Statistics

Perspectives on Carbon Emissions from Canadian Forest Fires

By Brian Amiro, Mike Flannigan, Brian Stocks and Mike Wotton

Fire continues to be a major factor in Canadian forests, and it will likely increase if climate change forecasts prove accurate.

The health of our forests depends on establishing the amount of fire that our forests need and can tolerate. Although forest fire carbon emissions are significant, their reduction may not be economically feasible.

Over the past four decades, Canadian forest fires have released an average of 27 Mt (10^{12} g) of carbon annually by direct combustion. An equal amount of carbon may also have been lost through decomposition of fire-killed vegetation, temporarily decreasing the forest sink. These emissions were calculated on the size of each fire, the dates over which it burned, and the fuel consumed (estimated using the Canadian Forest Fire Behavior Prediction System). The estimates are a product of the Canadian large-fire database, a geographically referenced data set of all fires larger than 200 ha in area, which includes information on the size of each fire, the cause, and the start date. The data are provided by all Canadian fire management agencies (provinces, territories, Parks Canada).

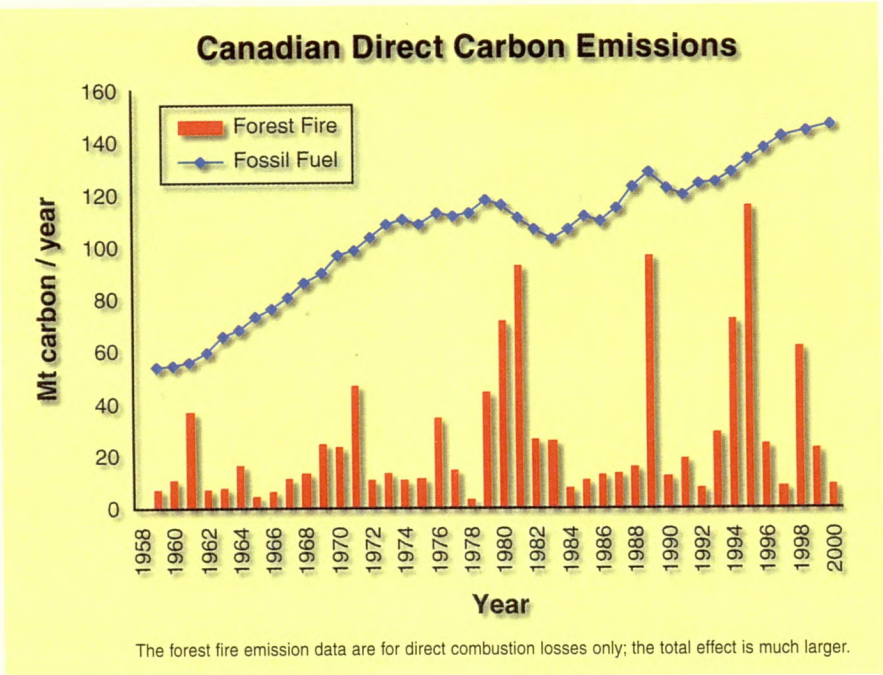
The emissions vary widely among years, ranging from 3 to 115 Mt carbon per year. This is caused largely by the wide inter-annual variability in area burned, which ranged from 0.3 to 7.5 million ha/year. Across the country, an average of 1.3 kg of carbon is lost per square metre of burned area, but this varies from about 1 to 2 kg carbon/m^2 (1 kg/m^2 = 10 tonnes/ha) on average among different ecozones.

The importance of this carbon

Fires release carbon in a mixture of carbon dioxide (CO_2), other gases such as methane and carbon monoxide, and particles (smoke), with the mixture depending on the degree of combustion. However, about 90 per cent of the carbon is released as CO_2. Comparing emissions from forest fires to carbon dioxide emissions from fossil fuels in Canada (Fig. 1), it is clear that fossil fuel emissions have been increasing with time while fire emissions are more variable, but may also be increasing. These direct fire emissions are significant, especially in high fire years. Fires contribute to greenhouse gases in the atmosphere, such as CO_2, methane and nitrogen oxides, which are important drivers of climate warming. Hence, a positive feedback is possible, where increased emissions cause warming, potentially supporting more fires.

