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Forest management must shift from profit to prevention

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Canada's forest disturbance costs have been rising quickly. We propose that silviculture must be reframed as a risk mitigation tool under an 'avoided costs' framework as proactive investments become essential to prevent far greater damage to society and ecosystems.

Increasing forest disturbances, including wildfires, storms, drought, pests and pathogens, are profoundly disrupting forest ecosystems and the viability of the forest sector across the globe. Unprecedented disturbance levels in the past decades have caused immense losses of forest capital and alarming carbon emissions[1], causing a surge in economic costs for disturbance control and significant infrastructure damage. Critically, some disturbances like wildfires incur devastating, irreparable consequences, from irreversible biodiversity loss to severe impacts on human health and life. Canadian forests, which represent 10% of the world's forested area, are at the forefront of this new reality.

Among a plethora of catastrophic events that have affected Canadian forests in the past few decades, the mountain pine beetle epidemic and wildfires can help measure the economic impacts of changing disturbance regimes. In western Canada, the native mountain pine beetle population exploded in the 1990s in an unprecedented outbreak lasting until the mid-2010s, fueled by warmer winters and widespread mature lodgepole pine that are particularly vulnerable to infestations. The outbreak affected an estimated 18 million hectares of pine forests, over half of British Columbia's merchantable pine volume. This severe disturbance caused devastating socio-economic impacts: $57 billion GDP loss over 2009–2054 and $90 billion economic welfare reduction from 2009 to 2054[2].

The 2023 Canadian wildfires also resulted in major economic losses by reducing the availability of timber and high-quality fiber, while incurring massive government expenditures for fire suppression and long-term forest recovery. In the province of Quebec alone, the 2023 wildfires burned over 4.5 million hectares, costing over $8.2 billion across public and private sectors, and the civil society[3]. Citizens bore substantial costs through public health impacts, including the trauma associated with evacuations[4] and the premature death of thousands of people in North America and Europe from air pollution[5]. Wildfire also incurred massive carbon releases from vast territories, and ecosystems suffer a risk of regeneration failure[6].

Past and projected increases in wildfires, climate anomalies, pest outbreaks, and their cascading effects in Canada and around the globe underscore the urgent need to develop and invest in integrated adaptation strategies to mitigate impacts. Managing forests primarily for disturbance resistance and resilience is imperative, as the decline of ecosystems precludes benefits like carbon sequestration, timber harvesting, and climate regulation. Additionally, the alarming impacts on public health and safety underscore the need to account for human health in management decisions. Considering the vast expanse and the catastrophic consequences of disturbances in both current and future conditions, Canadian forests can serve as testing grounds for a new strategy in silvicultural investment.

We argue that existing adaptive silviculture knowledge and technologies can stabilize forest resources and reduce the risk of catastrophic losses. Leveraging Canadian silvicultural investment data, we illustrate the need to move beyond the traditional cost-benefit paradigm—generally analyzed from the perspective of the forest products industry—to one that explicitly incorporates avoided costs for society.

Adaptive silviculture

Although the scale of the challenge is daunting, the knowledge and tools to begin building more resilient forests are already at our disposal. By deploying established silvicultural treatments to manage forest structure and diversity, while simultaneously harnessing advanced technologies to anticipate threats and target interventions effectively, we can reduce risks substantially.

Forest thinning, one of the most common silvicultural treatments, has shown great potential for increasing forest resilience to multiple disturbances at a broad scale. In multi-risk management contexts, thinning can significantly reduce drought and pests' impacts on growth and survival[7], and lower the vulnerability to fire by reducing the fuel load. Thinning can also increase biodiversity in several types of forest stands[8], and there is generally greater public support for partial harvesting methods over large-scale clearcutting. Yet, partial harvesting treatments are seldom applied due to low profitability under traditional cost-benefit analysis. As a result, Canada's most common silvicultural system consists of emulating only severe natural disturbances through clearcuts and compensating for the lack of natural regeneration through planting, when needed. Yet, clearcutting alone cannot be considered a risk mitigating tool, especially when it regenerates the same types of stands that were initially at high risk of disturbance.

Increasing tree species richness at the stand level is key to mitigating the adverse effects of global change on forests. At a small scale, greater diversity enhances resilience to disturbances, including invasive insects, pathogens, herbivores, fire, and drought[9]. For instance, increasing species diversity reduces the abundance and accessibility of host trees for specialist pests[10]. At larger scales, a higher proportion of broadleaves in conifer-dominated forests reduces fire risk drastically. Despite the advantages of mixed forests, monocultures remain the standard in forestry, particularly in plantations[11]. The preference for monocultures stems from simpler logistics and

management, and the often-lower productivity associated with mixed stands, which has led to the continued dominance of monocultures worldwide. In Canada, current practice in boreal forests often includes the suppression of early-successional broadleaved species, which tend to regenerate naturally alongside conifers after clearcuts. This silvicultural choice to restore simpler, conifer-dominated stands seems ill-advised as it will promote a higher risk of fire.

