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Changing fire regimes and carbon storage in the Canadian boreal forest

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The circumpolar boreal forest stores about 800 Gt carbon over an area of 1.4 billion ha, approximately one-third located in Canada. Wildland fire is a prevalent disturbance in the boreal forest and has a major influence on carbon dynamics. In Canada, about 9,000 wildland fires burn 2.8M ha annually, resulting in average annual direct carbon emissions of about 27 Tg. The average annual area burned in Canada has increased sharply during the last 30–40 years, causing the boreal forest to shift from a carbon sink to a carbon source during that time period. This is due to direct carbon losses by wildfire and a shift towards a younger age-class structure in the boreal forest, which reduces the current carbon sequestration rate of the forest. However, the carbon sequestration rate of young age-classes will increase over time as forest stands grow, affecting future forest carbon balance.

The increase in fire activity during the last few decades is an indicator of changing fire regimes as climate change progresses. Future fire regimes are expected to be characterized by increased fire intensity, fire frequency, and fire severity (or fuel consumption), longer fire seasons, and higher rates of lightning- and human-caused fire. Changing fire regimes will have a direct and immediate impact on forest carbon storage, but it will also affect future carbon sequestration rates by its ecological impacts. Boreal species have adapted to the fire environment over millennia through various fire ecology traits. For example, increasing fire frequency in the future will favour quickly re-sprouting species (e.g., some hardwood species) over species that require decades to produce a reliable seed crop (e.g., conifer species). Hardwood species such as aspen are generally faster-growing than conifers, so any shift in forest species composition

would also affect forest carbon sequestration rates.

This study examines the range of potential impacts of future changing fire regimes on forest carbon storage in the Canadian boreal region using the Boreal Fire Effects (BORFIRE) Model. Future fire regimes are estimated for $2\times$ CO_2 and $3\times$ CO_2 conditions using the Canadian Global Coupled Model. Direct carbon emissions are calculated with BORFIRE using fuel consumption sub-models for individual stand components. BORFIRE is also used to determine future forest stand composition to estimate carbon sequestration rates. A summary of patterns in carbon emissions, sequestration, and storage under future fire regimes is presented.