considered, but economic analyses in the United States suggests that this technique is cost effective mainly in high-value areas. Costs and logistics are prohibitive over large regions.

Increased use of prescribed fire has also been mentioned. This can be applied to large regions, but the liability associated with potential escaped fires can substantially increase the cost of preparing and executing a burn. Also, prescribed fire has a history of use following harvesting in Canada; this will probably continue. The use of prescribed fire in ecosystems, such as the boreal forest, that tend towards stand-replacing fires is unlikely to increase.

Finally, there is the issue of public acceptance. Negative impacts of a wildfire are attributed to nature; those from a prescribed fire are attributed to the agency that started it. Public acceptance is not an issue in areas where prescribed burning has been carried out for a century or more. In Canada, however, the European view that wildland fire is "bad" still holds considerable sway.

Fire management agencies will have to address increased fire-fighter stress. Fewer crews mean more frequent response with consequent risk of "burn-out." More responses also mean increased exposure to smoke, risk of injury, and other hazards associated with fire fighting. Smaller crews mean that greater efforts will be needed to contain a fire. Fire-fighters will be expected to be more knowledgable in the future and high staff turnovers will exacerbate the situation.

Interagency resource sharing will probably increase. This has been particularly useful for filling the gap between a reasonable agency-planning level (e.g. the ninetieth percentile of fire activity) and the absolute peak. No agency or nation can afford the resources necessary to manage extreme fire situations. Yet there is a limit to the extent to which resources sharing can be profitably employed. Every agency must have an adequate number of initial-attack crews to handle routine and above-average fire loads. Relying too heavily on outside support for this function results in additional escaped fires, substantially increased area burned, and much higher overall costs.

Interagency sharing has been made possible through establishment of the Canadian Interagency Forest Fire Center (CIFFC) which administers the Mutual Aid Resources Sharing Agreement. CIFFC facilitates resource sharing and information exchanges among agencies. Another key element has been the development of national equipment standards. Any hose from any agency will connect to any pump from any other agency in Canada—a seemingly simple yet crucial development. National training standards are currently being developed to enhance the exchange of suppression personnel.

Fire management can probably become more efficient marginally, but probably not substantially. A crew can only be dispatched to one fire at a time. It takes a fixed amount of work to overcome the energy produced by a fire. Regardless of how efficient we become at pre-positioning, there will always be substantial uncertainty about where and when the next fire will occur. Equipment will still break down—the more complicated it is, the more likely it is to break down. Lightning fires will still occur in clusters that can overwhelm any organization. One area of potential cost savings to fire management involves better knowledge of when resources will not be needed; they can then be temporarily used for other purposes. The best long-range strategy is to objectively quantify how much fire management is appropriate for each region and to have fire-management policies that reflect the consensus of stakeholders.

K. Forest Industry

This issue is concerned with the long-term viability of the forest industry—a key component of the Canadian economy. The forest industry depends on a constant supply of wood.

Wood Supply—If fire regimes increase, wood supplies will likely be reduced in quantity and quality. Less total wood will be available and the amount of cull in standing timber will increase. Stands may have to be cut on shorter rotations, which will reduce the amount of higher-quality wood in mature stands. A higher proportion of harvested wood will come from lower-quality salvage cutting. In addition, processing plants that are already in place will not be able to follow migrating forest ecosytems. They will have to either process different species or close their operations. There is general agreement about such statements, but it is not currently possible to quantify the effects.

Harvesting costs will also increase. Wood will have to be transported farther as mills harvest from increasingly distant sources. The fixed cost of establishing a cut will have to be written off against a lower volume of wood. The cost per cubic metre harvested will likely increase as smaller trees are processed. Counteracting these trends, a reduced wood supply should increase the value of the resource so that returns on investments may not be significantly affected.

These arguments lead to an important question—are current levels of area burned properly incorporated into forest growth calculations across Canada? Although all agencies reduce growth to account for fire losses, are these adjustments based on pre-1980 fire-activity levels or those currently being reported? As harvesting moves north, the impact of modified-response fires becomes increasingly significant. Further, Canada's forests cannot be sustainably managed at the limits of growth. Given the considerable unknowns and extreme peaks of fire activity, some buffering is essential to the long-term sustainability of Canada's forest industry.

L. Social Systems

This issue is concerned with how wildland fire will affect people and communities—a fundamental concern of governments at all levels. There are two aspects to this issue: socio-economic impacts and social conflicts.

Socio-economic Impacts—Perhaps the most evident impact will be an increase in the number of wildland/urban interface fires. These will result in more high-profile community evacuations and attendant media interest. These will also involve increased threats to public health and safety. In all likelihood, destruction of homes, infrastructure, and other property will increase proportionally. This may ultimately lead to increased regulation of development in areas subject to significant risk from wildfires. It will also become increasingly important to establish cross-training between urban and wildland firefighters.

Other social impacts, although no less real, will not be as prominent due to indirect linkages to fire. Employment and tax revenues may be reduced because of reduced harvesting. Tourism and recreation may be reduced, but this is not as clear. For example, after the massive 1988 fires in Yellowstone National Park, tourism actually increased because people were curious to see what had happened.

Aboriginal activities associated with traditional values, such as trapping, and hunting for food, and locations including sacred sites may be affected. The ultimate consequences are unclear, however. Wildlife is generally enhanced by small, patchy fires but not by massive fires that may alter traditional migration routes and habitats on a large scale.

Social Conflicts—Conflicts between fire management and other social functions may prove more problematic than the socio-economic consequences of fire. Decreases in budgets coupled with increases in values at risk guarantee increased conflicts between resource protection and protection of property. Cases have been documented where limited suppression resources forced large areas of wood resource to be abandoned to save a community—not an easy choice. Increasing non-timber values will only serve to exacerbate such situations, which will probably become increasingly common.

The delineation of protection-zone boundaries will be scrutinized more closely by more stakeholders than previously. Case-by-case decisions of full vs. modified suppression will have to become rigorously and legally defendable. Currently, no quantitative methods exist to support such decisions. Development of decision-support systems to quantitatively analyze these fundamentally important alternatives will be essential.

Increased social conflicts must inevitably lead to increased political influence on fire-management decision making. This is simply part of the process of governing a democratic society. In such cases, it will be necessary to select alternatives based on quantitative and defendable criteria, which stakeholders have previously agreed to by consensus. The same rationale applies to fire-management budgeting. Fear will no longer work. Fire management agencies will have to demonstrate a relationship between budget allocations and fire-management outputs.

IV. Possible Responses

Overarching the many possible responses to increasing fire regimes, a clear vision of desired future forests and ecosystems is needed. What sort of balance shall we strike between producing wood fibre and allowing fire to assume a natural role in managing the landscape? To what extent should we mitigate the negative effects of fire in the light of competing social imperatives? We must know where we want to go before we can select a path to our destination. Possible responses to fire activity trends in Canada can be grouped into three categories: government, private industry, and research.

M. Government

How should governments and fire agencies respond to the impacts of global climate change and consequent increasing fire regimes in Canada? First, fundamental differences in the mandates of different levels of government must be recognized. The focus of the federal government is on fire research, interprovincial activities, and international issues. Provincial governments have jurisdiction over fire policy while firemanagement agencies are responsible for fire management. Local governments focus on public health and safety, and property protection. This issue has three aspects: management perspective on global warming, the policy dilemma, and government response.

Fire-Management Perspective on Global Warming

In fire management's view, there is growing evidence that significant climate change is happening. Recent years have been the warmest this century. The national area burned has more than doubled during the past 20 years. The average number of reported fires has increased from 6 000 to 10 000 during the past 35 years in Canada.

