

A sensible climate solution for the boreal forest

Authors: Rasmus Astrup¹, Pierre Y. Bernier², H el ene Genet³, David A. Lutz⁴, Ryan M. Bright^{1*}

Affiliations: ¹The Norwegian Institute of Bioeconomy Research, 1431  s, Norway; ²Natural Resource Canada, Laurentian Forestry Centre, Qu bec, Quebec, G1V 4C7, Canada; ³University of Alaska Fairbanks, Institute of Arctic Biology, Fairbanks, AK, USA 99775-7000; ⁴Dartmouth College, Environmental Studies Program, Hanover, NH, USA

*Corresponding author contact: ryan.bright@nibio.no

Standfirst. Climate change could increase fire risk across most of the managed boreal forest. Decreasing this risk by increasing the proportion of broadleaved tree species is an overlooked mitigation-adaptation strategy with multiple benefits.

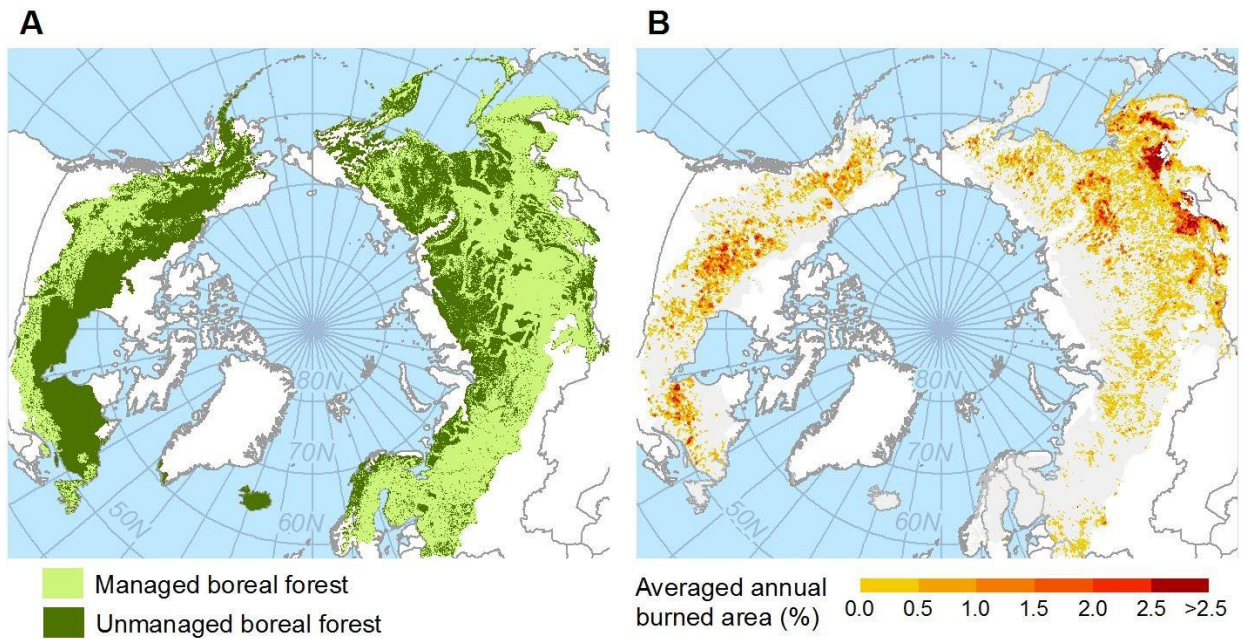
Summary. The boreal forest is experiencing increasing levels of natural disturbance largely attributable to a changing climate. Among the most prevalent are stand-replacing wildfires that may accelerate warming and place local populations at risk ¹. Both adaptive and mitigating measures are urgently required to counter wildfire disturbance trends. Increasing the proportion of broadleaf tree species in the boreal zone through forest management is a unique large-scale combined mitigation-adaptation strategy that is presently absent from the science-policy dialogue. A greater broadleaved tree species component within a needleleaf-dominated landscape can reduce the risk of forest fire ² and enhance surface albedo ³ -- both of which result in negative feedbacks to climate change. From the perspective of forest-based communities, lowered fire risk reduces the loss or damage to infrastructures as well as the risks to human

24 health and safety. We present below the scientific evidence to support this management option

25 and encourage the scientific and policy communities to consider its implementation.

