JULY 2020
R: 20-07-B

REPORT

THE LOGGING LOOPHOLE:

HOW THE LOGGING INDUSTRY'S UNREGULATED CARBON EMISSIONS UNDERMINE CANADA'S CLIMATE GOALS

AUTHOR
Jennifer Skene

ACKNOWLEDGMENTS

The author would like to express deep gratitude to all the people who contributed their time, expertise, and talents to this report. Special thanks to Dale Marshall for his numerous reviews and tremendously constructive feedback and to Graham Saul and Teagan Yaremchuck for their expert advice and continuous support. Thanks as well to Anthony Swift, who oversaw the conceptualization and creation of this report, and to Tina Swanson for her thoughtful review. Leah Stecher's editing, guidance, and endless patience were, as always, indispensable and tremendously appreciated. This communication and release of this report would also would not have been possible without the tireless dedication of Margie Kelly, Lauren Gonzales, Barbara Hayes, Alex Almendrades, and Andrew Aziz. The author would also like to thank the many people who reviewed various iterations of this report and provided invaluable feedback: Shelley Vinyard, Courtenay Lewis, Ashley Jordan, Danielle Droitsch, Liz Barratt-Brown, Brendan Guy, Josh Axelrod, Sasha Stashwick, Jeff Wells, Jay Malcolm, Dominick DellaSalla, Florence Daviet, Keith Kisselle, Julee Boan, and Tim Gray.

Environmental Defence Canada gratefully acknowledges the contributions of the Metcalf Foundation.

METCALF
FOUNDATION

About NRDC

NRDC is an international nonprofit environmental organization with more than 3 million members and online activists. Since 1970, our lawyers, scientists, and other environmental specialists have worked to protect the world's natural resources, public health, and the environment. NRDC has offices in New York City, Washington, D.C., Los Angeles, San Francisco, Chicago, Montana, and Beijing. Visit us at nrdc.org.

About Environmental Defence Canada

Environmental Defence Canada is a leading Canadian advocacy organization that works with government, industry and individuals to defend clean water, a safe climate and healthy communities. Visit us at environmentaldefence.ca.

About Nature Canada

Over the past 80 years, Nature Canada has helped protect over 110 million acres of parks and wildlife areas in Canada and countless species that depend on this habitat. Today, Nature Canada represents a network comprised of over 100,000 supporters and engages a community of more than 900 nature organizations across the country. It is focused on effecting change on issues of national significance, including wilderness protection and endangered species, and encouraging people to embrace a culture of conservation in their everyday lives. Visit us at naturecanada.ca.

NRDC Chief Communications Officer: Michelle Egan
NRDC Managing Directors of Communications: Lisa Goffredi and Jenny Powers
NRDC Publications Director: Mary Annaïse Heglar
NRDC Policy Publications Editor: Leah Stecher

Design and Production: www.suerossi.com
Cover: © River Jordan for NRDC

Table of Contents

Introduction

While the international community has struggled to curtail greenhouse gas emissions, forests around the world have been buying us time to transition to clean, renewable-energy economies. Forests act as giant carbon vaults, storing away in their wood, leaves, and soil more carbon than is found in all currently accessible coal, oil, and gas reserves combined.[1] Forests also continuously add to this carbon vault and in recent decades have absorbed nearly one-third of the greenhouse gases we release each year.[2] The global scientific community has made it clear we must limit warming to no more than 1.5 degrees Celsius (C) in order to avoid the worst impacts of climate change,[3] and that doing so will require not just ending our reliance on fossil fuels, but also protecting intact and primary forests' ability to store and absorb carbon.[4]

The Canadian boreal forest, which comprises a quarter of the world's remaining intact forestland[5] and is part of the most carbon-dense forest biome on the planet,[6] is particularly key to achieving a 1.5 °C pathway. In its soils and vegetation, the Canadian boreal stores twice as much carbon as the world's oil reserves.[7] It is central to global carbon regulation,[8] making its protection and management a matter of global importance. Yet each year, industrial logging erodes the Canadian boreal's value for the climate, cutting down more than 400,000 hectares of the forest[9] to turn it into toilet paper, newsprint, lumber, and biofuels.[10] To put this in perspective, Canada falls just behind Brazil and Russia in terms of annual intact forest landscape loss, even when losses caused by wildfires are removed[11]—with 60 percent of this loss occurring in areas leased by logging companies.[12] More than 90 percent of this logging is in the form of clearcutting,[13] a practice in which the logging operation removes nearly all the trees from a given area.[14]

