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Projections of future fire activity and area burned in Canada

M.D. Flannigan
Canadian Forest Service, Northern Forestry Centre, Edmonton, Alberta, Canada

K.A. Logan, B.J. Stocks & B.M. Wotton
Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario, Canada

B.D. Amiro & J.B. Todd
Canadian Forest Service, Northern Forestry Centre, Edmonton, Alberta, Canada

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ABSTRACT: In this study we use historical relationships between weather, the Canadian Fire Weather Index (FWI) System components and ecozone area burned in Canada on a monthly basis in tandem with output from GCMs from the Canadian Climate Centre and the United Kingdom Hadley Centre to project future area burned. Our results suggest significant increases in area burned but there are large regional variations in fire activity with with the Canadian GCM some ecozones show little change in area burned in the future. On average, area burned in Canada is expected to increase by 74-118%. In our initial assessments, we assume that the future vegetation mosaic will have similar fuel characteristics to the present situation. Refined estimates will be developed to include changes to fuel types in a changing climate with particular emphasis on the feedbacks caused by a changing fire regime. Other considerations such as changes in ignitions, fire season length, human activity (fire management and land use activities) that influence area burned will also be discussed.

1 INTRODUCTION

Forest fires shape and maintain many of Canada's forests. Fire also influences biodiversity and the biogeochemical cycling in Canadian forests. During the 1990's there was an annual average of close to 10,000 forest fires burning about 2.8 Million ha in Canada. These fires were typically crown fires that were responsible for renewal of stands (Weber and Stocks 1998). Fire activity is strongly influenced by four factors – weather/climate, fuels, ignition agents and humans (Johnson 1992; Swetnam 1993). Climate and the associated weather are dynamic and are changing due to changes in the earth's orbital parameters, solar output and atmospheric composition. Recently, our climate has been warming due to an influx of radiatively active gases (carbon dioxide, methane etc.) as a result of human activities (IPCC 2001). This altered climate which is modelled by General Circulation Models may have a profound impact on fire activity.

In Canada, weather/climate is the most important natural factor influencing forest fires (Hely et al. 2001) as fuel and ignitions are not limiting fire in most cases. In addition to being the key factor, weather also plays an indirect but critical role for the fuel and ignition factors. Weather controls fuel moisture which largely determines if the fuel will smoulder or burn. Also, lightning ignition which is responsible for most of the area burned in Canada is a function of the weather, i.e., thunderstorms which is the result of atmospheric moisture and instability.

The objective of this study is to predict how much area burned will occur in Canada by the end of the 21st century. Most previous work has addressed how fire weather will change with a changing climate (Flannigan et al. 1998; Stocks et al. 1998; Flannigan et al. 2000). Most studies suggested that there would be a significant increase in the severity of fire weather though there would be large regional variation with some regions having no change or even a decrease in fire weather severity.

2 DATA & METHODS

Daily data were collected from both the Canadian Climate Centre (CCC) model and the Hadley model for two time periods. For the CCC model 1975-1995 was considered to correspond to a $1xCO_2$ scenario, while 1975-1990 was the $1xCO_2$ scenario for the Hadley model. The CCC model used was the First Generation Coupled GCM (CGCM1). This model included both greenhouse gas and sulphate aerosol forcing contributing to a 1% increase in CO_2 per year. At this rate, the time period 2080-2100 roughly corresponded to a $3xCO_2$ scenario. The grid spacing is approximately 3.75° longitude by 3.75° latitude. The Hadley model, HadCM3GGa1, contained only greenhouse gas forcing and output 2080-2099 as its $3xCO_2$ scenario. The grid for the Hadley Model had slightly better resolution at 3.75° longitude by 2.5° latitude. The modelled variables examined from both models were maximum temperature, precipitation, wind speed, and humidity. Only daily noon values were used in the analysis. Noon temperature was estimated as the maximum daily temperature – 2.0 °C. All analyses used a fire season defined as May 01 to September 30. Additional information on these GCMs can be found in Flato et al. (2000) and Gordon et al. (2000).

