

Limiting Carbon Emissions from Wildfires in North America's Boreal Forests

Fire Management as a Carbon Mitigation Strategy

HIGHLIGHTS

Fires in boreal forests threaten our ability to limit the most catastrophic consequences of climate change. By releasing large quantities of carbon dioxide to the atmosphere, these fires, which are intensifying under climate change, interfere with our ability to keep global warming to well below 2°C. They also harm local and Indigenous communities by worsening air quality, hindering tourism, and disrupting subsistence activities. New research, led by the Union of Concerned Scientists (UCS) and the Woodwell Climate Research Center, finds that increased investments in fire management are a previously unrecognized opportunity to intervene, reduce emissions, and keep carbon in the ground—in turn, limiting the societal damage of intensifying wildfires.

Boreal forests, the largest land biome on Earth, occupy more than 6 million square miles, more than twice the land area of Australia (Figure 1). Coniferous species such as spruce and pine, as well as deciduous species including larch and birch, thrive in these ecosystems. Bogs and wetlands interspersed within forested stands create a rich mosaic of habitat on the landscape. Boreal zones are home to iconic animal species, including salmon, grizzly bears, wolves, and moose, as well as iconic locations, such as Alaska's Denali National Park.

Boreal forests also contain huge amounts of carbon. Although they represent a third of global forested area, boreal forests contain roughly two-thirds of global forest carbon (Bradshaw and Warkentin 2015, Pan et al 2015). In contrast to other types of forest, most carbon in the boreal biome is stored belowground, as seasonally thawed organic soil and permafrost, or permanently frozen ground. Permafrost can be “continuous”—frozen year-round—or “discontinuous,” interspersing patches of permafrost with non-permafrost (yet still carbon-rich) soil.

Historically, boreal forests across North America—where fire is a naturally occurring phenomenon—have experienced relatively infrequent but high-intensity fires that kill large areas of vegetation and restart the process of forest succession (Rogers et al. 2015). These ecosystems have a different relationship with fire than those in the continental United States, which historically experienced frequent but low-intensity fires. Due to their high latitude, boreal forests are warming twice as fast as other ecosystems, leading to a pronounced increase in burned area over the past 50 years (Figure 2). Rising temperatures increase the risk of fires and facilitate their spread by priming ecosystems to burn. Snowmelt happens sooner,

FIGURE 1. The Boreal Biome

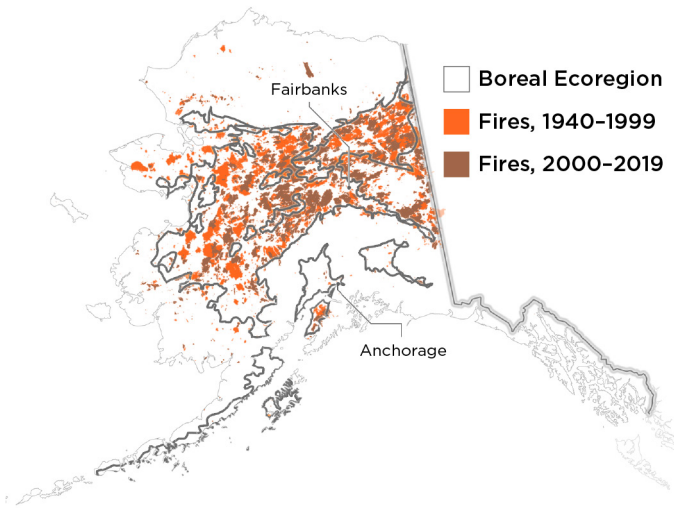


The boreal region of North America, spanning the United States and Canada. Forest cover denotes forested land as of 2000.

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FIGURE 2. Fire History in Interior Alaska



In the 60 years between 1940-1999, an average of 568,520 acres of boreal forests burned each year. In contrast, in the 19 years between 2000-2018, an average of 1.4 million acres burned each year.

allowing more time for trees, soils, and dead vegetation to dry out. Lightning strikes, which ignite some of the largest fires in these ecosystems, occur more often, and high winds, low humidity, and other conditions that facilitate the spread of fire are more likely to occur in extreme conditions.