Advanced monitoring technologies

Technological advances, such as remote sensing and airborne laser scanning, provide crucial solutions for helping silviculturists adapt to changing realities. These technologies fuel the development of improved, near-real-time forest characterization and monitoring methods. As such, technological advances can promote better decision-making through an unprecedented ability to track early warning signals that precede major events, like large-scale forest decline for example.

Airborne laser scanning, now widely available across Canada's managed forests and elsewhere, can produce wall-to-wall fuel load maps, while time-series satellite imagery can detect subtle phenological anomalies related to defoliation or water stress. These broad-scale tools are complemented by ground-based systems. Networks of connected sensors, such as electronic dendrometers and digital phenocams, can now stream real-time data on individual tree growth, water status, and overall health. Such spatially explicit, temporally-rich information improves capacity to both observe and anticipate threats, identify vulnerable areas for intervention, and maximize the impact of adaptive management efforts. These technologies have demonstrated potential for anticipating risks, but they remain underused, especially in preventive strategies.

The cost-benefit trap

Silvicultural investments remain strikingly modest despite alarmingly high levels of forest disturbances. From a cost-benefit perspective, silvicultural decisions are generally guided by maximizing the stand's net present value and ensuring profit from wood products. Forest managers evaluate intervention outcomes on standing timber value. To do this, they consider growth rates, stumpage values, interest rates and product markets—all under the more and more questionable assumption of predictable stand development until harvest. Within the framework of cost-benefit analyzes, the pressure imposed by discounting early investments makes it challenging to financially justify silvicultural investments.

Prevention pays off

After the unprecedented 2023 wildfire season, Canada's provincial governments announced exceptional budgets to enhance forest resilience to future fires.

British Columbia invested $130 million[12] in programs to increase prescribed burning and fuel management, including thinning. The aim of the investment was to lower vulnerability of targeted areas around high-risk communities and critical infrastructures. Part of these efforts focused on removing dead trees from the mountain pine beetle infestation.

In Quebec, the provincial government announced a yearly envelope of $58 million for five years to promote climate change adaptation and mitigate the risk of wildfires. Similarly to British Columbia's investment, this budget is dedicated to targeted areas around communities and critical infrastructures in flammable landscapes and includes efforts on public education and adapting community safety plans.

Such tailored investment programs represent only a negligible fraction of the tens of billions of dollars of costs associated with forests disturbances. We propose a change of economic strategy in forestry that rethinks silviculture as a strategic risk mitigation tool. With the colossal economic costs of current and projected forest disturbances in Canada and worldwide, the 'avoided costs'[13] economic approach should serve as the new strategy that guides the silvicultural decision-making process.

Strong evidence suggests that funds dedicated to climate-adapted silvicultural treatments aimed at reducing forest vulnerability will far outweigh the avoided social and economic costs that can be anticipated under the status quo.

In Canada, a striking example is the Early Intervention Strategy, successfully tested since 2014 in the province of New Brunswick to control the spruce budworm outbreak using intensive monitoring and localized applications of a biological insecticide. In itself, the Early Intervention Strategy constitutes a major investment, with a projected cost of $300 million over the duration of the current outbreak[14]. But when comparing the investment to the estimated cost of a traditional reactive scenario of uncontrolled outbreaks that would have led to 96 million m^3 of timber harvest losses and economic cost of $15 billion projected over 50 years in the province, the Early Intervention Strategy becomes very affordable.

Call for action

Levels of disturbances to forests worldwide, and particularly in Canada, have had dire consequences at multiple scales, from the profound trauma of local communities to exacerbating global issues such as climate change and air quality. We propose that these catastrophic, highly visible costs should serve to initiate action—and investment — in adaptive forest management at the global scale.

As global change accelerates, the foundational tools of forestry must be re-evaluated. The long-standing reliance on traditional cost-benefit analysis to guide silvicultural investment—once a cornerstone of management—is no longer tenable in an era of high risk. We therefore call for a fundamental shift in strategy. The first and most critical step toward adaptive forest management is to replace outdated economic models with an 'avoided costs' framework. This approach reframes silvicultural decisions, valuing proactive investment as a strategic hedge against the increasing likelihood of catastrophic events.

To facilitate implementation, a prevention-oriented framework will require clear, quantitative and scientifically grounded information on how prevention measures reduce economic risks. As a scientific community, we must produce and communicate such knowledge urgently and efficiently, in a way that makes the invisible benefits of prevention so visible that decision-makers will take action.

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Competing interests

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