Fire characteristics reflect climate change. Extreme fire seasons are occurring more frequently and are increasingly severe. More fires are escaping initial attack. Fire-management expenditures are increasing exponentially. Disruptions to infrastructure and social systems are increasing. This has led to reassessments of fire-exclusion policies and fire-management expenditure levels. Notwithstanding such reviews, fire-management agencies are still receiving demands for increased protection of the wood supply, wilderness areas, and infrastructure.

Policy Dilemma

Several policy issues were identified in a recent review of fire management in Saskatchewan:

- Should the provinces take responsibility for fire suppression?
- Who should pay for fire suppression?
- Who should manage fire-suppression resources—public or private agencies?
- What are the alternatives for program delivery?

Fire regimes and forest ecosystems evolve very slowly over time; fire management policies should not change with elections. Yet, it may be difficult for governments to take a long-term view of wildland fire, when faced with immediate events, such as hospital and school closures. Involving stakeholders might tend to shift fire policies from government-dependent short-term horizons to longer-term ones based on stakeholder needs.

Wildland fire overlaps two domains—resource management and emergency management. Yet wildland fire is not really quite part of either; it is often perceived as "someone else's problem." Resource management may be subject to across-the-board reductions including those for fire. But emergency management tends to be non-negotiable, thus increasing the conflict between resource management and infrastructure protection.

Larger cities that may be the most able to pay are generally the least threatened by wildland fire; forest communities, which are at greater risk, are often the least able to pay. If the forest industry pays part of the cost, they will surely emphasize protecting wood supplies, possibly to the detriment of other values.

The funding issue is exacerbated by the highly variable nature of fire coupled with the difficulty of carrying unused government funds from moderate to severe years. Another difficulty is that, in many cases, when there is a fire protection "tax," it goes directly into a general fund that is not linked to the fire-protection budget. The latter is, therefore, subject to across-the-board reductions.

Government Response

Governments should embrace the principles of ecosystem management. To do this, however, ecosystem management must be defined and the role of fire in it determined. A basis and rationale for reintroducing fire into the forest must be developed. Forest design within a landscape-management context should be considered. The use of fuel management and prescribed fire to manage the landscape should be fostered. These, particularly the latter, will require increased public education and understanding before being implemented.

Governments should develop methods and systems to analyze the economic and non-economic rationales for fire-management policies. The value of fire management to each province, as well as to the national economy and the welfare of all Canadians, should be demonstrable. Levels of protection, in terms of how much is enough and how much should be spent, should be more precisely defined. This should be a collaborative effort among fire-management agencies, the federal government, the forest industry, and universities.

Governments should collaborate with research to continue expanding our knowledge of fire and ability to predict outcomes, and to continue developing advanced fire-management systems. From a management perspective, the focus should be on problems of greatest economic benefit. For example, objective methods are needed to support decision making on potential large fires before they escape. Research should focus on short-term and immediate issues. The commercial potential of Canadian fire-management technology for export should also be promoted.

Fire-management agencies cannot survive in isolation. They must seek, establish, and utilize partnerships with the forest industry, forest residents, native groups, and other stakeholders in developing fire-management policies. This will require governments to address the perception that developing consensus and partnerships is not simply a process of "off-loading" responsibilities and costs to stakeholders. However, this will be challenging, given the conflicts inherent in wildland fire management.

Partners must understand the need to share the financial burden of implementing fire-management policies, based on the values that are protected. They must also understand the limits of what is physically possible and what is not. Partners must recognize the various strengths of different stakeholders and use these to collectively benefit all interested parties. Finally, given resource limitations, the fire community cannot afford to duplicate efforts.

The wildland/urban interface is a particularly important point of interaction. When wildland fire occurs there, it can have considerable impact on resource protection because infrastructure protection has a higher priority. Resources will always be found to protect communities in the path of a fire. Yet, most municipalities are as strapped for funds as their provincial counterparts; therefore, many are reluctant or unable to share the costs of fire suppression. On the other hand, some municipalities are responsible for fire suppression within their jurisdictions. Improved planning for managing wildland/urban interface fires will become increasingly important.

Universities and community colleges could play an important role in educating stakeholders to assist them in becoming more involved in setting fire policies. They could provide introductory courses in fire management, seminars, and correspondence courses tailored to the general public.

N. Industry

How should private industry adapt to the expected changes? Can it manage the commercial forest in ways that mitigate the impacts of increasing fire regimes? There are two aspects of this issue: protecting resource values and protection efficiency.

Protecting Resource Values

Stumpage rates have increased substantially, partially in response to pressure from United States lumber interests. The value of standing wood has gone up correspondingly while fire-management budgets are holding steady or decreasing. Fire protection should be commensurate with wood values. The forest industry is not happy with government downsizing of fire protection. It would appear that the industry will be expected to assume a greater proportion of fire-management costs, probably in proportion to the land area being managed or the volume of resource being protected. In some provinces, the forest industry is responsible for initial attack on its own fires.

Direct industry participation in establishing fire policies and fire management will be necessary. This could be beneficial in that the industry might then be encouraged to adapt its harvesting patterns to better fit existing fire regimes and fire management. Conversely, greater industry involvement will increase pressure to protect the wood resource rather than other values, such as life and property, The latter currently have higher priorities, in keeping with broader social values. Industry has questioned whether suppression resources that are used in non-commercial forest areas should be funded from a separate source, such as emergency management rather than fire management.

On the other hand, it has been suggested that industry's expectations for resource protection are excessive. It may not be physically possible for fire agencies to meet the desired level of protection. How can the protection of timber values be balanced with other forest values, particularly when the other values allow fire to assume a more natural role in managing the landscape?

Protection Efficiency

Quebec legislation mandates landowner and industry involvement, and the funding of fire protection. Seven fire protection associations (Sociétés de protection des forêts contre le feu) were formed in 1972. The Quebec government paid 50% of the cost; the balance was paid by industry and large landowners. The Sociétés are like non-profit crown corporations that operate at arm's length from the government.

The overall organization was reviewed in 1989 because of concerns about the cost-efficiency of the fire-protection system. Key problems follow:

- The number of associations made it difficult to share resources.
- Detection and air-tanker fleets were not efficiently allocated.
- Administrative groups overlapped.
- Strong central coordination was lacking.

A new organization of three administrative regions started in 1994. Each region has a board with members from industry, landowners, the ministry of energy and resources, and local communities. The regional boards supply members to a provincial board which directs the provincial fire centre and four field bases. The amalgamation resulted in fewer staff positions, bases, and vehicles with a consequent budget saving of $5 million. Quantitative objectives, which have been developed for Quebec's centralized organization, are:

- 0.5 ha at detection (88% success in 1995)
- 1 ha at response (80% success in 1995)
- 3 ha at control (87% success in 1995).

Air-tankers are a major fire-management expense. There are 44 airtankers across Canada currently. By 1997, air-tankers will account for 53% of the total Quebec fire budget. How many air-tankers are needed for each agency? Quebec maintains 14, while Ontario maintains 9 for a comparable protected area with a higher average fire-danger than Quebec.

Improved quantitative methods should be used to determine the appropriate types and numbers of air-tankers for different fire regimes and values at risk.

Detection may be the most cost-effective component of fire management. Quebec is currently using 33 Cessna 182s with retractable gear. Fires are reported directly to the provincial fire centre, which also coordinates the daily flight patterns for the detection fleet.

There must be a pan-Canadian approach to resource sharing. The CIFFC should maintain its role in facilitating interagency resource sharing.

O. Science

Every aspect of climate change and fire regimes is hampered by a fundamental lack of knowledge about underlying long-term and large-scale processes. This section considers information gaps in existing databases, monitoring the fire environment, science priorities, and an overview of the CFS fire-research network.