Global Carbon Emissions: The Consequences of Unchecked Burning

As of January 1, 2018, the United Nation’s Intergovernmental Panel on Climate Change has quantified the specific ceiling of remaining carbon dioxide (CO₂) humans can emit while still maintaining the increase of global average temperatures to less than 1.5–2°C above preindustrial levels—roughly 400 gigatonnes (IPCC 2021). Our research suggests that emissions from boreal forest fires in North America might increase by roughly 30 to 160 percent by midcentury. Left unchecked, fires in this region could release nearly 12 gigatonnes of CO₂ during that time (Figure 3). That’s nearly 3 percent of the remaining allowable emissions if the world is to keep global temperature increase to 1.5°C (see methodology box).

These numbers alone are cause for alarm and intervention, yet they likely underestimate the total carbon loss associated with wildfires, which modify ecosystem processes affecting carbon dynamics. For example, boreal wildfires accelerate permafrost thaw and degradation, exposing

anciently stored carbon in vegetation and soil to decomposition. By some estimates, emissions from post-fire decomposition are more than four times those from fire (Genet et al. 2013). Further, our analysis also did not include emissions of other, more potent heat-trapping emissions from fires such as CH₄ and N₂O, which can double the climate impact. In contrast, projected shifts from spruce-dominated forests to less-flammable deciduous species, such as birch and aspen, may reduce the likelihood of future burns. However, such transitions may exacerbate permafrost thaw, and as a result, send more CO₂ into the atmosphere.

Beyond the feedbacks related to climate change, increasingly large and severe boreal wildfires threaten the livelihoods and health of communities across boreal North America. During wildfire season, high concentrations of smoke and particulate matter can both reduce local air quality to hazardous levels and also travel as far as Europe and the east coast of the United States. Further, rampant boreal wildfires can disrupt subsistence activities such as hunting, threatening both climate mitigation efforts and human health.

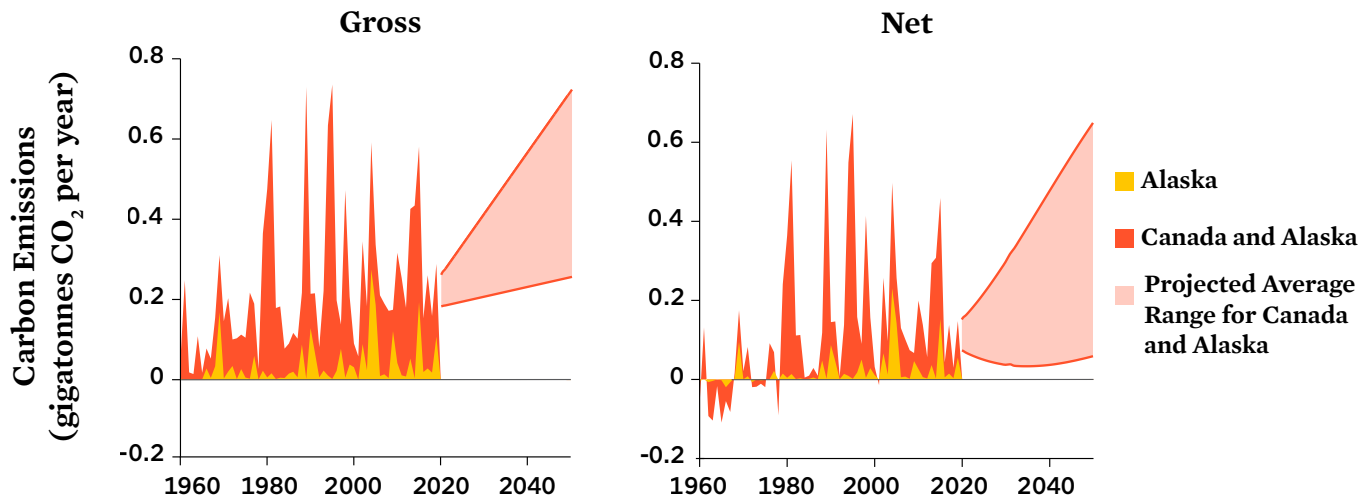
Boreal Fire Management as a Climate Mitigation Strategy

To facilitate and prioritize rapid decisionmaking around suppressing fires, all land across Alaska is grouped into four distinct management zones. Fires in the Critical Zone, often

Methodology for Fire Management Analysis

UCS and the Woodwell Climate Research Center based their research on data from approximately 3,000 fires that burned in Alaska’s boreal zone between 2000 and 2018. To contextualize the conditions in which any given fire burned, we gathered fire history data, vegetation databases, and satellite data detailing weather conditions. We then used a random forest (a type of machine-learning model) to understand fire size as a function of many variables, including weather, vegetation cover, and management strategy. Using a subset of these data, we used a two-stage, instrumental-variables approach to model the relationship between spending and fire size and to quantify the cost of averting one ton of CO₂ emissions.

