Boreal Forest Composition and Biomass Storage Under Changing Fire Regimes in Canada

Introduction

Canada has a massive forest resource that serves as a large global carbon storage unit. Large-scale natural disturbances, such as fire, play a significant role in determining if Canada's forests are a carbon sink or source in any given year. The stand-level boreal fire effects model (BORFIRE) was developed to provide estimates of the impact and sensitivity of carbon dynamics in a changing fire regime.

Fire in the boreal forest

A naturally regenerating forest 3 months after fire

- Of the 415 million hectares of Canadian forest, approximately 340 million hectares are considered boreal (Lowe et al. 1996).
- Stand-replacing crown fires burn an average of 2 million hectares per year in Canada (Stocks 1991)
- Climate models estimate an average Canadian summer temperature increase of approximately 5-10°C for the period 2080-2100 (3 x CO_2) (Flannigan et al. 2000).
- A warmer future climate is estimated to increase the fire season in Canada by approximately 22% or 30 days (Wotton and Flannigan 1993).
- Fire intensity and fire severity are expected to increase as a result of climate change.

How BORFIRE Works

Fire Ecology Traits

Different tree species in the boreal forest have their own fire survival and post-fire regeneration strategies. For example, some species most successfully regenerate from seed, others from vegetative sprouting from the roots or root collar. Another example includes individual species tolerance to competition for site resources. These fire survival and post-fire regeneration and recruitment strategies influence the likelihood of each species to successfully survive in an altered fire regime.

Table 1. Fire related characteristics of various boreal forest tree species.

Ecological characteristics	Jack pine	Black spruce	White spruce	Aspen	Birch	Balsam fir
Fire strategy	Fire evader, fire resister	Fire evader, fire avoider	Fire avoider	Fire endurer, fire invader	Fire endurer, fire invader	Fire avoider
Regeneration method	Canopy-stored seed	Canopy-stored seed, periodic seeding	Periodic seeding	Re-sprouting from roots, wind-disseminated seed	Re-sprouting from root collar, wind disseminated seed	Periodic seeding
Bark protection from fire	Moderate	Low	Low	Very low	Very low	Very low
Season fire effect	None	None	Self-seeds only after autumn fire	Does not re-sprout if burned before leaf flush	Does not re-sprout if burned before leaf flush	None
Age to reproduction (years)	20	25	25	5	5	25
Maximum life span (years)	150	250	350	150	150	200
Shade tolerance	Intolerant	Moderately intolerant	Tolerant	Intolerant	Intolerant	Tolerant

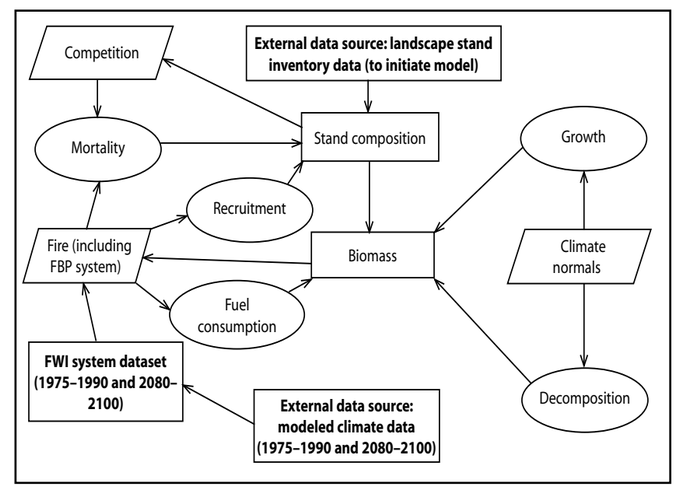
Model Inputs

Climate data—Current and future climate data is required to model the timing of leaf flush, leaf fall, seed ripening, and herbaceous curing. Daily temperature, humidity, wind speed, and precipitation are also used as inputs into the Canadian Forest Fire Weather Index (FWI) System to calculate burning conditions.

Fire cycle—BORFIRE uses the historical fire cycle to determine the probability that a forest stand will burn in any given year. The future fire cycle is determined by proportionally changing the fire cycle according to the change in FWI System values in the future climate.

