Fire Management Adaptation to Future Climate Change in Canada

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Abstract

Forest fires in Canada currently burn 2–3 M ha annually (~0.5% of forest land), causing an estimated $2 B in timber losses. Total annual fire suppression expenditures in Canada are about $500 M. Fire statistics for the last 40 years show an increasing trend in the average annual area burned and this is expected to continue into the future with a changing climate. Global and regional climate models also suggest that there will be a general increase in fire intensity, fire severity and fire season length. This will increase suppression costs and create a greater risk to life and property as the population continues to expand into the ex-urban environment. In order to meet environmental, social and economic goals in the future, fire management must adapt to these changing conditions.

This study examines different fire management scenarios to adapt to future fire regimes. The future fire environment was estimated using data from two global climate models (Canadian CGCM1 and Hadley HadCM3) and the Canadian Forest Fire Weather Index System. Fire management scenarios were based on different levels of fire suppression capability, coupled with economic, social and environmental values. An indication of likely future impacts at the national level are presented.

Introduction

In Canada, stand-replacing crown fires currently burn an average of 2–3 M ha (~0.5% of total forest area) each year (Stocks et al. 2003), with typical fire cycles of 75–150 years depending on the local fire regime. As a result of climate change in the Canadian boreal forest region, future fire regimes are expected to support a general increase in fire intensity, fire severity (depth of burn), and fire season length (Flannigan and Van Wagner 1991, Wotton and Flannigan 1993, Stocks et al. 1998, Flannigan et al. 2001). Change in the fire regime is also expected to have an effect on fire frequency, which may have significant ecological, social, and economic impacts.

The purpose of this paper was to review potential fire management options in adaptation to future climate change and altered fire regimes. National estimates of future area burned, timber and property losses, and fire suppression costs were obtained through a literature review of fire and climate change studies and extrapolation of current cost-loss-area burned relationships to future conditions. Scenarios presenting different adaptive strategies for future fire and forest management are discussed.

Estimating the future fire environment

Several data sources were used to estimate future area burned, fire suppression costs, and losses. Data output from the Canadian Global Coupled Model (CGCM1) (Flato et al. 2000) and the Hadley model (HadCM3GGa1) (Gordon et al. 2000) were used to represent present

(1975–1990) and future (2080–2100) climate conditions across Canada (Flannigan et al. n.d.). These two time periods were used to approximate 1× and 3× CO_2 scenarios and provided estimates of future burning conditions as measured by the Canadian Forest Fire Weather Index System and area burned.

Future fire suppression costs were estimated by extrapolating current funding patterns into the future based on area burned. Future timber and property (eg, buildings) losses were similarly estimated by projecting forward current losses using relationships to area burned. Annual data for total area burned, productive timber area burned, budgeted fire fighting costs, extra fire fighting costs, and property losses for 1970–1995 were obtained from the National Forestry Database Program (Canadian Council of Forest Ministers 1997). This was the latest available published data on fire suppression costs. Total annual fire fighting costs were calculated as the sum of budgeted and extra fire fighting costs. All costs were adjusted to 1995 dollars using an average annual inflation rate of 3%.

Fire-caused loss in timber value was calculated using forestry statistics from the National Forestry Database Program (Canadian Council of Forest Ministers 2003). The average timber value used in this study ($4445/ha in 2001 dollars; converted to $3722 in 1995 dollars for scenario comparisons) was estimated as the total domestic forest product export value ($44.1 B) divided by the total harvested area (993,056 ha) for 2001 in Canada (latest available data). This was assumed to be the average value for all mature and overmature stocked stands on accessible, non-reserved, timber-productive forest land. All other forest land (including immature and regenerating stands on productive forest land) was assumed to have no current value. The value of timber lost in any year was calculated as the product of average timber value, the amount of productive timber area burned, and the proportion of productive timber area represented by mature and overmature stands (44%). While the economic cost of fire on timber supply is complex (Martell 2001), this simple approach to estimating the value of timber loss was used to illustrate the relative impact of different fire management scenarios.