Information Gaps

There are three gaps in Canada's national information database that limit our ability to resolve the issue of fire-activity trends: fire statistics, vegetation inventory, and lightning occurrence. These information gaps will have to be at least partly filled before it will be possible to study the primary questions.

National fire statistics are only available as provincial summaries. This precludes all but the most cursory trend analyses. Not all historical fires have been recorded, particularly large fires that were not suppressed; therefore, archival data cannot be used for trend analyses. The quality of reporting varies considerably among and within agencies; the uniformity of the available data is questionable. The experience of the research community has been that the national fire-statistics database is of limited use for scientific studies. A review of the role and purpose of this database appears warranted.

The question of who should collect and archive national fire statistics ought to be examined. Historically, the CFS fire group has done this, but supporting this activity has often been problematic within a science organization. The CIFFC compiles daily operational statistics during the fire season. These provide immediate information but they cannot be archived until the accuracy and completeness of the reports have been validated. Statistics Canada might compile fire data, but that would probably increase the cost and difficulty of the process. It seems logical to retain this function within the forest sector. The best solution might be to add fire statistics to the data compiled by the CFS as part of reporting annual forestry statistics.

The use of existing vegetation and fuel inventories for research is limited by large unmapped areas, maps of varying scales and standards, and the variable quality of the inventories. Currently, the CFS at Edmonton has a national fuels map, but it is based on satellite-derived vegetative cover and it comprises only five of the 17 FBP fuel types. A national vegetation/fuels inventory at 1 km resolution will be needed to address national-scale fire-activity trends.

Resolving the question of whether or not lightning activity is increasing will require a national lightning-occurrence database, which will aggregate data from all the existing provincial networks. Whether such a system is housed at CFS—Edmonton, at CIFFC, or a host province matters little. Development of such a system is a precursor to advancements in this area. It could lead to a national fire-occurrence prediction system to compliment the fire-behavior prediction system now in widespread use.

Monitoring the Fire Environment

By what criteria shall we conclude that Canadian fire regimes have changed? What indicators should be monitored to indicate the imperceptible transition into a new regime? Potential criteria include a statistical change in fire activity, modified spatial and temporal distributions of fire, impacts on the carbon budget, or shifting age-class distributions or forest composition. Further, can completeness and accuracy of historical fire data be improved enough to permit fire activity to be used as an indicator of climate-change ?

Answering these questions will require substantial improvements in monitoring fire activity throughout the Canadian and global boreal regions. These concerns are an international priority and a multinational project is currently under way to address them. A large-fire database for Canada is currently under development. Data for the 1980s have currently been entered manually. Related cooperative research with Russia and the United States has also begun. Finally, NASA has proposed FireSat for global-scale satellite monitoring of fire activity.

A related proposal for automated quasi-daily satellite mapping and monitoring of fires greater than 200 ha across Canada is currently under consideration. Such a system would provide:

- timely acquisition of data on remote fires
- near real-time status of the national fire situation
- quasi-daily data on fire growth and severity for fire research use
- inputs to national criteria and indicators of sustainable forestry
- approximate measures of fire severity.

The current operational Canadian Wildland Fire Information System (CWFIS) provides daily national maps of historical, current, and forecast fire danger and fire-behavior potential for Canada. It automatically accesses weather data from the Atmospheric Environment Service national observation network as well as numeric forecasts produced by the Canadian Meteorological Center. Future plans call for producing automated situation-reports as well links to fire-agency sites on the World Wide Web. Daily national fire-occurrence prediction maps would quickly follow the development of a national occurrence-prediction system. Finally, large-fire data obtained through the satellite monitoring system would also be displayed. In addition to facilitating interagency resource sharing, these data would provide an unprecedented opportunity to study fire phenomena over longer-time and larger-spatial scales than ever before. This technology would enable fire research on scales appropriate to the study of the dynamics of fire regimes.

Science Priorities

The ongoing and unresolvable debates between basic vs. applied research, long- vs. short-term studies, or science vs. problem solving will not be pursued in this report. Only issues raised by the workshop will be addressed. It should be noted, however, that the rate of scientific progress is directly proportional to funding levels. There may be a considerable gap between what needs to be done and what can be done.

Analyses should begin with a statistical description of fire-activity trends. Several questions should be answered. Have the fire size-class distributions, the fire season or spatial distributions of fire changed? Is the recent increase due to only a few very large fires (i.e tail of the distribution)? Are the number of lightning fires increasing compared to human-caused fires? A current national large-fire database shows large regions with long fire-return intervals. Do these reflect fire regimes or level-of-protection decisions?

The large spatial-scale effects of an increasing fire regime are a key issue. The newly emerging field of landscape-level fire modelling may provide new insights to these questions. How will changing fire regimes affect forest composition? How will it change the age-class distribution? What will happen to the national balance between carbon storage and release?

A second essential issue is forecasting future climates—an area fraught with difficulties. Collaboration with the numerical-modelling community will be necessary to properly interpret outputs from state-of-the-art global and regional climate models. Collaboration is also needed to foster analyses of variables and weather elements of interest to fire researchers.

Combining landscape-scale fire models with long-term regional climate forecasts and fire-behavior models will enable development of stochastic landscape-fire models. These could be used to simulate changing disturbance regimes and ecosystem responses. They could also simulate various weather scenarios, such as different drying cycles, upper ridge patterns, significant wind events, and lightning occurrence to establish the range of probable future fire regimes and forest ecosystems.

Trends of prehistoric fire regimes provide another important perspective. Analyses of the charcoal contents of stratified lake sediments might extend our understanding of fire regimes several thousand years into the past. Dendrochronological studies could help to fill in more recent periods. Analyses of the distribution of forest age classes could supplement dendrochronological studies over large areas.

Many of the models needed to study changing fire regimes will have utility in and of themselves. Therefore, after the models have been verified, the results will be applied through a set of large-fire decision-support tools. These include:

- mesoscale spot fire-weather forecasts for specific sites
- modified suppression-response systems to support the decision whether or not to fight the fire
- suppression-effectiveness guidelines to aid dispatching
- fire-growth models to support suppression operations
- a fire-economics analysis system to balance costs and values at risk.

CFS Fire-Research Network

The CFS has restructured its research programs around 10 national science and technology networks. One network, with the lead centre in Edmonton, focuses on forest-fire research. A national network structure was selected for the following reasons:

- changing federal roles imply new organizational and management philosophies
- external federal science reviews and reports indicated a need for change
- maintain critical mass with reduced resources
- link the research program to national policy issues
- build on CFS, departmental, and national strengths
- emphasize partnerships with other federal departments
- clearly define the scope and objectives of the research program

- encourage collaboration and resource sharing among scientists
- responsibility and accountability for national collaborative programs.

The following principles will guide the implementation of Natural Resources Canada's new S&T networks:

- increasing the effectiveness of federally-supported research
- capturing the benefits of partnerships
- emphasizing preventative approaches and sustainable development
- adopting policies, practices, and regulations that encourage innovation
- extending information networks—the infrastructure of the knowledge economy
- strengthening international science and technology linkages
- promoting a stronger science culture.

Research partnerships should not be used primarily to obtain funds; partners tend not to have funds either. Rather, joint efforts should be for mutual support. Partnerships with agencies are essential as they have the authority to do things on the land and resources with which to do them. Universities have a major role to play in Canadian fire research. They have unique knowledge and skills, which other groups may not have; they also have access to different funding sources. Partnerships with industry have not been established to anywhere near their potential. Arguments that industry supports public research through taxes miss the point that general revenues are not targeted to fire research.