In addition, there is evidence that smoke promotes positive lightning strikes (which deliver more ignition potential than negative strikes), while reducing precipitation.

Smoke is always an issue, sometimes creating health and transportation hazards. Canadian fires have been implicated in elevated carbon monoxide concentrations in the U.S., and black carbon particles may influence climates globally. The combination of these issues makes Canadian forest fires a prime target for discussions concerning decreases in emissions from natural sources.



The forest fire emission data are for direct combustion losses only; the total effect is much larger.

Canadian carbon emissions from forest fires and fossil fuels.

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Forest fires' role in meeting Canada's Kyoto commitments

The Kyoto Protocol sets out goals to restrain global warming by limiting carbon emissions and increasing carbon sinks on a national basis.

For Canada, the goal is to reduce greenhouse gas emissions to six per cent below 1990 levels by the 2008 to 2012 commitment period. Negotiations are still underway on the details, but credits for carbon sinks will likely form part of Canada's strategy to achieve the goals.

Modelling estimates of Canadian forest carbon dynamics indicate that fires and other disturbances are important drivers of net carbon sequestration. In fact, in recent years our forests likely have been a small source of carbon, or at best, a small carbon sink, caused primarily by fire and insect disturbances over the past few decades. However, the inclusion of forest issues in meeting Kyoto Protocol commitments (such as defining the managed part of the forest, and which activities should be included) remains to be decided by the countries ratifying the Protocol.

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If Canada includes forest management in its emissions-reporting requirements under the Protocol, carbon losses from fire would need to be calculated. Improved fire management could reduce these emissions, but it is not yet clear if and how emission credits would be given for such activities. These issues will become better defined before the first commitment period, as domestic and international negotiations proceed. However, there are future commitment periods, during which different rules could apply.

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Mitigating forest fires to reduce emissions

Forest fire suppression has been an active part of forest management for decades. Despite direct suppression costs of about $500 million annually, an average of two million ha of forested area has burned annually over the past four decades.

About half of the area burned is in the active fire protection zone. Fires outside the protection zone are often not suppressed unless a community or another value is at risk. Most of the burning is caused by a few large fires, with typically three per cent of the fires burning 97 per cent of the area. Hence, there will always be a few fires that escape and grow quickly during multiple-ignition or extreme fire weather situations, even in areas with a high degree of protection.

Fire management currently aims to protect values at risk, mostly public health and safety, property, infrastructure, and timber.

Recent studies indicate that the allocation of substantially more resources may not be effective at reducing escaped fires and may only postpone large fires until severe fire weather occurs. Modification of fuels on the landscape may limit the spread of large fires by providing fuel breaks or anchor points to aid suppression. This may help to protect communities or specific targets, but it would be difficult to establish and maintain such modifications over large regions. Further, it would be virtually impossible to treat the whole Canadian forest or even a substantial part of it. If we created fuel breaks of 200 m width to restrict the size of an individual fire to 2000 ha, we would need to treat more than 15 million ha to protect the total Canadian forest. This far exceeds the current annual harvested area of about one million ha. Hence, our best hope is to optimize protection of specific areas and not focus on influencing the total area burned nationally.

How much fire does the forest need?

Fire management currently aims to protect values at risk, mostly public health and safety, property, infrastructure, and timber. Carbon itself is not yet valued in the same context. Indeed, if carbon protection became a priority and financial budgets remained unchanged, the emphasis on fire protection would need to balance issues such as the wildland/urban interface (where people and property are at risk) with protection of peat lands, which contain vast amounts of carbon.

Direct carbon losses are through gaseous release of carbon dioxide during combustion, which also releases other gases and particles (smoke). Photo by D. Flanders, Canadian Forest Service.

The difficult question is how much fire does the forest need. The boreal forest comprises about three-quarters of the total Canadian forest, and fire is a dominant process for stand renewal. Biodiversity in the boreal forest depends on fire, with fire exclusion altering the normal forest renewal process, negatively impacting historical ecosystem function. Canada has international agreements regarding biodiversity, where protection of carbon by excluding fire would cause conflicts. But too much fire, caused by a changing climate, could also be detrimental by changing ecosystem function.