FIGURE 3. Unchecked Wildfires in Boreal North America Increase Carbon Emissions



Observed (1960–2019) and projected (2020–2050) gross and net CO₂ emissions from boreal North America show that wildfires are having an increased impact as global temperatures rise. Gross emissions represent direct carbon loss from combustion, while net emissions account for ecosystem regrowth post-fire. Left unchecked, carbon emissions could nearly quadruple by mid-century compared with today.

near population centers or other values at risk, are fought most aggressively. On the opposite end of the spectrum, fires in the Limited Zone are mostly monitored and allowed to burn. Full and Modified zones receive intermediate suppression efforts.

These designations integrate several values at risk in any given area, including human life, structures, and wildlife, and they streamline the decisionmaking process across government agencies, Alaskan Native communities, and others who own and manage land. Although these zones cannot capture every factor that goes into decisions, they serve as a proxy for suppression and help to quantify the impact of those efforts. Notably, risks associated with carbon emissions are not part of priority-setting considerations for managing fires in Alaska or other boreal forest regions.

Using data from more than 3,000 fires that burned across Alaska’s boreal zone from 2000 to 2018, our research shows that Alaska’s existing fire-management plan invests the greatest suppression effort in fires that are, on average, smaller in area. This suggests that fire suppression in Alaska, as currently executed, effectively limits fire size and, therefore, could be operationalized to limit emissions.

We also examined the economics of fire management, namely the relationship between spending and fire size, as well as the cost of averting boreal wildfire emissions (in US dollars per ton of CO₂). That enabled us to compare fire suppression in boreal forests to other emissions-reduction

strategies. Within the United States, Alaska receives disproportionately few federal resources for fire management—an average of less than 4 percent of resources each year despite accounting for roughly 20 percent of US land area and half of average annual US fire emissions. Since fire management does not consider carbon and climate mitigation, these resources are allocated to protect human lives and then assets/property. Our analysis of data on suppression spending suggests that increasing spending in Alaska’s boreal forests by 1 percent would reduce fire size by 0.21 percent on average; thus, increasing resources for fire suppression in Alaska could decrease burned area and emissions, while moderating the negative impacts of smoke and particulate matter.

Our results also indicate that fire management in Alaskan boreal forests costs relatively little (~\$12.63 to avert a ton of CO₂) compared with other well-known strategies for reducing emissions, such as on-shore wind power (~\$23–\$26 per ton) and utility-scale solar (~\$32–\$41 per ton) (Gillingham and

Alaska receives only 4 percent of federal wildfire management funding, despite accounting for half of annual US fire emissions.



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Directing more resources towards fire suppression in Alaska's boreal forests not only protects the health and safety of Alaskan communities, but can also reduce the carbon emissions that drive climate change.

Stock 2018). Further, we find that reducing emissions to historic levels in Alaska would require an average investment of roughly \$696 million annually, roughly four times the annual average on Alaskan fires (~\$120 million), or about \$6.96 billion over the next 10 years. This investment would not only reduce carbon emissions but also improve air quality and limit disruptions to Alaskan communities.

Conclusion

Escalating carbon emissions from boreal forest fires threaten our global ability to reach net-zero emissions by 2050. As temperatures rise, fires across boreal North America burn larger and larger areas, in the process emitting huge quantities of carbon and decreasing air quality in downwind communities. However, management strategies present opportunities to reduce emissions from these forests and improve air quality for communities that experience the negative effects of these fires. Given the complexity of fighting large fires in

extreme weather, our research highlights the potential role of increased resources and options for initial attack on ignited boreal fires. Further, by allocating more resources for Alaskan fire management, which are currently far less than Alaska's proportion of burned acreage and wildfire emissions relative to national spending, the United States can decrease burned area and reduce carbon emissions.

Taken together, the UCS/Woodwell-led research indicates that increased spending could reduce fire size by expanding fire-suppression efforts. While limiting boreal wildfires has not been explicitly considered as a climate mitigation strategy, our results suggest that increased investments in managing boreal fires could cost-effectively reduce emissions and yield significant collateral benefits. In the context of a portfolio of climate mitigation strategies that include dramatic reductions in fossil fuel emissions, enhanced boreal fire management could play an important, previously overlooked supporting role toward bringing emissions to net-zero by mid-century and limiting global temperature rise to 1.5°C.

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