Four policy issues provide the foundation for the CFS Fire Research Network. Although developed independently, the Network's policy issues appear to be very compatible with the issues raised by this workshop. The network issues are:

- How does the environment affect wildland fire and what are the probable effects of global climate change?
- What are the impacts of fire on public health and safety, ecosystems, the atmosphere, and timber supplies?
- What information systems are needed to monitor the national fire environment and report on criteria and indicators?
- What values are at risk from fire and what are appropriate levels of fire management?

The CFS Fire Research Network is committed to a comprehensive list of deliverables for the period 1996 to1999. The deliverables, which reflect a transition between old and new ways of organizing fire research, balance tactical and strategic problems. Network deliverables include:

- framework for the Canadian Wildland Fire Information System to integrate all fire models
- physically-based surface and crown fire-behaviour models
- spatially and temporally dynamic fuel-moisture models
- fire effects and succession models for major species and ecosystems
- a long-term landscape-scale fire-simulation model
- decision Support Systems for fire weather, behaviour, and occurrence prediction
- resource allocation models
- tactical- and strategic-level fire growth models
- the Canadian Wildland Fire Information System
- assessment of global fire activity
- prediction of climate-change impacts on fire frequency and vegetation response.

V. Findings

1. Wildland Fire-Activity Trends

The combined workshop presentations and discussions yielded a total of 117 findings. A few important findings are summarized first followed by an unordered list of all findings related to each issue.

A. Fire Regimes

Every place has an inherent fire regime that results in a given amount of fire. A fire regime is the product of many natural and cultural influences; no individual factor should be studied in isolation. Canadian fire regimes span two orders of magnitude—from 100 to 10 000 years between fires greater than 200 ha. Fire management will have to vary substantially across this range.

- There is an important knowledge gap in that Canadian fire regimes are poorly defined, measured, or understood. There is no basis for comparisons over time or space.
- There are no criteria and indicators to identify changing fire regimes.
- A fire regime only changes permanently when the climate changes or humans substantially change the fuel structure by converting forest to agriculture, grasslands to forest, or developing wildlands.

- Suppression can significantly lengthen the interval between fires, but it is not clear that an unnatural fire regime can be maintained indefinitely.
- Biomass burning will shrink as third-world economies move towards fossil fuel use, but lightning fires will continue.
- Current fire-management policies evolved from historical social and cultural development patterns related to colonization, industrialization, and state management of public land.
- Publicly acceptable management policies for public lands will continue evolving away from exploitation towards preservation. Polarization between the two will increase—away from multiple use.
- It is difficult for governments to respond to gradual long-term changes—particularly when signals are weak, mixed, and not recognized by a majority.
- Fire research is almost always state-sponsored, due to the history of public forests under British colonial rule. Fire-research resources are collapsing due to the inability of many countries to continue sponsorship.
- The media focuses on wildland fire primarily from a public-safety perspective.

B. Fire Statistics

Wildland fire statistics serve many purposes, constituencies, and organizational levels. Current statistics are no longer adequate to resolve complex land-management issues. A spectrum of indicators of the fire environment, successful fire management, and fire impacts should be measured.

- Considerable variability, numerous dichotomies, and lack of direct measures complicate monitoring criteria and indicators for fire.
- Suppression expenditures can make a substantial difference in average fire size, yet there are no methods currently available to link the two. Despite the variability across Canada, most agencies are probably near their appropriate level.
- Computer, satellite, communication, and information technology could automate and facilitate monitoring, reporting, compiling, and analyzing fire statistics.
- Compiling and analyzing operational and archival fire statistics will require partnerships between national and provincial agencies.

C. Historical Record

Existing fire records cannot be used to draw conclusions about the influence of climate change or other factors leading to apparent, increased fire activity in recent decades. Until the fire record is corrected, it will continue to be misused in public debates.

- Despite similar social trends in Canada and the United States during the first half of this century, Canada has a much weaker fire trend than the United States; the Canadian record may be substantially incomplete.
- Under-reporting of area burned throughout much of Canada before 1975 appears to have been significant. Recent and early fire statistics are not comparable.
- The current area burned may be within the range of natural conditions experienced during the pre-suppression era (before 1920) in Canada.

D. Fire-Activity Trends

There is no consensus that fire activity has actually increased in Canada. There is a strong consensus that fire activity will increase in response to global warming. It is prudent to be prepared. As with all large systems, the one in question will not respond quickly to attempted changes. Action will be necessary before all the evidence is in; waiting for the latter virtually assures failure.

- Indicators of the threshold of changing fire regimes will be needed, because the transition to a new regime is likely to be imperceptible.
- An empirical approach to modelling climate and fire-regime processes will not work. The underlying science must be unerstood to be able to make projections in a changing environment.
- An adequately funded national project will be needed to determine actual fire-activity trends in Canada.

2. Explaining Fire-Activity Trends

The most likely explanation is that the observed trend of fire activity results from a complex combination of most, if not all, of the possible causes.

- Some potential causes of increasing fire activity in Canada, such as weather variability, climate change, and declining budgets, are consistently viewed as more important.
- Some potential causes received mixed reviews. (These would be worthwhile areas for research to increase our understanding of the underlying processes.) Suppression success was considered important despite limited evidence. On the other hand, changing fire policies and improved

fire statistics were considered unimportant despite a consensus that the fire record before 1975 is missing significant data on unsuppressed fires.

- Some possible causes, such as increasing population, increasing occurrence, and harvesting activity, were consistently considered less important.

E. Weather and Climate

Greenhouse gases have increased significantly in the past half-century. Part of the increase has been attributed to anthropogenic (human) activities. Without major human intervention, greenhouse gases will increase to several times their pre-industrial concentrations by 2100. If the climate changes as projected, average fire danger in circumpolar regions will be significantly higher than it is today. Preliminary research projects longer fire seasons, more severe fire weather, and earlier season start-up, particularly in western Canada.

- The global climate has varied considerably during the past million years.
- There have been both extended warm and cool periods during the approximately 12 000 years since the last ice age.
- Average temperatures in western Canada were warmer in the 1980s than in the previous 3 decades. The greatest departures from normal were in winter and spring. The signal for eastern Canada suggests little annual change to a slight cooling.
- The observed warming trend is consistent with projections of global climate-change models.
- Persistent high-pressure systems correlate well with severe fire activity. Analyses suggest an increasing occurrence of a 50 kPa-height anomaly over western Canada since 1945.
- The Canadian Forest Fire Danger Rating System correlates well with daily fire activity but not with longer term fire business. A fire-severity model is needed to better describe synoptic-scale fire processes and link to GCM outputs.
- The magnitude of the apparent fire-activity increase exceeds the total projected to result from climate change. Climate change is, therefore, unlikely to be a primary cause of the statistical trend.

F. Social Context

The questions of who benefits from and who should pay for fire management in Canada have not been generally addressed. A firm financial footing will be ensured in the future only by resolving these questions.

- Although increasing fire occurrence may be related to increasing population and forest activity, cause and effect cannot be demonstrated. Relationships with area burned, if any, are likely to be minimal.
- Fire management has not satisfactorily demonstrated a strong relationship between budgets and system outputs, in terms of saved area or resources. This precludes quantitatively determining appropriate levels of fire management.
- Many provinces are managing their forests at the limit of fibre production. If we do not provide some buffering, current productivity levels may not be sustainable.

G. Fire Management

Many fire policies now reflect the reality that some fires are not suppressed. The total area burned by these fires has been reported accurately since the mid-1970s.

- Although pre-suppression budgets and consequent resource availability have been reduced in recent years, a direct cause-andeffect relationship to increased area burned has not been demonstrated to date.
- There is evidence that suppression success has lengthened fire-return intervals in Canada relative to natural fire regimes, but it cannot be demonstrated that unnatural fuel buildups are causing increased area burned.