Industrial logging practices are undermining the boreal forest's value for the climate and resulting in significant annual emissions.[15] When this forest is logged, it releases stored carbon from its vegetation and soils, and until it regenerates, it loses its capacity to continue absorbing the amount of carbon it held prior to being cut, creating a carbon deficit.[16] Thus, just like building a new polluting factory or drilling a new oil or gas well, industrial logging in the boreal has long-term climate impacts.[17]

Nevertheless, the Canadian logging industry has consistently downplayed its impact on the global climate, as well as on species that live in the boreal. The industry and its representatives are overselling the forest's capacity to regenerate, misrepresenting forest carbon dynamics, and omitting critical portions of its life-cycle analysis in order to present a narrative of climate sustainability[18] that science is increasingly refuting.[19]

Unlike fossil fuel industries that must be phased out over the course of a few decades, a sustainable forest industry can align with keeping warming below 1.5 °C. However, given its current rate, intensity, and extent, today's industrial logging is incompatible with a goal of maximizing the boreal forest's critical role in carbon storage and threatens long-term, global climate repercussion.[20]

The Canadian federal government has signaled an eagerness to become a leader in tackling land-based carbon emissions, including taking advantage of the boreal's unique characteristics and benefits through nature-based climate solutions,[21] which use the value of natural ecosystems to address climate change.[22] As a flagship part of this effort, the federal government committed to planting two billion net additional trees over 10 years as a means of meeting global emissions targets.[23] Additionally, the federal government has pledged to protect 30 percent of Canada's lands by 2030.[24] These are meaningful and encouraging measures that position Canada to lead on nature-based climate solutions and have an additional benefit of addressing global species collapse.

However, the government has left significant policy gaps around mitigating the logging industry's emissions and protecting intact forests—both crucial to achieving its climate targets. These loopholes bolster the logging

industry's false narratives around its own sustainability and undermine actions essential to safeguarding the boreal's role as a climate solution. Ultimately, there are two steps the federal government will need to take to address the impacts of logging and ensure that the boreal's climate value is preserved.

First, the Canadian government needs to adjust the way it calculates and reports its forest sector emissions each year to the U.N. Framework Convention on Climate Change (UNFCCC), so that the reports accurately reflect net emissions from forests. Canada, in its carbon model, has not accounted for the fact that, contrary to industry claims, large areas fail to reforest following logging.[25] The model also does not consider critical soil carbon dynamics that may significantly increase logging's climate impact.[26] At a higher level, under the Intergovernmental Panel on Climate Change's (IPCC) accounting methodology, Canada is able to present its managed forests as a net carbon sink, burying the impact of logging, which is a net source of emissions, within its broader calculation of the entire managed forest's carbon sequestration capacity.[27] Because the resulting portrait of Canada's forests is still that of a carbon sink, it significantly downplays the logging industry's carbon impacts,[28] allowing the industry to continue its current practices and even contributing to its claims that industrial logging is climate friendly.[29]

Second, the Canadian government needs to regulate the logging industry's greenhouse gas emissions. Doing this could serve as a powerful incentive for the industry to adopt climate-friendlier practices and motivate the protection of intact forests. Canada's national carbon tax, the Greenhouse Gas Pollution Pricing Act, is a critical step in regulating and reining in the fossil fuel industry's emissions, but the absence of a similar measure for the logging industry leaves a vast carbon source unmitigated.

Canada's commitments concerning protected areas and nature-based climate solutions are promising indicators of the federal government's intentions, and the nation is well placed to reform current industrial forestry practices to be consistent with needed climate action and biodiversity protection. However, to fully lead, Canada must protect the climate value of its intact forests and adequately account for and regulate logging's carbon emissions. Doing so will not only benefit the climate but also protect unique and treasured species and ecosystems. Failing to update accounting methods and properly regulate the logging industry will make it difficult to secure a livable planet for future generations.