Given that the current increase in atmospheric greenhouse gases is driven by fossil fuel emissions, reducing these emissions is likely to be of greater longer-term value in addressing climate change than efforts to reduce fire emissions with marginal gains.

Fire outlook

Some of the largest annual carbon emissions from forest fires in the last four decades have occurred since 1980. Further, despite data limitations, it appears that fire has increased during the past four decades compared to the previous four. Climate model predictions suggest that weather will be more conducive to fire in the future due to warmer temperatures and drier conditions in the boreal forest zone of west-central Canada. Hence, it is likely that carbon emissions from fire will be larger in future Kyoto Protocol commitment periods than in past base periods, recognizing that fire occurrence is highly variable years.

Most of the burning losses in Canada is caused by lightning, which will continue and may even increase if climate warming causes more convective storms. Future human activity in forest areas may increase human-caused fires, but also will provide better access for forest protection. However, this will increase the demand for fire management resources, especially when lives and property are in jeopardy. Forest fragmentation by towns, industrial operations and transportation corridors has little impact on fire growth during severe weather conditions, when a fire can jump obstacles of several hundred metres.

Perhaps the best future activity that will mitigate greater fire impacts involves altering forest fuel types to less flammable ones. Changes in land use could reduce forest areas, and, in some parts of Canada, forest conversion from conifers to deciduous species will slow fire growth. These land use changes themselves would have large impacts on carbon sequestration, and would need to be considered as part of the national carbon balance.

Carbon is also lost indirectly by decomposition of fire-killed vegetation, as well as the forest's reduced photosynthetic fixation of atmospheric carbon dioxide, soon after the fire. Photo by B. Amiro, Canadian Forest Service.

The bottom line is that fire will continue to be a major factor in the Canadian forest and will likely increase if current estimations of future climate change prove accurate. Fire is a natural process in the boreal forest, and our forests have evolved and depend on it. Although forest fire carbon emissions are significant, their reduction may not be economically feasible.

The health of our forests depends on establishing the amount of fire that our forests need and can tolerate, especially in a future environment that will evolve in the presence of increased fire activity.

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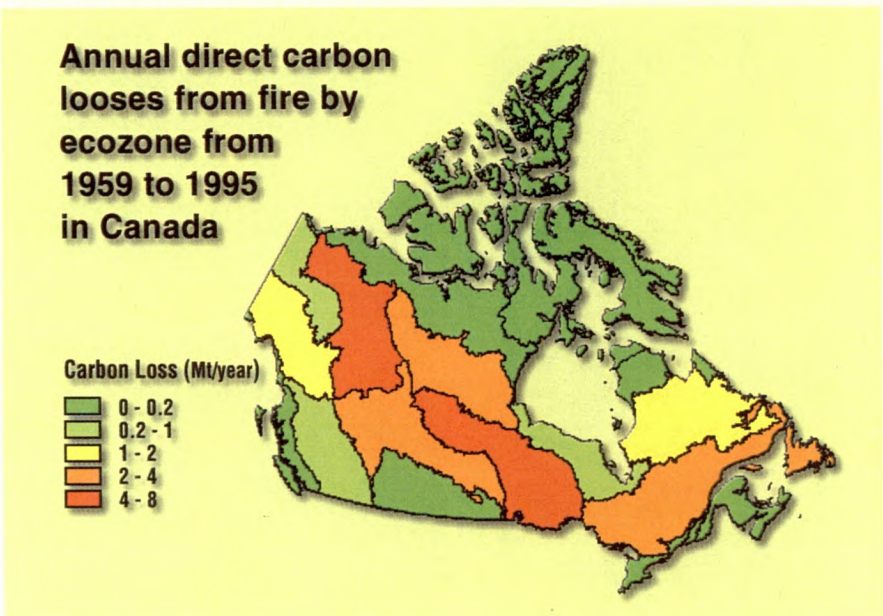

Canadian annual direct carbon losses from fire, by ecozone, from 1959 to 1995. The western boreal ecozones have the greatest fire activity, and release the greatest quantity of carbon.