3. Potential Impacts of Increasing Fire Regimes

H. Ecosystems

Most ecosystems are expected to migrate northward in response to climate change. Grasslands and temperate forest are also expected to expand while the boreal forest may contract. Fire may be an important catalyst in speeding ecosystem migration and expansion. Because fire significantly affects the national carbon budget, Canada's forests could shift from a net sink to a net source of carbon.

- Landscape patterns will probably shift towards a larger, size-class distribution of burned areas.
- The composition of forest communities will shift toward fire-tolerant pioneer species.
- An increasing fire regime will generally benefit wildlife populations.
- Increasing fire and insects may result in a larger combined response than would be generated from either alone. Little is known about fire–insect relationships.
- Effects of fire regimes on forest health and biodiversity are poorly understood.

I. Environment

Particulates and trace gases emitted by forest fires will probably increase. Increased smoke production from wildland fires could reinforce global climate change.

- Techniques have been developed for reducing the impacts of smoke produced by prescribed fires; nothing can be done about wildfires.
- An increased fire regime could result in reduced water quality, increased soil erosion on hilly sites, and increased permafrost melting. These effects will not be major, will tend to be site-specific, and can be mitigated to an extent.

J. Fire Management

Declining fire-management resources coupled with increasing fire activity increases the chance of a sudden decrease in fire-management effectiveness and the point of onset is not known.

- The level of fire activity that the public is willing to accept is not known. Would a natural fire regime, averaging 3 to 4 million ha burned annually, be acceptable?
- The cost of maintaining suppression capability to preserve artificially low levels of area burned may increase significantly.
- Fire-management agencies will become increasingly pro-active in addressing fire issues.
- Increased pre-suppression activities (e.g. prevention, fuel management, prescribed fire) are not likely to substantially improve (e.g. double) fire-management effectiveness.
- Interagency resource sharing has proven invaluable during recent extreme fire situations; this will increase.
- Although there will always be opportunities to increase fire-management efficiency, the potential for improvement may not be sufficient to maintain current levels of management in the face of increasing fire regimes.

K. Forest Industry

Canada's forests cannot be managed sustainably at the limits of growth; some buffering is essential to ensure long-term sustainability.

- An increased fire regime will reduce the quantity and quality of wood available for harvest; currently, the reduction cannot be quantified.
- The cost of harvesting will increase, but this may be offset by increased resource values.
- Potential fire losses must be incorporated into forest-management planning.

L. Social Systems

Limited suppression resources will exacerbate conflicts between resource and property protection. Sacrificing one to preserve the other will become increasingly necessary. Public education about fire issues and public participation in developing fire-management policies are the only strategies likely to obtain continuing support for fire management.

- Wildland/urban interface fires will probably increase, with consequent community evacuations, loss of homes, property, and infrastructure, threats to public health and safety, and media attention.
- Other potential social impacts on employment and tax revenue, tourism and recreation, and aboriginal interests are indirectly linked to fire and are, therefore, more difficult to forecast.
- Many stakeholders will increasingly scrutinize the delineation of protection-zone boundaries and selection of full or modified suppression. Decision-support systems for analyzing these issues and justifying decisions will become essential.
- Political scrutiny of fire management will likely increase, making rigorous quantitative analysis of selected alternatives necessary.

4. Possible Responses

M. Governments

Different levels of government have different mandates and possible responses vary accordingly. Key policy issues include who should be responsible for fire management, how much is appropriate, how it should be funded, who should manage it, and how the program should be delivered.

- Government funding processes are not well suited to fire management. Fire-management income goes to general revenues and often is not linked to costs. Carrying over unused funds from moderate to severe years is generally not possible.
- Agencies will need to provide a socio-economic rationale for fire policies that demonstrate the value of fire management.
- Partnerships will be essential to continued, stable support for fire management.
- Collaboration and consensus will require rigorous policies, balanced goals, and objective decision making to resolve the many conflicts inherent to wildland fire.
- Budget limitations add to the inherent conflict between resource protection and infrastructure protection.

- Fire regimes evolve very slowly; fire-management policies must reflect long-term trends even though governments change.
- All stakeholders should be involved to shift the focus of fire policies from government priorities to a broader set of priorities, based on diverse stakeholder values.
- Agencies should adopt an ecosystem management approach, but the concept will have to be better defined and understood than is currently the case.
- Educational institutions could facilitate stakeholder involvement by providing fire courses tailored to the general public.

N. Industry

Levels of resource protection are decreasing while wood values are increasing. Industry may be expected to assume a greater share of the cost of protecting the wood resource. Industry will have to become increasingly involved in setting fire policies and in fire-management operations. This could lead to increased pressure to protect industry interests.

- Industry and government should reevaluate their investment in fire protection and determine appropriate levels, based on the values that are being protected.
- Forest managers should not invest in silviculture without protecting that investment.
- A partnership of government, industry, and large landowners could fund fire management and a non-profit corporation could implement it.
- Centralized command and control can increase fire-management efficiency.
- Better methods are needed for determining air-tanker requirements for different fire regimes and values at risk.

O. Science

Every aspect of studying climate change and fire regimes is hampered by a fundamental lack of knowledge about underlying long-term and large-scale processes. Scientific knowledge and technology are inadequate to objectively evaluate current fire policies or to support policy development during the anticipated escalation of fire regimes.

- The range of probable, future forest ecosystems could be established if landscape-scale fire models were combined with long-term regional climate forecasts.
- Several methods are available for analyzing long-term fire-regime trends.
- The current national database of fire statistics has limited usefulness for scientific research. Existing national vegetation and fuel inventories are similarly limited.
- The absence of a national lightning-occurrence network precludes developing a national lightning-fire occurrence prediction system.
- Substantial improvements will be needed in monitoring fire activity in boreal forests. Large fires might be automatically monitored and mapped via satellite.
- The CWFIS monitors and maps the national fire environment on a daily basis.
- The policy issues underlying the CFS Fire Research Network are very compatible with the issues raised at this workshop. The research program balances tactical and strategic problems.

VI. Recommendations

The workshop resulted in a total of 92 recommendations, after similar wording and duplication from individual discussion groups were combined. The report includes 99% of all recommendations; the remainder was considered inconsequential. The 92 recommendations have been combined into 14 overall recommendations to simplify the discussion.

Table 2 lists the recommendations according to priority (see Appendix II, section 4), responsible group, function, and constituency. There is a substantial difference between the highest- and lowest-priority recommendations, which suggests that the prioritization process was successful. Most of the recommendations involving external constituencies head the list, which indicates that linkages to society and

Table 2. List of recommendations by priority.

No.	Priority	Responsibility	Function	Constituency
1.	14.8	policy	planning	forestry
2.	14.0	research	indicators	fire
3.	13.7	policy	awareness	society
4.	10.2	research	knowledge	society
5.	7.4	research	analysis	society
6.	7.4	information	archives	fire
7.	6.6	research	coordination	fire
8.	5.1	information	statistics	fire
9.	5.1	management	fuels	fire
10.	4.7	information	network	fire
11.	3.9	research	decisions	fire
12.	2.0	management	protection	society
13.	2.0	research	scale	fire
14.	2.0	management	effectiveness	fire

sustainable forestry are viewed by the fire community as most important. The general trend is that policy issues head the list, followed by policy support, management information, and fire management.

The 14 combined recommendations were classified into four priority groups: linkages to higher-level processes, technical support for policymaking, fire-management information, and fire management and research. Groupings were subjectively based on notable differences in priority scores and similarity of recommendations. Priority differences within groups were not considered significant.

Although stemming from the 15 issues raised at the workshop, many of the 14 overall recommendations relate to several issues. Therefore, a one to one relationship between the issues and recommendations is not possible.