The Canadian Boreal Forest's Global Climate Importance

The Canadian boreal forest stretches across North America, from the eastern shores of Newfoundland and Labrador to the rocky cliffs and mountains of the Yukon Territory.[30] This green crown across North America is home to more than 600 Indigenous communities, all of whom have relied on the land for millennia.[31] It is also habitat for cherished species such as the boreal woodland caribou, Canada lynx, and pine marten and is the nesting ground for billions of migratory songbirds that traverse the skies across the Western hemisphere.[32] However, the boreal forest's beauty and wildlife are only part of the region's richness. There is another, invisible layer to the boreal's wealth, found in its carbon-dense soils, trees, mosses, and peat bogs.

The boreal is the most carbon-dense forest biome on earth, storing twice as much per acre as tropical forests.[33] The Canadian boreal alone holds nearly twice as much carbon than exists in all the world's recoverable oil reserves.[34] This extraordinary storage capacity stems largely from the boreal's short summers and acidic soils.[35] Because the boreal is so cold for much of the year, dead biomass decays very slowly, trapping the carbon that is normally emitted through decomposition.[36] The coniferous forest's acidic soils also inhibit decomposition.[37] In contrast to the Amazon, which stores most of its carbon in vegetation, more than 80 percent of the carbon in the boreal is found within its layers of soil.[38] Some of this soil carbon has been locked up for thousands of years.[39]

INTACT AND PRIMARY FORESTS

Not all forests are created equal, and intact and primary forests, terms that are used interchangeably in this paper to mean forests that are free of any significant human footprint,[40] have far greater biodiversity and climate value than forests that have been degraded by industry.[41] These forests develop over a long period, as species of plants, animals, and fungi interact and form complex relationships across decades and even centuries.[42] (The term "old growth" forest, sometimes used to refer to primary and intact forests, has no standard definition and is therefore not used in this paper.)

Protecting intact and primary forests, especially under the leadership of Indigenous Peoples, is essential to combating climate change[43] and is, in fact, one of the cheapest and most technologically feasible climate solutions.[44] These forests contain a diversity of species and habitats that is missing in areas that have been logged or impacted by other industries such as mining and oil and gas.[45] They also typically store more carbon than their degraded counterparts,[46] and they can be more resilient to natural disturbances like fires,[47] which is increasingly important as climate impacts worsen.

Industrial Logging's Climate Impact

Industrial development has taken a large toll on Canada's boreal forest over the past century.[48] Though logging rates have declined somewhat in the past two decades, the logging industry nonetheless logged more than 11 million hectares of boreal forest between 1996 and 2015,[49] an area more than twice the size of Nova Scotia. Today the logging industry fells an area the size of seven NHL hockey rinks every minute.[50] Over the past several decades, loss of forest habitat from logging has led to a decline in wildlife populations such as the boreal caribou.[51] In addition, while some Indigenous communities directly benefit from and support logging operations, many others oppose the rate and scale of industrial logging in their territories, which is threatening forests central to their ways of life.[52]

Industrial logging also has an unseen global impact on the climate.[61] NRDC conservatively estimates, using optimistic industry assumptions about how forests recover after being logged, that the current rate of logging in the Canadian boreal forest releases 26 million metric tons of carbon dioxide per year (not including emissions from products removed from the forest), which is equivalent to the annual emissions of 5.5 million cars.[62] This is due to the fact that, while trees regrow, logging reduces the forest's capability to continue absorbing carbon. At the same time, soil disturbance, decaying logging litter, and increased plant respiration flood the atmosphere with carbon that had previously been locked up in the boreal ecosystem.[63] The rate of forest regeneration across the boreal cannot keep up with the amount of carbon that harvesting releases each year, resulting in a significant climate impact.[64]

BOREAL CARIBOU

Boreal caribou, the iconic species emblazoned on Canada's quarter, have been federally listed as "threatened" since 2003[53] and are declining across Canada at a rate of 30 percent every 18 years.[54] Boreal caribou depend on intact forests for their survival,[55] and human-caused habitat disturbance, principally due to industrial logging, is their primary threat.[56] Today only 15 of Canada's 51 boreal caribou herds are self-sustaining for the long term given the level of disturbance to their habitat.[57] Further, caribou are an indicator species, meaning that a population's decline signals broader concerns in the forest ecosystem.[58] The condition of this species is thus a proxy not only for the forest's climate value[59] but also for logging's impact on other species.[60]