In a recently completed study (Flannigan et al. In prep.), monthly area burned in most of the forested ecozones of Canada (Figure 1) for the period 1959-1997 was related to weather and fire weather indexes. Area burned data came from the Canadian large fire data base (Stocks et al. 2002). The study was an updated and modified version of the work done by Harrington et al. (1983) and Flannigan & Harrington (1988) who related monthly provincial area burned to the Canadian Fire Weather Index System (Van Wagner 1987) components and to the weather. The relationships in the most recent study were able to explain 39-67% of the variance. Using these relationships the monthly area burned for each of the ecozones was calculated for the $1xCO_2$ and $3xCO_2$ scenarios for the CCC and Hadley models. Monthly area burned for May to September was summed for each year and then averaged over all the years. The $3xCO_2/1xCO_2$ ratio of averaged annual area burned was determined and then multiplied by the observed area burned for each ecozone to obtain a prediction of area burned.

3 RESULTS & DISCUSSION

Table 1 shows the ratio of $3xCO_2/1xCO_2$ area burned predictions using the two GCM models. Notice that the Hadley model predicts more area burned than the CCC model for most ecozones. For all ecozones, the Hadley model suggested an average ratio of 2.52 whereas the CCC model had a ratio of 1.76. Table 2 shows the observed annual area burned by ecozone along with the predicted area burned for each ecozone and all ecozones. The ratio of predicted area burned over actual area burned was 2.18 for the Hadley model as compared to 1.74 for the Canadian model. Note that these ratios are different than the average ratios in table 1 as the table 2 ratios are weighted by the actual area burned in each ecozone. The observed area burned for all ecozones used in this study accounts for 97% of the area burned in the large fire data base. There is significant variation between different ecozones with some ecozones, at least in the Canadian model, showing little change in area burned. In both tables it is apparent that the Canadian model had trouble with ecozone 14 (see figure 1) in that for both the $1xCO_2$ and $3xCO_2$ scenarios the calculated area burned was zero ha. Ecozone 14 is mountainous and GCMs with their coarse spatial resolution should be used with caution in complex terrain regions.

Table 1. Ratio of $3xCO_2/1xCO_2$ area burned by Ecozone using the Canadian and Hadley GCMs

Ecozone	Canadian	Hadley
4	1.39	1.57
5	2.12	2.11
61	1.67	1.92
62	1.63	1.72
9	1.09	3.45
11	2.79	3.81
12	3.38	3.32
14	0.00	2.24
All Ecozones	1.76	2.52

Table 2. Predicted area burned by Ecozone for the Canadian and Hadley GCM $3xCO_2$ scenario

Ecozone	Actual AnnualArea Burned ('000s of ha)	Canadian ('000s of ha)	Hadley ('000s of ha)
4	366	508	574
5	387	821	817
61	493	824	947
62	154	252	266
9	218	237	751
11	32	88	120
12	106	360	353
14	23	0	51
All Ecozones	1,779	3,090	3,879
Ratio ($3xCO_2$/Observed)		1.74	2.18

These results suggest a significant increase in area burned in Canada which could have important implications on forestry activities, community protection and carbon budgets. Emission of carbon dioxide from forest fires on average already over the last 40 years are equivalent to 20% of fossil fuel emissions in Canada (Amiro et al. 2001). Canada already spends half a billion dollars a year on direct suppression costs - if this prediction is anywhere close to being accurate these suppression costs could rise significantly.

The increases in area burned are similar to those suggested in other studies. For example, Flannigan and Van Wagner (1991) suggested that area burned in Canada would increase by 44% for a $2xCO_2$ scenario due to an increase in Seasonal Severity Rating (SSR – a derivative of the Canadian Fire Weather Index). Price and Rind (1994) who looked at lightning ignitions in the U.S.A. suggested that area burned would increase by 78% for a $2xCO_2$ scenario based on a 44% increase in lightning fire ignitions. In this study, we did not address any changes in the number of ignitions. Also, in this initial assessment, we assume that the future vegetation mosaic will have similar fuel characteristics to the present situation. Future studies will include changes to fuel types in a changing climate with particular emphasis on the feedbacks caused by a changing fire regime. Changes in fire season length that are anticipated with climate change are not included in this present study. Wotton and Flannigan (1993) found that the fire season length in Canada increased by an average of 22% or 30 days using the Canadian GCM $2xCO_2$ scenario. Lastly, future human activities could impact on the area burned numbers. Humans start forest fires but they also try to suppress most of the fires. People can fragment the forest with agricultural, urban development and transportation corridors. Given all these factors that are not included in this preliminary study we feel that our numbers may be conservative.