A. Linkages to Higher-Level Processes

The three very-high priority recommendations share a common attribute—they attempt to better link wildland fire and fire management to higher-level natural and social processes, which are sustainable forestry, fire regimes, and social awareness. Workshop participants emphasized the importance of linkages to higher-level processes to obtaining the support necessary to implement fire-management's mandate to support the attainment of higher-level goals, such as sustainable forestry and land management.

1. Incorporate Fire Regimes into Sustainable Forest Management Policies and Planning

This is the highest-priority recommendation. It aggregates policy-level actions relating to fire and sustainable forestry, fire and ecosystem management, fire policies, and fire-management goals. It attempts to better relate fire management to sustainable forestry and land management. This is a critical recommendation because wildland fire has a major impact on achieving forest- and land-management goals. However, all natural resource agencies may not recognize this fact and consequently may not fully achieve their higher-level goals. There are 12 specific sub-recommendations.

- Reconfirm/reconstitute the role of government in fire management.
- Develop a clearer vision of the future forests desired in Canada.
- Provide information on the role of fire in sustainable forest objectives.
- Integrate fire management into sustainable forestry management strategies.
- Understand the role of fire in ecosystem and landscape management.
- The Model Forest Network should increase the emphasis on fire in their management plans.
- Use a holistic approach to establish fire goals in ecosystem management.
- Commitments to long-term priority are needed to implement fire-management policies.
- Revise fire policies to permit withdrawal when suppression efforts are ineffective.
- Develop better methods for setting measurable fire-management goals.
- Develop success-based indicators to evaluate fire management.
- Improve the salvage capability for fire-damaged wood.

2. Develop Methods to Measure Fire Regimes and Indicate Changes

This recommendation focuses on long-term processes, such as fire regimes, fire climate, criteria and indicators of climate change, climate forecasting, and climate-change models. These recommendations reflect the fact that more is unknown than known about fire and climate relationships. Our understanding of long-term processes will have to increase substantially before pronouncements can be made about long-term trends of fire activity. There are 11 specific sub-recommendations.

- Develop tools for predicting fire-regime trends.
- Link climate and climate change to wildland fire and forest ecosystems.
- Improve our understanding of the relationships between fire and climate.
- Better define and describe current Canadian fire climates.
- Develop fire-related criteria and indicators of climate change and variability.
- Improve forecasts of fire climates 5 to 10 years in advance for planning.
- Develop models to forecast future, long-term fire climates.
- Develop tools to assist in managing the effects of climate change on fire and ecosystems.
- Improve the spatial and temporal resolution of regional-climate models.
- Promote climate model outputs that are relevant to wildland fire.
- Develop better predictive tools for fire occurrence and fire behaviour.

3. Increase Public Understanding of and Participation in Developing Fire Policies that Balance the Needs of Society with Natural Fire Regimes

This recommendation attempts to better link fire management to society. It focuses on increasing public understanding, broad participation in policy setting, education, and training. Public understanding of and participation in establishing fire policies is essential to obtaining support from natural resource agencies. There are 11 sub-recommendations.

- Increase public understanding of the social, economic, and ecological impacts of fire.
- Communicate the effects of the presence and absence of fire in ecosystems.
- Ensure that stakeholders are aware of the limits of suppression capabilities.
- Base fire policies on public consensus.
- Encourage community co-planning in protection and fuels management.
- Northern strategies should be compatible with the interests of northern residents.
- Develop fire policies in conjunction with forest industry and other stakeholders.
- Use state-of-the-art technology to educate the public about fire issues.
- Develop school programs to increase awareness of fire issues.
- Encourage cross-training between wildland and urban fire suppression agencies.
- Anticipate and proactively address fire-management problems.

B. Technical Support for Policy-Making

The common thread in this group of recommendations is the creation of knowledge and the development of systems to provide technical support for establishing higher-level fire-management policies. The recommendations focus on predicting the effects of fire, developing a fire-economics analysis system, improving the historical fire record, and coordinating fire research.

4. Develop Methods for Measuring and Predicting the Effects of Wildland Fire

This recommendation relates to the physical and biological effects of wildland fire. The small number of sub-recommendations belies the high priority assigned to this recommendation. Several related recommendations are included under sustainable forestry, fire policy, and economic analysis. This reflects the close connection between this recommendation and others. The four sub-recommendations relate to specific effects of fire.

- Determine fire–insect–disease relationships.
- Link smoke management to public health.
- Use the 1995 fire season as a case study of the causes, responses, and effects of fire.
- Increase the use of fire.

5. Develop a Nationally Applicable Analytical System with a Capability to Determine the Socio-economic Implications of Wildland Fire

This recommendation is a precursor to measuring the costs and benefits of fire management, which are the key to determining the appropriate level of fire management. This broad recommendation includes who should finance fire management, appropriate levels of fire management, values at risk from fire, socio-economic impacts of fire, and the economic efficiency of specific fire-management functions. There are eight sub-recommendations.

- Determine who benefits from fire management, who should pay, and how much.
- Determine appropriate levels of fire management.
- Determine the economic implications of fire management.
- Determine the economic and non-economic values at risk from fire.
- Develop methods for appraising the effects of fire on resource and non-resource values.
- Develop a system to evaluate socio-economic effects of management alternatives.
- Determine the costs and benefits of suppression.
- Analyze the opportunity cost of not acting as well as acting on issues.

6. Improve the Historical Fire Record to Permit Analyses of Long-Term Fire-Activity Trends in Canada

Using the existing historical fire record to infer long-term fire-activity trends in Canada is not defensible scientifically. Yet, some groups outside the fire community use this approach which creates a problem for fire management. Time, effort, and energy are siphoned from essential fire-management activities to refute unsubstantiated claims based on this record. Until the fire record is corrected to better reflect what actually happened, it will continue to be used incorrectly by others to further their agendas. There are six sub-recommendations.

- Build a fire regime atlas for Canada.
- Publish maps of fires greater than 1 000 ha since 1918.
- Track down undocumented large fires.
- Document reporting history by agency, including the evolution of protected areas.
- Encourage accurate stand-origin determination in forest inventories
- Use historic forest inventory maps to supplement the early fire record.

7. Enhance Setting and Coordinating Fire-Research Priorities and Establishing Partnerships

For 44 years, the Canadian Committee on Forest Fire Management has been charged with linking the science and management communities and prioritizing national fire research requirements. This is a challenge because the committee has virtually no funds and it relates best to solving management problems. In contrast, science is motivated by creating knowledge and the need for funds. Lists of research priorities bear little fruit without ways to implement them. This group of six sub-recommendations relates to a long-standing need for improvements in this area.

- Enhance national-level steering and management of fire research.
- Identify a national body to enable (fund) national fire research projects.
- Improve the prioritization of fire research.
- Increase the sharing of research data.
- Conduct operational research by fire-management agencies.
- Develop an enabling mechanism to steer and implement these recommendations.

C. Fire-Management Information

The unifying element for this group of recommendations is a relation to fire-management information: fire statistics, a national information network, and decision-support systems. Accurate and timely information is critical to successful fire-management operations. It is also the basis of historical archives that ultimately support fire-management policies. Recommendation 9 (fuel-management strategies) does not relate to group C and is included in group D.

8. Maintain and Enhance the Compilation and Analyses of National Fire Statistics

Compiling national fire statistics is not simply a function with a 75-year-old tradition. Fire statistics are critical to understanding and reporting the national fire situation and projecting future trends. An apparent increasing trend was the starting point for this workshop. It is important to the Canadian fire community that closure of the Petawawa National Forestry Institute does not end the compilation of national fire statistics. The nine sub-recommendations detail specific improvements to compiling current statistics based on current management needs.