Current and future fire regimes

The historical annual area burned in Canada has been episodic and variable, ranging from 300,000 to 7 M ha (Fig. 1). National fire fighting costs increased significantly after 1979 with the occurrence of 3 consecutive large fire years, and steadily increased since then with the latest years showing fire suppression costs near $450 M. The average annual cost of fire suppression in Canada was $400 M during 1980–1995. This value was used as the average current cost of fire suppression in Canada, as costs during 1975–1979 are unrealistically low for the current fire environment. Productive timber area burned (Fig. 2) shows a similar trend to total area burned. Correlation between current costs, losses, and area burned were generally weak, but productive timber area burned (Timber AB, measured in hectares) and property loss (P Loss, measured in 1995 dollars) produced the following significant regressions with total area burned (Total AB, measured in hectares):

[1] $\text{Timber AB} = 60{,}668 + (0.282 \times \text{Total AB})$, $R^2 = 0.61$, $P = 0.001$

[2] $\text{P Loss} = 4{,}266{,}600 + (0.812 \times \text{Total AB})$, $R^2 = 0.24$, $P = 0.01$

Fire suppression cost (FS Cost, measured in 1995 dollars) was weakly correlated to property loss and timber area burned but it was strongly correlated with last year's fire suppression cost (LYFS Cost, measured in 1995 dollars) and total area burned:

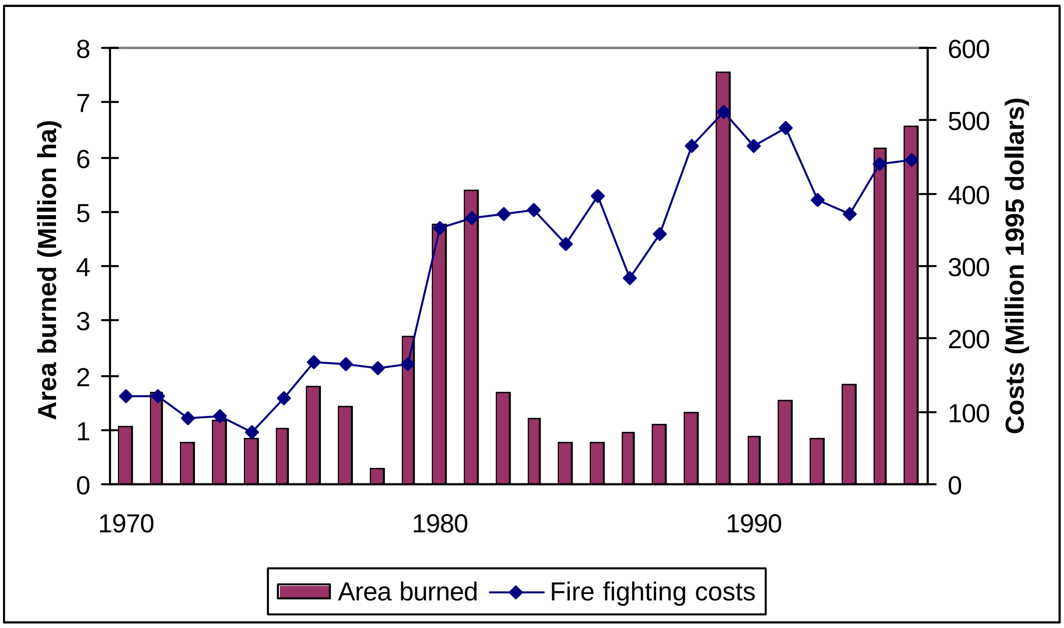

Figure 1. Total area burned and total fire fighting costs (in 1995 dollars) for Canadian forest fires. Fire fighting costs represent the sum of budgeted pre-fire suppression and extra fire fighting costs.

[3] FS Cost = 26,751,000+(0.84×LYFS Cost)+(14.686×Total AB), $R^2 = 0.86$, $P = 0.001$

Both global climate models (GCMs) suggest that burning conditions will become more severe over most of Canada by the end of this century (Fig. 3). The Canadian model indicates an average increase of 74% in total area burned in Canada, while the Hadley model indicates an increase of 118% (Flannigan et al. n.d.). Using these future estimates and the 1970–1995 average of 2.16 M ha, the average annual area burned during 2080–2100 was estimated to be 3.7–4.7 M ha.