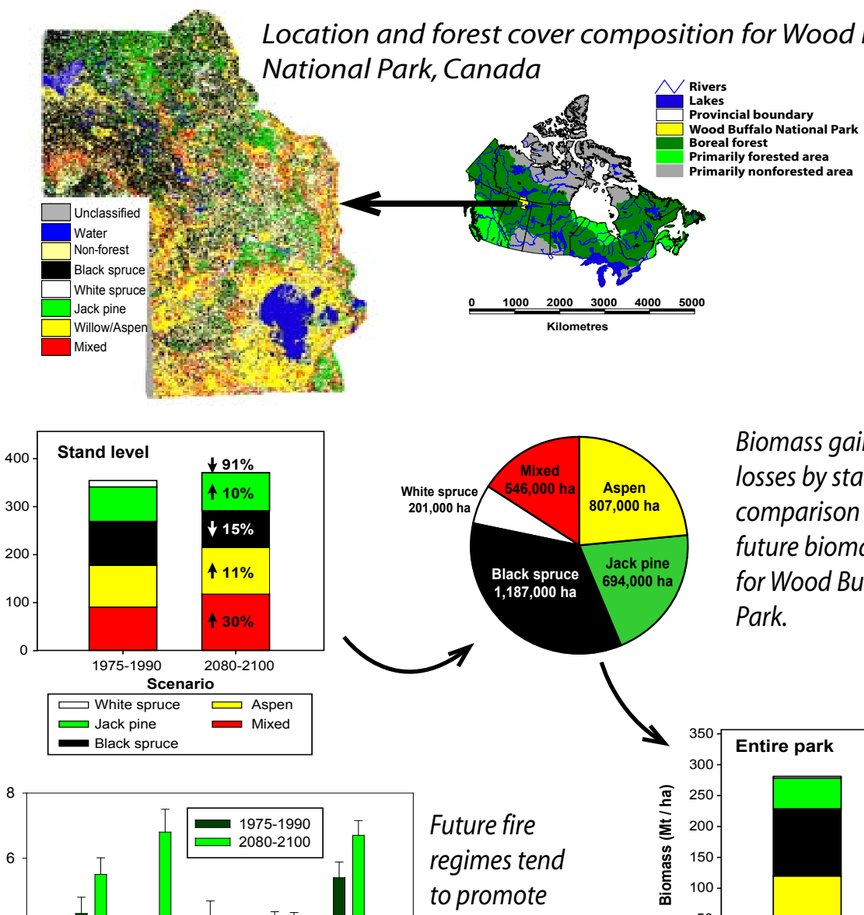
Biomass and carbon—BORFIRE estimates biomass dynamics according to live and dead material and both above- and below-ground pools. The model accounts for above and below-ground tree growth (including leaves, roots, and woody material) and decomposition of dead biomass such as branch wood, falling dead trees, leaf litter, and forest floor organic material.

Fire and fire effects—BORFIRE identifies burning conditions from monthly FWI System distributions and then calculates the fire's rate of spread, fuel consumption, and fire intensity from the Canadian Fire Behavior Prediction (FBP) System. Fuel consumption is then used to adjust the various biomass pools accordingly. BORFIRE uses the physical fire characteristics in mortality and recruitment models for each tree species. These models require data such as crown scorch and cambium death, season of burn, depth of duff remaining, status of leaf flush, and other important variables.



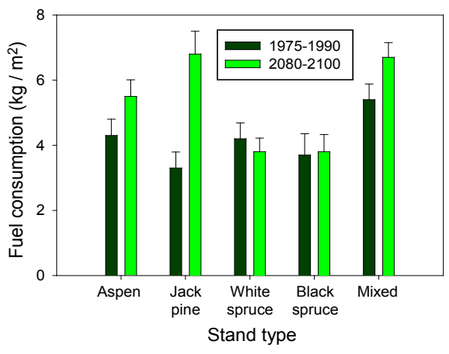
BORFIRE in Action *Modified from de Groot et al. 2003*

The following figures show the results of a case study that used BORFIRE to estimate future biomass and species composition for the period 2080–2100 (3 x CO_2 scenario) in Wood Buffalo National Park, Canada. Future climate was modeled using the Canadian Global Coupled Model (Flato et al. 2000). The fire cycle was estimated to decrease from 78 years to 56 years in the future climate.

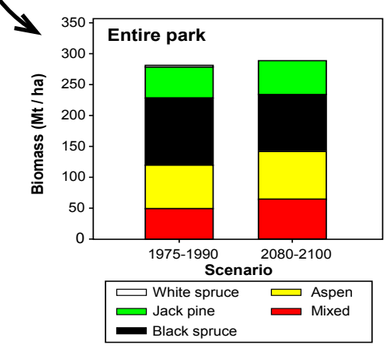


Location and forest cover composition for Wood Buffalo National Park, Canada

Biomass gains and losses by stand type and comparison of current and future biomass storage for Wood Buffalo National Park.



Future fire regimes tend to promote deeper burns and greater fuel consumption.



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