- Maintain a national capability to collect and integrate fire data.
- The CFS should continue reporting until an alternative system is established.
- Define common standards for types and format of information.
- Obtain data to support ecosystem management.
- Capture financial and human-resource information.
- Compile date by fire management zones.
- Include indicators of suppression level on each fire.
- Measure success or failure relative to varying risk and hazard conditions.
- Dedicate human and fiscal resources to the task.

10. Develop a National, Wildland Fire-Information Network to Link all Fire-Management Agencies in Canada

Modern communications, satellite, computer, and information technologies can substantially improve sharing information among fire-management agencies. Sharing information electronically will facilitate interagency resource sharing and result in more cost-effective fire management. It will also facilitate compiling national fire statistics. There are six sub-recommendations.

- Agencies should electronically share operational information.
- Use a national platform to facilitate compiling national fire statistics.
- Determine the level of detail required at the national level.
- Establish levels of security and access to the information.
- Select the management responsibility—CFS, CIFFC, or other.
- Determine requirements for the accuracy of fire information.

11. Develop Decision-Support Systems to Increase Fire-Management Efficiency and Effectiveness

One of Canada's greatest fire-management strengths is its world leadership in decision-support systems. The supporting technology is advancing exponentially and so much more is possible today than just a decade ago. Off-the-shelf systems now permit linking fire weather, fire behavior, fire growth, and fire effects—a prerequisite to incorporating fire into ecosystem management and sustainable forestry. There are five sub-recommendations.

- Continue developing decision-support systems.
- Adapt new technologies to fire, such as remote sensing and firegrowth models.
- Develop GIS-based analytical tools for managing large fires.
- Link existing knowledge of fire behavior to fire effects.
- Develop decision-support systems that incorporate public concerns.

D. Fire Management and Research

The last group combines four issues of interest to fire management and fire research: fuel-management strategies, protection-zone boundaries, multi-scale systems, and fire-management effectiveness. Although each is important, none have the breadth of linkages or levels of influence as the previous recommendations.

9. Develop Improved Fuel-Management Strategies

Recommendation 9 (fuel-management strategies) is classified most logically with this group. Canada does not have a tradition of fuel management like the United States; therefore, it is noteworthy that this issue received a moderate priority. Substantial reductions of fire-management resources may be leading to searches for alternative methods to achieve traditional levels of fire management, in which case fuel-management might prove useful. There are six sub-recommendations.

- Develop landscape-scale fuel management strategies for large-fire mitigation.
- Determine effectiveness requirements for fuel breaks.
- Determine the costs and benefits of fuel breaks.
- Develop scientific standards for fuel modification at the wildland/urban interface.
- Develop harvest patterns and scheduling which incorporate fuel-management strategies.
- Develop models of short- and long-term fuel dynamics.

12. Improve Strategies for Delineating Protection Zones

Protection-zone boundaries delineate intensive- and extensive-protection zones, which significantly affect average fire size and consequent fire impacts. Currently, there are no satisfactory quantitative methods for accomplishing this task. There are two sub-recommendations.

- Improve methods of establishing protection-zone boundaries.
- Improve strategies for protecting isolated communities.

13. Use a Multi-Scale Approach to Develop Fire-Management Systems

This recommendation is primarily of interest to scientists and system developers. Managing the complexities of current and projected operating environments will require systems with capabilities to analyze complex multi-scale problems. There are three sub-recommendations.

- Systems should permit analyses at different scales.
- Improve the spatial and temporal resolution of fire models.
- Consider operational, regional, national, and global implications.

14. Increase Fire-Management Effectiveness

One would expect a fire workshop to include recommendations about increasing fire-management resources and effectiveness. However, the low priority attached to this set of recommendations may reflect the current financial climate which precludes increasing resources. In addition, marginal improvements in efficiency will not be enough to cope with the magnitude of the potential changes that the environment and society may imposed on fire management. The ultimate solution to the current resource dilemma lies in understanding and demonstrating the impacts of wildland fire on achieving higher-level goals by parent organizations. There are four sub-recommendations.

- Enhance pre-suppression efforts—detection, prevention, and training.
- Increase suppression effectiveness—tactics and initial attack capabilities.
- Increase resource sharing.
- Maintain and enhance the use of fire as a management tool.

Appendix I. Agenda

Monday, April 1

1900 **Icebreaker** (Emerald/Sapphire Room)

Tuesday, April 2 (Edmonton Room)

0830 **Opening remarks**
Bob Rosehart, Lakehead University

0840 **Welcome**
Boyd Case, CFS—Edmonton

0850 **Workshop objectives**
Al Simard, CFS—Ottawa

0900 **A global fire perspective**
Steve Pyne, Arizona State University

0945 **The Canadian fire record**
Peter Murphy, University of Alberta
Marty Alexander, CFS—Edmonton

1030 **Break**

1100 **Escalating fire regimes: possible explanations**
David Martell, University of Toronto

1145 **Lunch**

1315 **Weather variability and climate-change impacts on fire**
Brian Stocks, CFS—Sault Ste. Marie
Walter Skinner, Atmospheric Environment Service

1400 **Working Group breakout session I**

1500 **Break**

1530 **Working Group breakout session I** (continued)

1700 **Adjourn**

1830 **Dinner** (Calgary Room)

Wednesday, April 3 (Edmonton Room)

0845 **Opening remarks**
A. Anne McLellan, Minister, Natural Resources Canada

0900 **Impacts of an escalating fire regime**
Ian Methven, University of New Brunswick

0945 **Fire-management agency perspectives**
Gus MacAuley, Saskatchewan

1030 **Break**

1100 **Forest industry perspective**
Dick Pickering, Stone Consolidated Corp.

1145 **Lunch**

1315 **Scientific research priorities**
Bryan Lee, CFS—Edmonton

1400 **Working Group breakout session II**

1500 **Break**

1530 **Working Group breakout session II** (continued)

1700 **Adjourn**

Thursday, April 4 (Edmonton Room)

0830 **Working Group reports**

1000 **Break**

1030 **Prioritizing recommendations**

1200 **Adjourn**

Appendix II. Workshop Process

1. Workshop Objectives

The purpose of the workshop was **"to understand the causes and increase awareness of the impacts of escalating wildland fire activity in Canada and recommend appropriate responses."**

The workshop had five objectives:

1. Determine whether fire activity has increased.
2. Evaluate and prioritize the possible causes.
3. Summarize the potential impacts.
4. Recommend appropriate responses.
5. Communicate the findings and recommendations.

2. Presentations

Eight papers were presented to stimulate thinking among the participants. Speakers were asked to review an issue, summarize current knowledge, and provide speakers with opportunities and challenges. Repeated references to speakers' comments in discussion notes indicate that these objectives were achieved. Each speaker received terms of reference, which included suggested topics for each issue (list follows). The lists of topics were generally too broad to be fully covered in a 30-minute presentation. By choosing specific topics to emphasize, however, the speakers began the process of focusing the workshop.

A Global Fire Perspective—Stephen Pyne, Arizona State University

- Is this a unique Canadian problem or are other countries experiencing similar increases?
- What is the global socio-economic context for wildland fire?
- What are the ramifications of similar/dissimilar temporal and spatial global patterns?
- What are the global social perceptions of forest fires as an issue?
- Other relevant topics.

The Canadian Fire Record—Peter Murphy, University of Alberta; Marty Alexander, CFS—Edmonton

- What do official fire statistics indicate?
- How reliable are these records?
- Is it possible to improve the available records?
- What does the paleoecological evidence indicate?
- What do dendrochronological studies indicate?
- What do stand-history studies indicate?
- What are the strengths and weaknesses of each type of study?
- Do the above studies provide just a sample or a national picture?
- Is it possible to make projections about the future, and if so, with what accuracy?
- Other relevant topics.