The potential effect of logging on boreal soils is particularly concerning. Because of the carbon density of boreal soils, releasing even a small proportion of this carbon can have a significant climate impact. While the full relationship between logging and soil carbon is still being studied, clearcutting can affect soils through changes in temperature and sunlight, compaction, and other physical disturbances.[65] As a result, the vast amounts of organic material stored there become more susceptible to decomposition, potentially converting carbon that had once been safely trapped within the boreal soil into atmospheric carbon dioxide.[66] One meta-analysis of soil carbon losses catalogued around the world found an average loss of 11.2% of carbon from the soils after logging.[67] Logging's impact on the carbon stored in deeper soil layers is more uncertain, but potentially significant.[68]

Clearcutting intact boreal forests also reduces the forest's capability to continue absorbing carbon while the trees regrow. Ultimately, the net effect of clearcutting over time is to create a landscape with more young trees and fewer older ones, pushing tree age and therefore carbon stores to a lower baseline.[69] The shorter the harvest rotation (the number of years between logging operations in the same area), the lower this baseline. While there is some evidence that younger trees do absorb carbon at a faster rate than older ones,[70] replacing an older and larger forest with a younger stand creates a long-term carbon debt.[71] Older forests already hold massive amounts of carbon, and they and the soils around them continue to absorb carbon as they age.[72] Not only does it take decades for a new tree to reach the size of the felled one and absorb the amount of carbon that the felled one previously held, but during that time the now-felled tree would have continued to sequester carbon.[73]

© River Jordan for NRDC

LOGGING SCARS: DEFORESTATION'S SIGNIFICANT, BUT HIDDEN, LEGACY

Unfortunately, current carbon emissions estimates, while troubling, may not even tell the whole story. They likely downplay logging's full climate impact because they assume complete forest recovery, in alignment with industry and provincial government claims that the forest grows back entirely after it has been cut (i.e., for every tree that is cut down, another tree regrows).[74] Under this assumption, eventually the forest will regain the carbon sequestration capacity and biodiversity functions it had prior to being clearcut, and this, the logging industry claims, makes it inherently sustainable.[75] And because the forest is not converted to another use, such as farmland or city development, Canada does not classify the logging that is occurring as "deforestation," instead designating it as "degradation."[76]

However, in addition to the fact that, as discussed below, second-growth forests tend to lack the same ecosystem services and health of primary forests,[77] a study of more than two dozen logged forest sites in northwestern Ontario found that more than 14 percent of the logged area was essentially barren 20 to 30 years after the logging occurred.[78] Nor was there evidence from those sites that trees would become reforested by the time re-logging of the site is planned.[79] These long-term scars are due to the creation of logging roads and "landings," where logs and unwanted logging residue are processed with heavy equipment and stacked, compacting the earth and suppressing regrowth.[80] While that research covered only one region of Ontario, the full-tree logging practice that led to this deforestation, in which the entire logged tree is dragged to the roadside, is the dominant approach in Ontario and accounts for about 50 percent of logging in Quebec.[81] It is also used in British Columbia, Alberta, and the prairie provinces.[82] Thus, it is likely that these scars exist in clearcuts throughout much of the Canadian boreal.

As a result, while Canada claims that it has nearly zero deforestation—and proudly holds itself up in contrast to countries like Brazil and Indonesia—the truth is that a significant portion of forest is not regrowing. If the results from the 27 clearcuts studied are indicative of conditions across all of Ontario (which should itself be a research priority), uncounted logging infrastructure in this province alone would increase Canada's reported deforestation rate by 700 percent.

In addition to harming wildlife, these essentially barren areas have a significant carbon impact. Because they

© Trevor Hesselink, Wildlands League

Logging scars in Ontario.

