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MODELING FIRE BEHAVIOUR, FUEL CONSUMPTION, AND WILDLANDFIRE CARBON EMISSIONS IN CANADIAN AND RUSSIAN BOREAL FORESTS

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INTRODUCTION

Wildland fires are estimated to burn between 12 and 20 million ha annually across the circumboreal forest. Boreal fire activity is increasing, and the amount of annual area burned just in North America has doubled over the last two decades. Wildland fire carbon emission rates are known to be highly variable because of fuel and weather conditions, which influence fire behavior. The boreal forest is characterized by large fires, and there is large spatial variability in carbon emissions as any one fire can involve numerous fuel types as it spreads across the landscape under continually changing weather or burning conditions. The purpose of this presentation is to provide a brief overview of the current system being used to model direct carbon emissions in Canada for annual national reporting, to discuss the potential for applying this methodology to Russian boreal forests, and to present an example of this application using Russian data.

BOREAL FIRE BEHAVIOUR

Wildland fire carbon emission estimates in Canada are based on the fuel consumption algorithms found in fire behavior models developed using empirical data collected on experimental burns and wildfires (Quintilio et al. 1977; Stocks 1987, 1989; Stocks et al. 2004). Much of the data was collected in *Pinus banksiana* stands, which is a large and frequently burned forest component of the North American boreal zone. Similar fire behavior data exists for Russian *Pinus sylvestris* stands from the Russian FIRE BEAR Project (Table 1) providing an initial start for modeling fire behavior in Russian forests. Comparing Russian and Canadian models for similar boreal species may also assist in model development for other boreal trees (e.g., *Populus*, *Larix*, *Picea* spp.) where data are limited. For instance, it may be possible to calibrate Canadian models to Russian forest conditions with minimal data if species show similar load, distribution, and flammability of the fuel complex. As another example, forest floor fuel consumption in Canadian forests was found to be largely dependent on initial fuel load and longer term drying conditions, regardless of species or stand type.

Comparing forest floor fuel consumption in Russian and Canadian pine forests could assist in adapting the Canadian forest floor model to Russian forests. To a large degree, if the basic relationships between fuel drying and weather can be established (from existing or new models), then fuel consumption can be modeled by determining the type of fire (crown vs. surface fire) and modeling the fuel load in each of the stand compartments that will burn (litter, duff, dead woody debris, bark, foliage, etc.).

Table 1. Summary[1] of range of burning conditions and fire behavior data collected at experimental burning projects in Canadian and Russian boreal pine forests.

Country	Number of plots	BUI [2]	ISI [2]	FWI [2]	Fire rate of spread (m/min)	Head fire intensity (kW/m)	Carbon emissions rate (kg/m^2)
Canada	42	24–108	3–27	8–56	1–70	134–93,476	0.2–2.8
Russia	11	24–85	1–9	9–25	1–27	183–23,824	0.5–1.5

[1] Sources: Quintilio et al. 1977; Stocks 1987; Stocks 1989; Stocks et al. 2004; McRae et al. (unpubl. data).
[2] BUI = Buildup Index, ISI = Initial Spread Index, FWI = Fire weather Index.

MODELING BOREAL CARBON EMISSIONS

The Boreal Fire Effects Model (BORFIRE) (de Groot 2006) was used to estimate North American and Russian carbon emissions from fires in *Pinus*. As an initial comparison, fire behavior and fuel consumption sub-models in BORFIRE were parameterized using Canadian and Russian pine data. The model was initialized with standard estimated pre-fire fuel loads for mature pine stands. This included live tree biomass (coarse roots, fine roots, stemwood, branchwood, foliage), standing dead tree biomass (stemwood, branchwood), dead and downed woody debris (medium and course woody debris), and forest floor organic matter (surface litter, duff). The model was run using the same burning conditions, as defined by component values of the Canadian Forest Fire Weather Index (FWI) System, which are used to drive BORFIRE sub-models.

In a second simulation exercise, recent historical fire weather data was collected and summarized to provide a representative range in Russian and Canadian burning conditions, as measured by the FWI System. Fuel consumption and carbon emissions from pine stands were calculated and summarized for both countries. Potential for developing fire behavior models for other Russian boreal tree species and applying this carbon emissions methodology on a national scale in Russia is discussed.

SUMMARY

Carbon emissions in *Pinus banksiana* and *P. sylvestris* stands were quite similar under the same simulated burning conditions (Fig. 1). However, carbon emission estimates were sensitive to pre-fire fuel loads, which can vary due to site quality, stocking

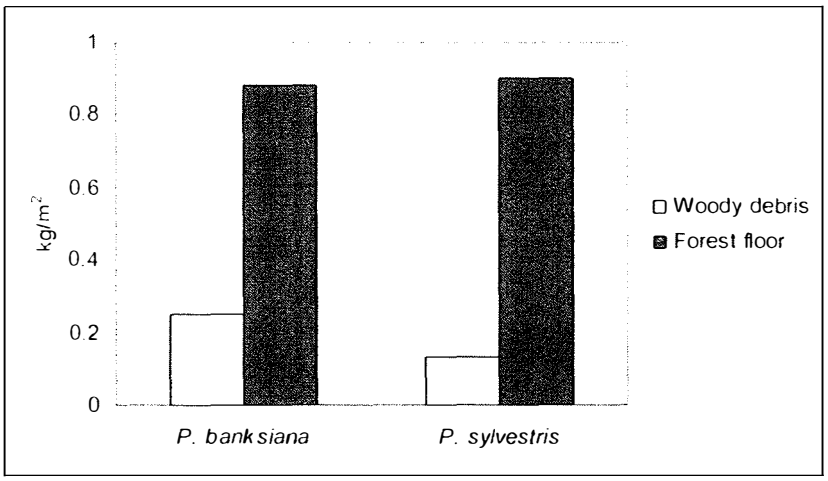

Figure 1. Comparison of estimated carbon emissions from surface fuels in Canadian *Pinus banksiana* and Russian *Pinus sylvestris* mature stands (Duff Moisture Code=35; Drought Code=300; Buildup Index=54). Total stand carbon emissions will depend on fuel load and degree of crown fire involvement.

level, and age. This indicates the importance of using accurate growth and yield models (or other source of fuel load data) to initialize fire effects models for calculation of carbon emissions. Another factor that could cause significant differences in total carbon emissions between *P. banksiana* and *P. sylvestris* is crown fire development. Crowning significantly increases carbon emissions, and the crown fire threshold (measured by the critical surface fire intensity) will vary depending on the live crown base height. Reliable modeling of the crown fire threshold also requires accurate stand growth models. However, it should be noted that surface fires are a much more common event on Russian fires than in North America. These findings will be used to develop similar models for other Russian tree species.

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