Escalating Fire Regimes: Possible Explanations—
David Martell, University of Toronto

- How does population affect fire activity and its trends?
- How do social and cultural activities affect wildland fire and its trends?
- How do values at risk affect wildland fire and its trends?
- How does the financial climate affect fire activity and its trends?
- How does the forest industry affect wildland fire and its trends?
- Other relevant topics.

Weather Variability and Climate-Change Impacts on Fire—Brian Stocks, CFS—Sault Ste. Marie; Walter Skinner, Atmospheric Environment Service

- What are the relations between short-term weather processes and wildland fire?
- What are the relations between long-term weather processes and wildland fire?
- What are the relations between weather and climate?
- What are the normal ranges of weather and climate variability?
- What are the observed weather trends and the probable effects on wildland fire?
- What are the projected climate changes and the potential effects on wildland fire?
- What are the levels of certainty or uncertainty for each of the above?
- Other relevant topics.

Impacts of an Escalating Fire Regime—Dr. Ian Methven, University of New Brunswick

- What is the magnitude (costs, resources, etc.) of fire management in Canada?
- What are the impacts of fire on forests, ecosystems, and the environment?
- What are the impacts of fire on wood and fibre supplies, and the forest industry?
- What are the impacts of fire on people, communities, and the well-being of Canadians?
- What are the likely future trends of these impacts?
- What implications will these trends have for governments, industry, and science?
- Other relevant topics.

Fire-Management Agency Perspectives—Gus MacAuley, Saskatchewan

- Are there any impacts of a shift from fire exclusion to fire-management policies?
- Has successful suppression resulted in unnaturally heavy fuel accumulations?
- Has decades of fire exclusion resulted in a shift to older forest age classes?
- Are there any effects related to centralized vs. decentralized fire-management?
- What evidence is available to support any of the above effects and trends?
- What are the probable future trends of these effects on wildland fire?
- What policies might the federal government adopt?
- How might fire-management agencies respond?
- Are there appropriate legislative changes?
- How might municipalities and local governments respond?
- Should long-term planning consider increasing fire activity?
- Should zoning ordinances and building codes be amended?
- Other relevant topics.

Forest Industry Perspective—Richard Pickering, Stone Consolidated Corp.

- What is the forest industry's role in fire management?
- What should be done to maintain a sustainable wood supply?
- To what extent should we protect timber and fibre resources?
- What technology is needed to enhance fire-management effectiveness?
- Are there forest-management practices that could mitigate fire impacts?
- Other relevant topics.

Scientific Research Priorities—Bryan Lee, CFS—Edmonton

- What are the critical knowledge gaps limiting resolution of this issue?
- What research must be undertaken to fill these gaps?
- What are the science priorities?
- What is the role of science in wildland fire?
- Other relevant topics.

3. Discussion Groups

The discussion groups were intended to develop a consensus among the experts. The groups were asked to discuss the issues, their knowledge, and their experiences, list their findings in order of priority, and draft recommendations. Participants were divided into 12 discussion groups covering five issues. Group members were pre-selected to ensure a relatively uniform and representative distribution of participants. Each participant served on two groups.

The suggested topics, which were given to the speakers, were also distributed to the discussion groups. The participants' perspectives ranged beyond the suggested topics. Many groups also overlapped topics covered by other groups; the relative importance of certain topics was underlined in such cases.

Facilitators helped focus on the objectives. A facilitator's handbook was provided to each facilitator and its use promoted compatibility among different groups. Each group had a rapporteur to record the discussions and elected a spokesperson to present their recommendations at a plenary session on the last day of the workshop. Although specific procedures varied slightly among groups, the general pattern included:

- unstructured brainstorming
- gap analysis (what is known and not known)
- findings and recommendations
- prioritization

Day 1

The Canadian Fire Record (groups 1 and 2)

These groups discussed both the global context and the fire record.

Escalating Fire Regimes — Possible Explanations (groups 3 and 4)

These groups also considered possible fire-management causes of increasing fire activity listed under a combined cause-and-response paper from fire agencies.

Weather Variability and Climate-Change Impacts on Fire (groups 5 and 6)

Although the emphasis was on meteorology, a sufficient cross section of participants ensured a broad representation of views.

Day 2

Impacts of an Escalating Fire Regime (groups 1, 3, and 5)

Groups from the first day were alternated to avoid concentrating specific knowledge, experience, or perspectives in the discussions on potential impacts.

Responses to Increasing Fire Activity (groups 2, 4, and 6)

These groups combined government, industry, and scientific representation to encourage balance and avoid special interests.

Group Participants

Floating participants:

Boyd Case
Dennis Dubé
Surj Malhotra
Bob Rosehart
Al Simard

Groups:

1. Mark Laserko (facilitator)
   Marty Alexander (rapporteur)
   Bob Bailey
   Mark Heathcott
   Bruce Lawson
   Ed MacAuley
   Peter Murphy
   Richard Pickering
   Stephen Pyne
   Don Thomas
   Paul Woodard
2. George Allan (facilitator)
   Kerry Anderson (rapporteur)
   Wayne Fisher
   Al Jeffrey
   Rick Lanoville
   Bryan Lee
   Jeff Monty
   Régis Proulx
   Cliff Smith
   Terry Van Nest
3. John Lilley (facilitator)
   Brad Hawkes (rapporteur)
   Petr Achuff
   Paul Corrigan
   Jim Farrell
   Francois Lefebvre
   Ian Methvin
   Kelly O'Shea
   Gerry Redbear
   Rob Thorburn
   Al Westhaver
4. Tim Lynham (facilitator)
   Ian Campbell (facilitator)
   Bernie Todd (rapporteur)
   Bill Bereska
   Bill de Groot
   Sheri Gutsell
   Dave Kiil
   David Martell
   Ian Naldor
   Glenn Peterson
   Tom Reid
   Pat Salm
   Tommy Warner
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   Mike Apps
   Peter Fuglem
   Lana Laird
   Gus MacAuley
   George Mercier
   Dennis Quintilio
   Walter Skinner
   Brian Stocks
   Elaine Wheaton
   Stephen Woodley

6. Carol Blair (facilitator)
   Rod Simpson (facilitator)
   Ted Hogg (rapporteur)
   Fraser Dunn
   Tim Goos
   Cliff Henderson
   Karl Larson
   Wayne Martin
   Dave Price
   Bob Stewart
   Paul Ward
   Ross Wein
   Steve Zoltai

4. Prioritizing the Findings

Two approaches were used to determine the priority of the 14 overall recommendations. In the first approach, individual recommendations were voted on by all workshop participants (five votes each). Although indicative, the results were inconclusive because individual recommendations had not been consolidated before the vote. As a result, some similar recommendations from different groups received widely varying votes. In other cases, voting seemed to be split among similar recommendations. Further, with 92 choices, the voting was highly dispersed with no apparent pattern.

The second approach involved counting the original number of recommendations in each group before similar wording and duplication had been conbined. This gave one point to every recommendation listed by every discussion group. The two approaches were combined to yield an overall group priority which was converted to a percentage. The dual approach resulted in a good range from highest to lowest priority.

Appendix III. Attendees

A total of 64 people attended the workshop (78% of those who were invited) indicating a strong interest in the subject within the fire community. Participants included fire managers and researchers from fire agencies, universities and technical schools, the CFS, other federal departments, the forest industry, environmental non-governmental organizations, and aboriginal groups. The findings and recommendations reflect the views of a broad cross section of Canadian expertise in wildland fire.

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