© River Jordan for NRDC

A replanted forest in Ontario.

remain stripped of productive forest cover, they remain in a significant carbon deficit.[83] Yet, because provinces have not reported these deforested areas in their forest surveys, these deficits are undocumented in Canada's annual accounting, meaning the logging industry's climate impact is understated. By 2030, assuming the current rate of deforestation continues, these logging scars plus 11 years of additional ones in Ontario will have reduced the forest's climate mitigation potential by a total of 41 million metric tons of CO_2, equivalent to more than a year of emissions from Canada's passenger vehicles.[84]

THE REDUCED VALUE OF SECOND-GROWTH FORESTS

Even where trees do return, there is evidence that these second-growth forests do not provide the same ecosystem services or have the ecological health of the original forest.[85] This is exacerbated by the logging industry's practice of replanting fewer species of commercially valuable trees that are all of a uniform age.[86] This "logging-centric" practice creates a regrown forest that is intentionally less biologically and structurally diverse than it was prior to logging.[87] Even under ideal natural regeneration conditions, however, it can take well over a century for a forest to achieve its original structural and biological diversity,[88] along with its original carbon storage and sequestration potential.[89]

The degradation of intact forests also has an often overlooked impact on the ecosystem's overall resilience. Intact forests are more resistant to natural disturbances and more adaptable to climate change than are previously logged, second-growth areas.[90] Though there is a range of predictions for how forests will respond to a warming climate, studies have shown that industrial logging can exacerbate fire risk and increase fire intensity.[91] Previously clearcut forests are also often more susceptible to harmful invasive species, especially insect infestations.[92] As a forest loses its ability to fend off or recover from these disturbances, it will experience even greater carbon loss.

WILDFIRE

Wildfires have been integral to the boreal forest's ecological health since time immemorial. As wildfires become more frequent and more extreme, industry often claims that logging thins the forest and prevents wildfires from raging out of control. However, this argument deflects attention from logging's overall ecological impacts and omits the fact that, in the face of wildfires, protecting intact forests only becomes more urgent.[93]

While some forestry activities can be helpful in reducing the frequency of fires,[94] intensive logging practices like clearcutting and second-growth forests are often associated with more frequent and intense blazes.[95] In addition, in terms of ecological disturbance, fires are not biologically, chemically, or structurally equivalent to clearcut logging.[96] Typical wildfires burn off less than a quarter of the total biomass, and much of the resulting dead wood continues to store carbon[97] or is converted to charcoal, which has an average age in the soil of 600 to 2,000 years.[98] By contrast, clearcut logging removes almost all of a region's trees for conversion into products with far shorter life spans.