26

27 **Climate Implications.** The boreal forest is the second largest forest biome in the world (Fig. 1)
 28 providing a diverse array of ecosystem services at multiple spatial scales. In the global context,
 29 boreal forests store the second largest quantity of carbon of any terrestrial biome with estimates
 30 of total storage ranging between 367.3 – 1715.8 Pg C ⁴, with an annual sink of 0.5 ± 0.1 Pg C yr⁻¹
 31 ⁵. The boreal region also produces over half of the world’s harvested timber as exports to the
 32 international market, in addition to a host of ecosystem services to local and regional
 33 populations.



34

35 **Figure 1. | Overview of the circumboreal forest management and wildfire patterns. A)**
 36 Delimitation of the managed (12.2 Mkm²) and unmanaged (11.6 Mkm²) portions of the
 37 circumboreal forest, and **B)** Estimates of percent annual area burned across this biome showing
 38 the regional variability in the prevalence of fire from 1997 to 2014. Adapted from ref. ¹. The
 39 mean annual area harvested over past decade was around ~8,700 km² y⁻¹ (based on ref. ⁶ and
 40 350 m³ ha⁻¹), while the mean annual burned area was around ~58,000 km² y⁻¹ ⁷.

41

42 The boreal forest is experiencing higher rates of warming than any other forested region on the
43 planet ¹, which is expected to impact greenhouse gas emissions through increased disturbance
44 regimes. In the last decade, wildfires burned 2.1 Mha y⁻¹ throughout boreal forests in North
45 America and 3.7 Mha y⁻¹ in boreal Eurasia ⁷, although these Eurasian estimates may be on the
46 lower end ⁸ (Fig. 1). As a result, CO₂ emissions from fires between 1997 and 2006 in the Arctic
47 Basin were equivalent to 79% of the total net CO₂ uptake by its ecosystems ⁹. Because of their
48 higher leaf moisture content and lower flammability, broadleaved tree species are less likely to
49 burn than needleleaved ¹⁰. In fact, pure broadleaved stands are about 24 times less likely to burn
50 in a stand-replacing event than pure needleleaf stands ^{2,11}. Reducing the risk of wildfires
51 (wildfire frequency and spread) in boreal biomes through increased broadleaved tree
52 composition is therefore a means to reduce greenhouse-gas emissions.

53 Beyond the carbon cycle, the boreal forest is coupled to the climate system through important
54 biogeophysical mechanisms such as surface albedo. The higher year-round albedos of deciduous
55 broadleaved forests compared to evergreen needleleaved forests equate to less solar energy
56 absorbed by the earth system. Recent empirical insight suggests that a switch from evergreen
57 needleleaved to deciduous broadleaved tree species would result in a local year-round cooling
58 throughout the boreal zone, driven by the change to surface albedo³. Thus, increasing
59 broadleaved forest cover in boreal regions can be considered an attractive mitigation measure
60 also from a biogeophysical standpoint.

61

62 **Socio-economic Implications.** Boreal forest fires cause significant socio-economic losses
63 through impacts on human health and safety, damages to physical infrastructure, and losses of
64 industrial timber. For instance, the 2010 wildfires around Moscow, Russia, were linked to

65 roughly 11,000 deaths through their effect on air pollution ¹². In Western Canada, the 2011
66 Slave Lake fire resulted in losses of 1bn CAD ¹³, while the 2016 Fort McMurray fire resulted in
67 estimated losses of 4.6bn CAD – an amount far greater than insured. Increasing the broadleaved
68 forest composition can therefore be viewed as a socio-economic adaptive measure towards the
69 increased regional fire risk from climate change.