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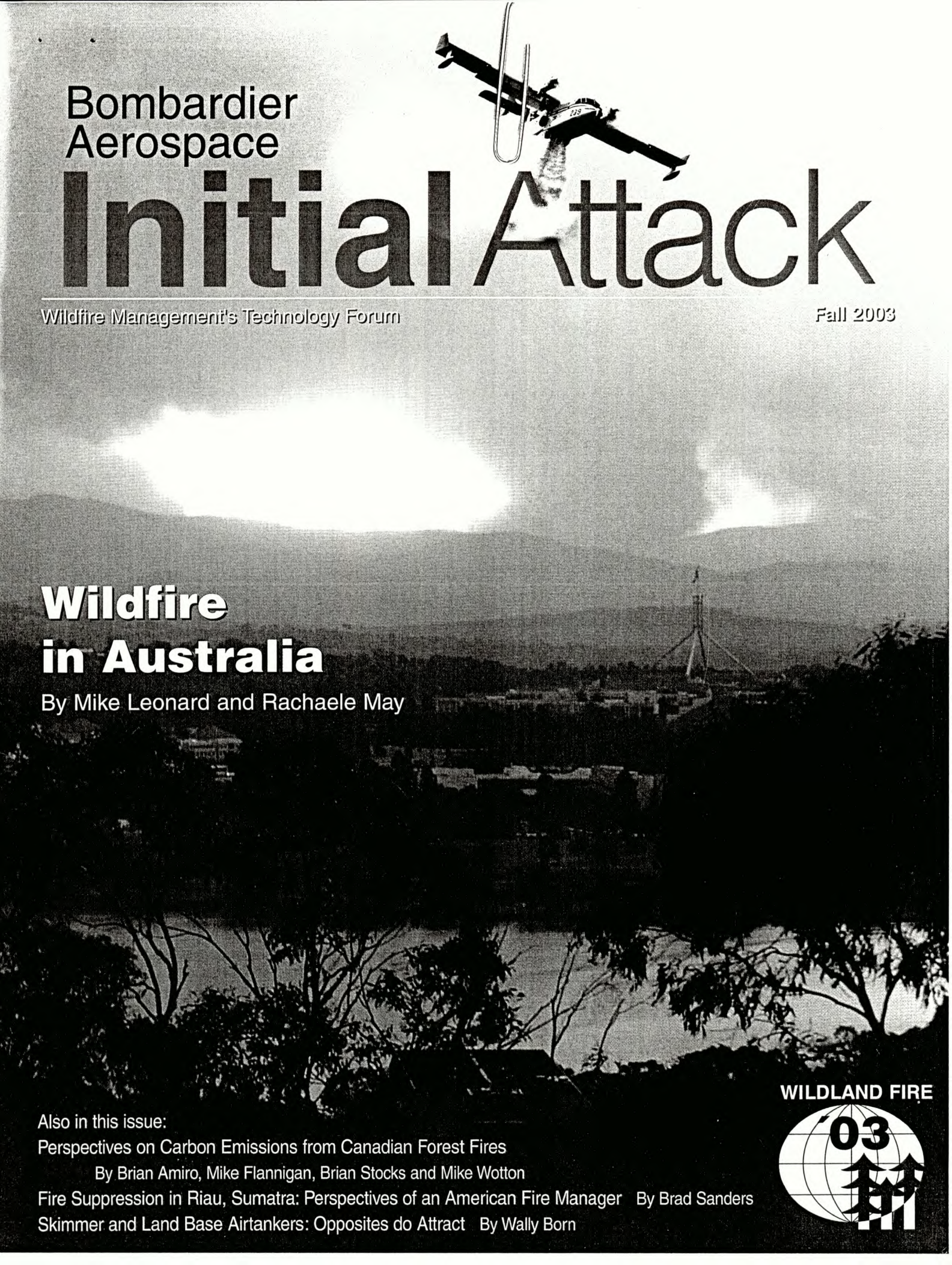

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