To estimate average 2080–2100 fire suppression costs, annual fire suppression costs were calculated for 1996–2100 using equation 3 for both of the GCM estimates of future area burned. For the Canadian GCM estimate, area burned was increased by 0.59% annually from the current value of 2.16 M ha to reach the average 2080–2100 value of 3.7 M ha; the Hadley GCM estimate used an annual increase of 0.8% to reach an average 2080–2100 value of 4.7 M ha. The average fire suppression costs for 2080–2100 by the Canadian and Hadley GCM estimates were $502 M and $582 M (measured in 1995 dollars). Using the area burned estimate of 3.7–4.7 M ha, the annual timber loss was calculated by equation 1 to be 1.13–1.39 M ha of stocked, timber-productive forest land. The annual harvestable (mature and overmature) timber area burned was 497–610 K ha with a calculated value of $1.83–2.27 B. Annual property losses were estimated using equation 2 at $7.3–8.2 M.

Future fire management options

The increasing fire danger trend of future fire regimes found in this study is in agreement with the predictions of other published literature (Clark 1988, Flannigan and Van Wagner 1991, Price and Rind 1994, Weber and Flannigan 1997, Stocks et al. 1998). While it is

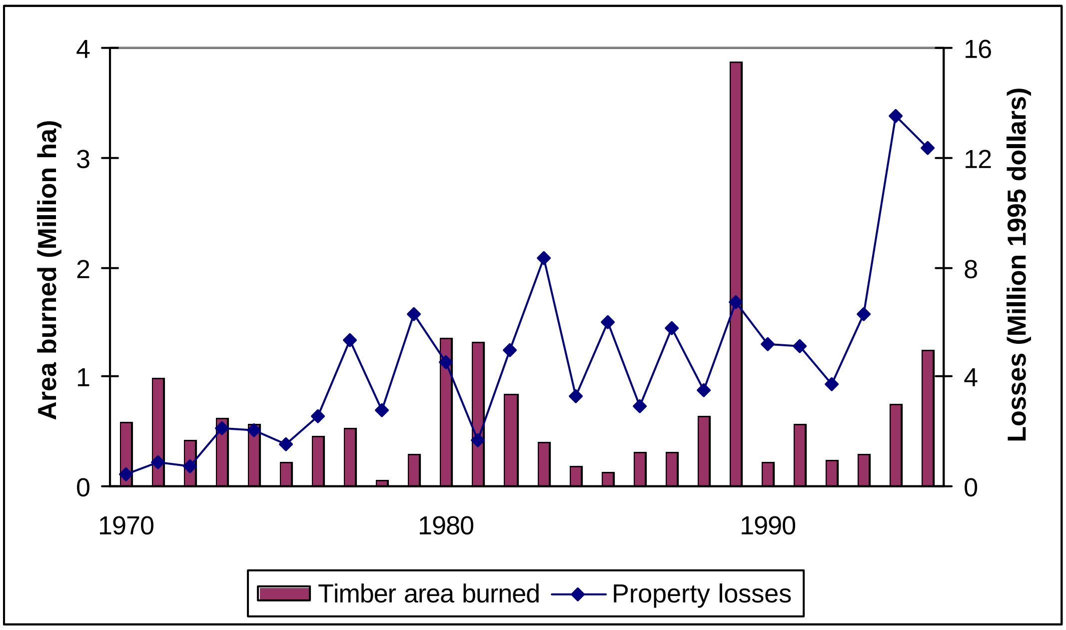

Figure 2. Timber-productive forest land burned by forest fires, and property losses to forest fire.

difficult to determine the ecological, social and environmental impacts of future fire regimes, it is possible to estimate future fire activity and forest condition using GCM estimates of future climate and historical relationships between fire, weather and fire suppression statistics.