70

71 **Making this happen.** In 2015, needleleaved forests represented 54% of the boreal biome. A
72 shift from mature needleleaved to mature broadleaved forest can reduce the fire risk between
73 three to five times for many boreal forest regions ². Converting just 0.1 to 0.2 % of forested area
74 in southern Canada per year (i.e. ~2100 to 4200 km² yr⁻¹) as part of regular management
75 activities in actively managed forests, starting in 2020, may even be sufficient to mitigate the
76 expected increase in fires due to climate change ¹¹ but even lower rates of conversion would
77 achieve mitigation and adaptation goals. This practice would also help reducing the risk of fire-
78 related economic damages and greenhouse gas emissions, and potentially even improve soil
79 carbon stability and forest resilience to drought risk ¹⁴. In addition, by increasing species
80 diversity, partial stand-level conversions could increase stand resilience to the impacts of
81 disturbances ^{7,15,16}. Locally, such shift may be already occurring naturally as a result of increased
82 fire severity and changing climate ^{17,18}, but actions to accelerate this change would increase the
83 expected mitigation and adaptation benefits.

84 The forestry sector is already considering a range of forest-based adaptation or mitigation
85 scenarios in response to climate change. Yet many of these, such as intensified management, or
86 the assisted migration of native tree species or provenances within or outside of their natural
87 range, rely on flammable needleleaved species and may therefore contribute to the projected

88 increase in risk of forest fires. As the footprint of sustainable harvest in the boreal forest
89 proceeds at a modest rate, and as the practice already incorporates vegetation management, the
90 transition process across broad forest landscapes could be carried out with modest expenditures
91 and would proceed at a socially comfortable pace. Implementation could be achieved by
92 modifying forest policies that encourage or require species-specific management practices ¹⁶ in
93 several boreal countries to include the promotion of broadleaved species. Greater cost would be
94 incurred for more rapid forest conversions around communities, but such expenses could be
95 compensated through other means such as reduced insurance premiums for buildings and other
96 fire-prone infrastructures.

97

98 **Implementation Challenges.** Despite its multiple combined mitigation-adaptation benefits,
99 several challenges must be addressed before such a strategy can be integrated into climate
100 policies and frameworks. Firstly, current forest production is predominantly oriented towards
101 products based on needleleaved species in response to market demands and current wood
102 processing technology. Forest managers may therefore be reluctant to promote a greater
103 component of broadleaved species within their forests in the absence of monetary incentive, at
104 least until the market becomes more favorable to broadleaved timber. However, the rapidity of
105 changes in both markets and technologies relative to the growth of a new forest weakens any
106 argument against implementation that is founded on an extrapolation of current markets and
107 technologies.

108 Secondly, accurate accounting procedures to ensure additionality and incorporate local socio-
109 economic circumstances will require decision support tools that make impact assessment
110 possible without running complex global-scale models. One efficient and transparent way to

111 facilitate these calculations is through map-based indicators that illustrate potential gains and
112 trade-offs in space^{3,19}.

113 Finally, the application of a broadleaf-enhancement policy may affect, to varying degrees, issues
114 such as how carbon is partitioned among forest pools, how biodiversity can be maintained, and
115 how traditional land uses can still be carried out. Incorporating knowledge on such interactions
116 into the planning of forest management activities will be required to ensure that the
117 implementation of this policy will be carried out only where appropriate.

118 In conclusion, we call upon the scientific and policy communities to urgently consider the
119 strategy of increasing the broadleaved component of actively-managed boreal forests in climate
120 change mitigation frameworks. The resulting reduced fire risk and enhanced surface albedo can
121 not only mitigate climate change, but also reduce socio-economic damages from forest fire,
122 thereby achieving a win-win strategy that couples climate mitigation with adaptation. The
123 development of tools for quickly assessing localized carbon and non-carbon climate-related
124 trade-offs in boreal forests could advance this effort by providing local guidance as to where this
125 strategy is most beneficial. While incentives for timber production in the boreal zone have so-far
126 favored conifer species, we encourage the policy-making community to question these measures
127 and give consideration to a strategy that provides a more diverse stream of ecosystem-services
128 and benefits.

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165 should be addressed to R.M.B.

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