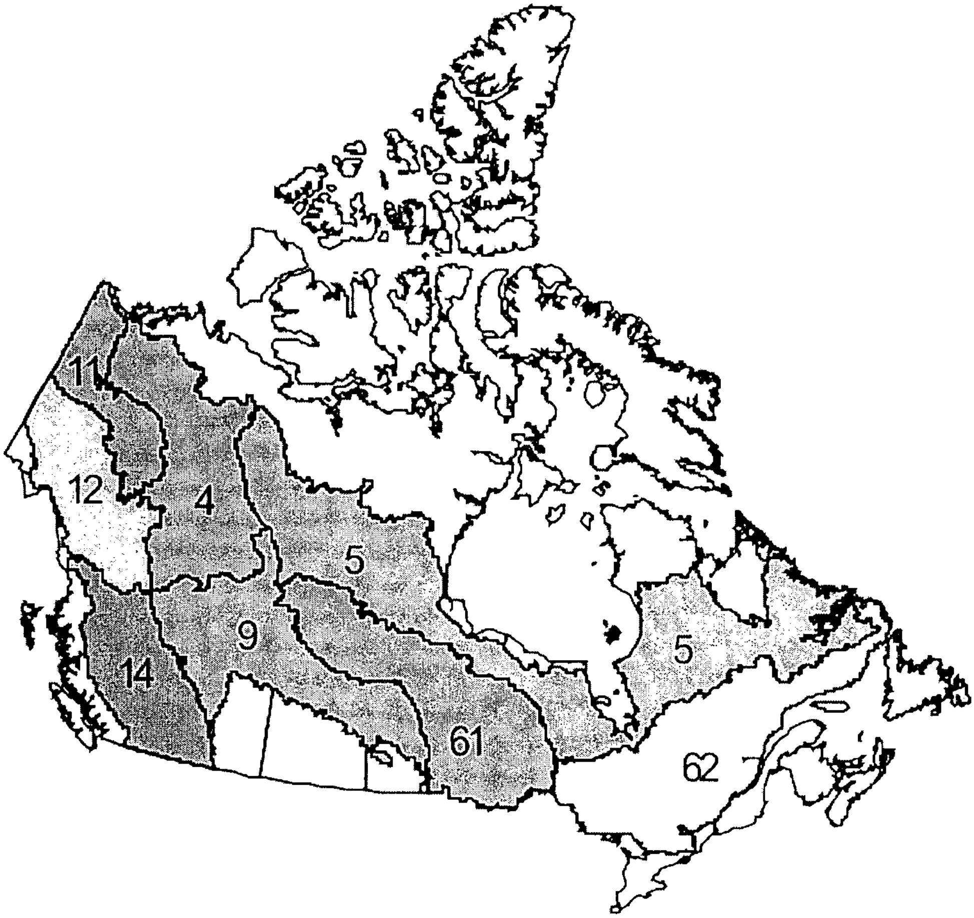

Figure 1. Ecozones of Canada used in this study were modified from Ecological Stratification Working Group (1995).

4 SUMMARY

Results from our study suggests that area burned in Canada could increase by 74-118% by the end of the 21st century. This could have significant impact on forest ecosystems and the forest industry. This initial study uses static vegetation; future work will use a dynamic vegetation model that accounts for the changes in climate and the fire regime. Other considerations including fire season length and changes in the number of ignitions should be included in future endeavours.

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Edited by
Domingos Xavier Viegas
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