It is clear that greater fire danger in the future will cause an increase in area burned, and timber and property losses. Higher fire suppression expenditures are also expected in order to maintain the current level of preparedness and suppression capability. Historically, fire budgets increased with annual area burned, as demonstrated by the strong relationship between fire suppression funding, last year's fire suppression costs and area burned. The difficulty in predicting fire season severity in advance is probably the main reason that funding is driven by the previous budget (as a pre-fire budget estimate) and the amount of area burned during that year (influencing extra fire fighting costs). Continuing with this funding pattern in the future will result in a 25–45% increase in fire suppression costs (compared to 1980–1995).

Future fire management options may include objectives that are based on area burned, funding levels, or losses. Different future fire management options can be tested to determine the relative impacts on costs, losses, and area burned using historical statistics but there is difficulty in doing this because previous data does not show a strong, direct relationship between funding and area burned. In a simulation study to examine the effect of increased pre-fire budgets and levels of protection in Ontario, McAlpine and Hirsch (1999) found that the percentage of escaped fires quickly decreased to about 6% with minimal funding increments. However, significantly greater funding beyond this level only reduced the percentage of escaped fires to near 4%. Obviously, the marginal benefit of increased funding decreases at higher funding levels (Martell 2001) so that even infinite funding cannot control all fires. Currently in Canada, roughly 95% of the area burned is caused by 5% of all fires. Therefore, it could be argued that fire suppression is currently operating near its most

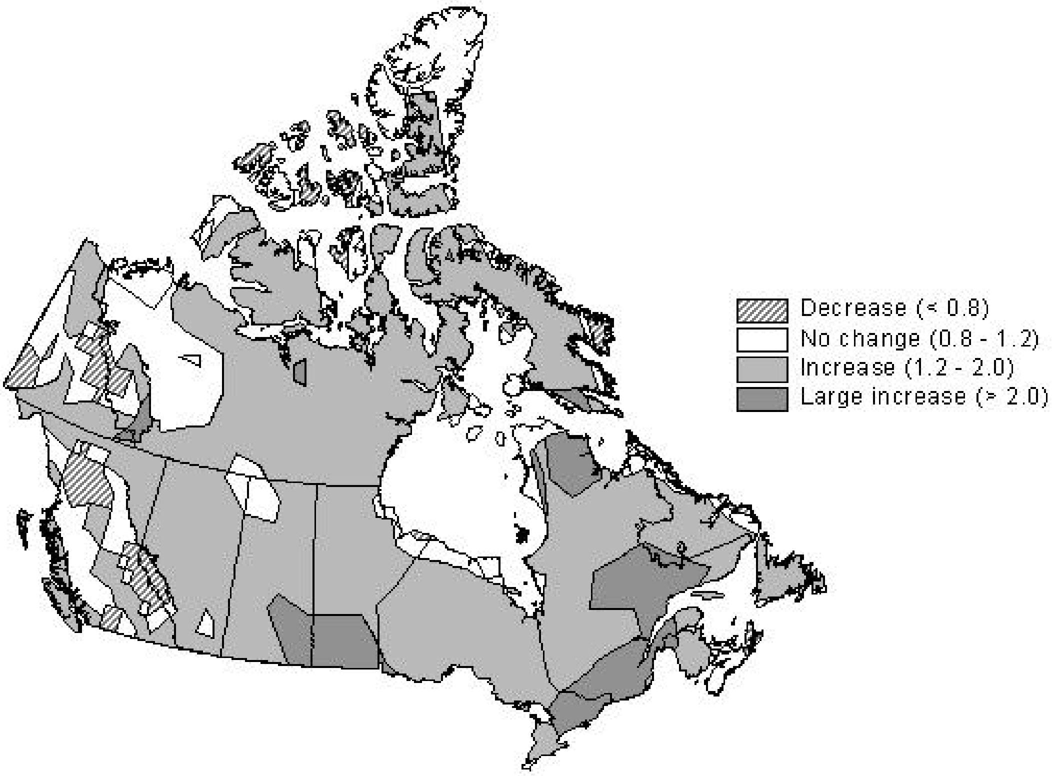

Figure 3. Changes to the seasonal severity rating (SSR) for fire in Canada as a ratio of 3x CO_2 (about 2100) scenarios to the 1xCO_2 (present) state (value of 1 indicates no change). The SSR reflects the difficulty of controlling fire, based on weather conditions, with higher values indicating more difficulty. Estimates for the extreme west of the country are based on a regional climate model (Flannigan et al. 2001), whereas the rest of the country is based on averaging results from the Canadian and Hadley general circulation models (Logan et al. 2003). Regions where the models don't match are uncertain and are marked as "no change".

