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A sensible climate solution for the boreal forest

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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-adaption 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

health and safety. We present below the scientific evidence to support this management option and encourage the scientific and policy communities to consider its implementation.

Climate Implications. The boreal forest is the second largest forest biome in the world (Fig. 1) providing a diverse array of ecosystem services at multiple spatial scales. In the global context, boreal forests store the second largest quantity of carbon of any terrestrial biome with estimates 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} [5]. The boreal region also produces over half of the world's harvested timber as exports to the international market, in addition to a host of ecosystem services to local and regional populations.

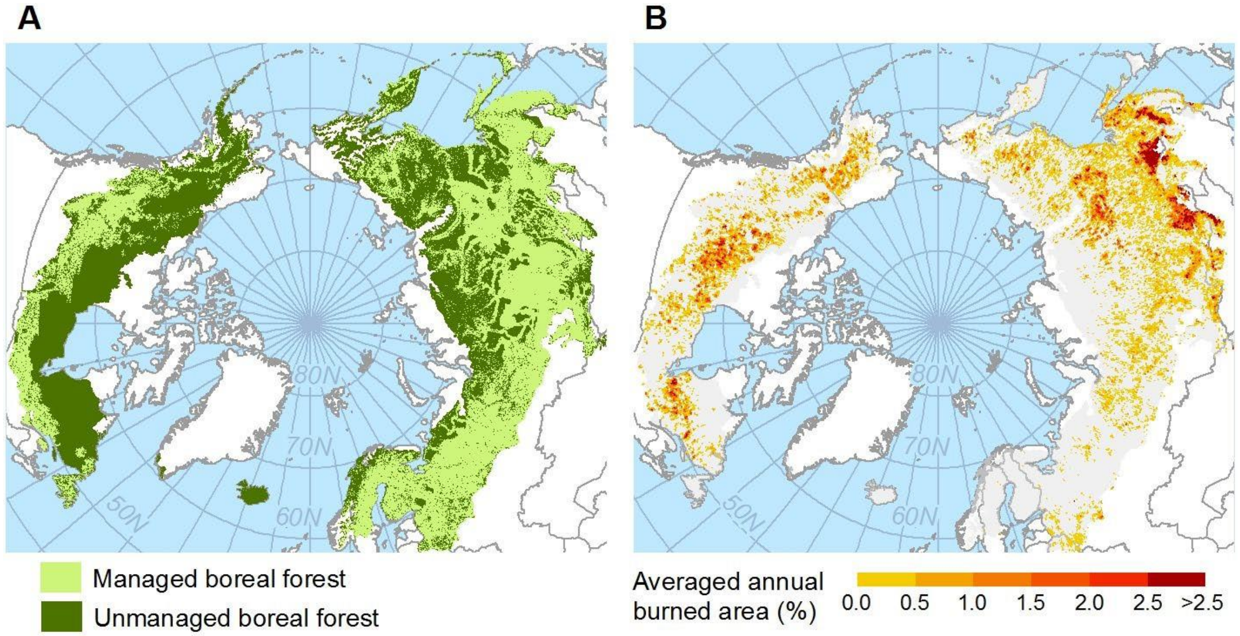

Figure 1. | Overview of the circumboreal forest management and wildfire patterns. A) Delimitation of the managed (12.2 Mkm^2) and unmanaged (11.6 Mkm^2) portions of the circumboreal forest, and **B**) Estimates of percent annual area burned across this biome showing the regional variability in the prevalence of fire from 1997 to 2014. Adapted from ref. [1]. The mean annual area harvested over past decade was around ~8,700 km^2 y^{-1} (based on ref. [6] and 350 m^3 ha^{-1}), while the mean annual burned area was around ~58,000 km^2 y^{-1} [7].

The boreal forest is experiencing higher rates of warming than any other forested region on the planet [1], which is expected to impact greenhouse gas emissions through increased disturbance regimes. In the last decade, wildfires burned 2.1 Mha y^{-1} throughout boreal forests in North America and 3.7 Mha y^{-1} in boreal Eurasia [7], although these Eurasian estimates may be on the lower end [8] (Fig. 1). As a result, CO_2 emissions from fires between 1997 and 2006 in the Arctic Basin were equivalent to 79% of the total net CO_2 uptake by its ecosystems [9]. Because of their higher leaf moisture content and lower flammability, broadleaved tree species are less likely to burn than needleleaved [10]. In fact, pure broadleaved stands are about 24 times less likely to burn in a stand-replacing event than pure needleleaf stands [2,11]. Reducing the risk of wildfires (wildfire frequency and spread) in boreal biomes through increased broadleaved tree composition is therefore a means to reduce greenhouse-gas emissions.

Beyond the carbon cycle, the boreal forest is coupled to the climate system through important biogeophysical mechanisms such as surface albedo. The higher year-round albedos of deciduous broadleaved forests compared to evergreen needleleaved forests equate to less solar energy absorbed by the earth system. Recent empirical insight suggests that a switch from evergreen needleaved to deciduous broadleaved tree species would result in a local year-round cooling throughout the boreal zone, driven by the change to surface albedo[3]. Thus, increasing broadleaved forest cover in boreal regions can be considered an attractive mitigation measure also from a biogeophysical standpoint.

Socio-economic Implications. Boreal forest fires cause significant socio-economic losses through impacts on human health and safety, damages to physical infrastructure, and losses of industrial timber. For instance, the 2010 wildfires around Moscow, Russia, were linked to roughly 11,000 deaths through their effect on air pollution [12]. In Western Canada, the 2011 Slave Lake fire resulted in losses of 1bn CAD [13], while the 2016 Fort McMurray fire resulted in estimated losses of 4.6bn CAD – an amount far greater than insured. Increasing the broadleaved forest composition can therefore be viewed as a socio-economic adaptive measure towards the increased regional fire risk from climate change.

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

The forestry sector is already considering a range of forest-based adaptation or mitigation scenarios in response to climate change. Yet many of these, such as intensified management, or the assisted migration of native tree species or provenances within or outside of their natural range, rely on flammable needleleaved species and may therefore contribute to the projected increase in risk of forest fires. As the footprint of sustainable harvest in the boreal forest proceeds at a modest rate, and as the practice already incorporates vegetation management, the transition process across broad forest landscapes could be carried out with modest expenditures and would proceed at a socially comfortable pace. Implementation could be achieved by modifying forest policies that encourage or require species-specific management practices [16] in several boreal countries to include the promotion of broadleaved species. Greater cost would be incurred for more rapid forest conversions around communities, but such expenses could be compensated through other means such as reduced insurance premiums for buildings and other fire-prone infrastructures.

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

Secondly, accurate accounting procedures to ensure additionality and incorporate local socio-economic circumstances will require decision support tools that make impact assessment possible without running complex global-scale models. One efficient and transparent way to facilitate these calculations is through map-based indicators that illustrate potential gains and trade-offs in space [3,19].

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

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

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