effective level (although it may or may not be at it's most efficient level in terms of costs). If that is true, then substantial changes in the pre-fire budget may only cause small changes in the percentage of escaped fires. On the other hand, a small change in the latter could have a large impact on the amount of area burned, extra fire fighting costs (which historically, is often similar to or greater than the pre-fire budget) and therefore, total fire costs. Given that the exact relationship between fire suppression funding and area burned is still unclear, two future scenarios are examined using the assumption that an increase or decrease in funding will cause a proportional decrease/increase in area burned. Although this assumption is probably not quantitatively true, it provides a relative means to make initial comparisons between scenarios.

If a future priority was to restrict the rising costs of fire suppression, one option is to freeze fire funding at current levels. In this scenario, the main concern would be the resulting impact on area burned, and timber and property losses. In this case, the annual fire suppression budget for 2080–2100 was held at the current (1980–1995) level of $400 M, representing a funding level that was 20.3 and 31.3% lower than the two GCM estimates ($502 and $582 M) for 2080–2100. The annual area burned for this scenario was 4.5–6.2 M ha (representing a 20.3% and 31.3% increase in the annual area burned for the two GCM estimates) and the annual harvestable timber area burned was 587–792 K ha. The greater amount of area burned resulted in larger annual timber and property losses of $1.98–2.99 B and $7.9–9.3 M, respectively.

Another potential future objective is to maintain the current average annual area burned (2.16 M ha) in the future. Fire suppression costs would clearly be impacted in this scenario. The current annual area burned (2.16 M ha) represents a 42.5% and 54.1% decrease in future area burned from the two GCM estimates. Assuming that this objective could be met by increasing fire suppression funding by the same proportion, the annual cost for this scenario was considerably higher ($715–897 M) but the average annual harvestable timber area burned (294 K ha), timber losses ($1.00 B) and property losses ($6.0 M) remain the same as the 1970–1995 averages.

Obviously, there are a lot of other factors to consider when comparing future scenarios. Additional adaptive strategies include increased salvage logging to reduce timber losses, and fuels management through forest harvest planning. The latter can reduce forest flammability by species conversion, and restrict fire spread by compartmentalizing the forest (Hirsch et al. 2003), reducing the amount of future area burned. There are also many other non-timber forest values to be considered including tourism, aesthetics, wildlife, biodiversity, water supply, carbon storage, etc. Another important factor is increasing forest access. This will increase the amount of accessible productive forest land for commercial use, and expand the wildland urban interface. Therefore, increased fire suppression capability will be required in the future to protect a larger amount of forested area.

From these scenarios, it is apparent that future fire management policy will have a substantial impact on fire suppression costs, losses and area burned. Increased economic loss to the forest sector is a likely scenario, although the extent is dependent on the severity of future fire regimes and the ability to adapt to changing conditions. The scenarios suggest a substantial downside to decreasing fire suppression funds due to lost timber value, and a considerable reduction in timber loss by a comparatively modest increase in funding. However, this depends entirely on the method of forest timber valuation (eg, stumpage versus export value), and on fire suppression efficiency and effectiveness as related to funding. The economics of fire and forest management is an area of research that has been largely neglected in the past but will become increasingly more important as climate change progresses.

Conclusions

A substantial increase in annual area burned is expected under future fire regimes. This is expected to occur even if the current level of fire suppression capability is maintained using the current fire suppression funding pattern, which increases funding with area burned. Decreased fire suppression funding will reduce fire suppression costs, but it could result in a substantial increase in area burned and fire losses. Alternatively, an increase in suppression funding may result in a considerable reduction of timber loss. The degree to which these results are realized is dependent on the severity of future fire regimes, and fire suppression efficiency and effectiveness in relation to funding level.

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