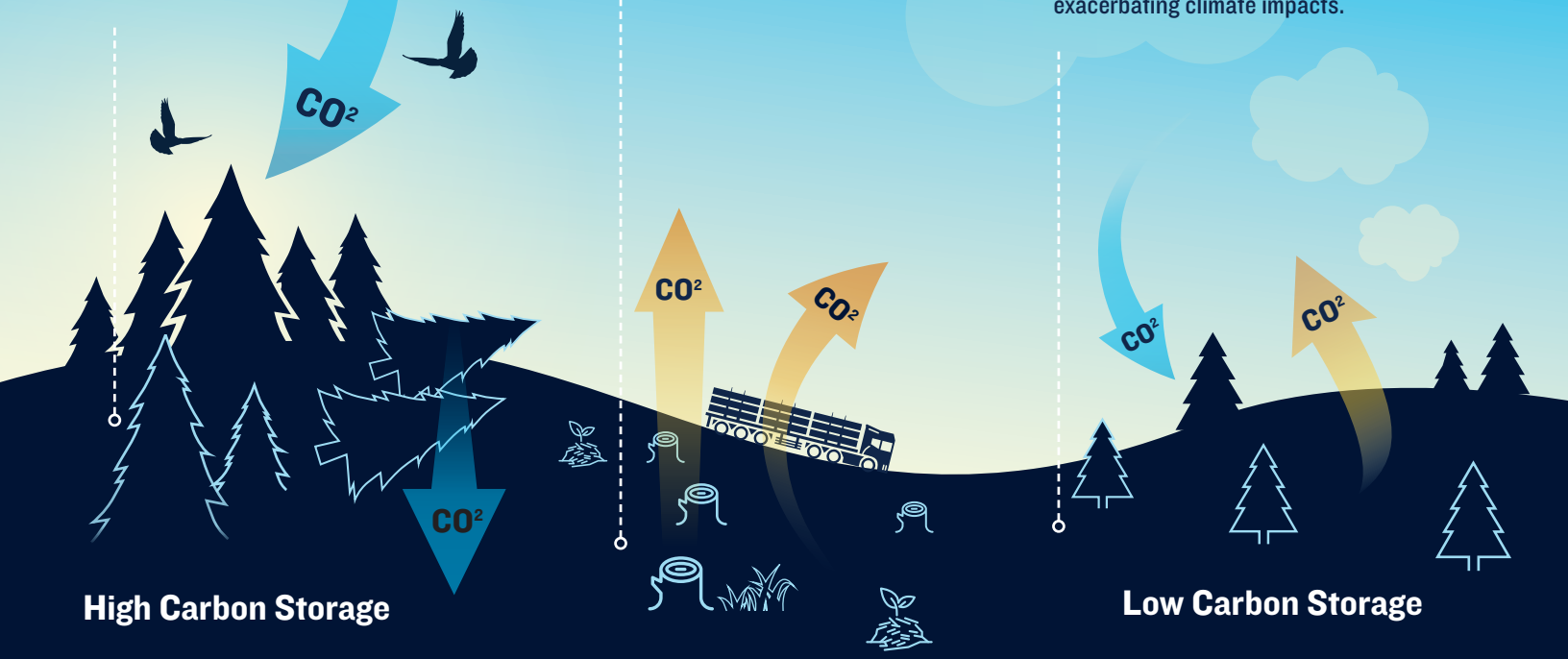
Furthermore, the climate-caused increase in fires is not occurring uniformly across Canada, meaning that an argument that logging will reduce wildfires would be irrelevant in some areas. This is especially true in the eastern boreal forest, which has avoided the large-scale fires that dominated the summer and fall news cycles in Canada in recent years.[99] Models forecasting climate change impacts show that this trend will continue, with eastern forests far less impacted by fires than western ones.[100] This further drives the need to protect intact forests—especially in the east, where a significant percentage of boreal logging occurs—as critical bastions for carbon and biodiversity in a changing climate.

HOW CLEARCUTTING THE BOREAL RELEASES CARBON INTO THE ATMOSPHERE

1. An intact boreal forest has vast stores of carbon locked away—more than 80% of which is found in its soils.[iv] Even older trees continue to sequester carbon as they age. When a tree dies, it slowly releases some of this carbon over time, but much of the carbon—up to 90% even after a fire— ends up back in the ecosystem.

2. Logging leaves woody debris and disturbs the carbon-rich soil, emitting carbon into the atmosphere.[vii] Clearcutting also dramatically reduces the landscape's capacity to sequester carbon, resulting in a carbon debt.

3. The clearcut forest continues to emit carbon from the soils and logging debris. As trees regrow, they begin absorbing carbon, but the forest remains at a significant carbon deficit from where it was before. Furthermore, recent studies have shown that significant areas of clearcut stands remain barren even decades later, further exacerbating climate impacts.



High Carbon Storage

Low Carbon Storage

4. After the wood is cut and manufactured into a long-lived Harvested Wood Product (HWP), it retains only a fraction of its original carbon—as little as 15 percent.[ix] However, much of the wood from Canada is instead turned into paper or throwaway tissue products, which are even less effective at retaining carbon. When the wood is burned for biofuel, all its carbon is emitted.[x] As an HWP ages, it continues to emit its remaining carbon.[xi] When it is discarded in a landfill, it begins emitting both carbon and methane.[xii]

[i] Joshua Axelrod, "Pandora's Box: Clearcutting in the Canadian Boreal Unleashes Millions of Tons of Previously Uncounted Carbon Dioxide Emissions," NRDC, 2018, https://www.nrdc.org/ sites/default/files/pandoras-box-clearcutting-boreal-carbon-dioxide-emissions-ip.pdf.

[ii] Liao C, Luo Y, Fang C, Li B (2010) Ecosystem Carbon Stock Influenced by Plantation Practice: Implications for Planting Forests as a Measure of Climate Change Mitigation. PLoS ONE 5(5): e10867. https://doi.org/10.1371/journal.pone.0010867.

[iii] Wildlands League (2019) Boreal Logging Scars: An extensive and persistent logging footprint in typical clearcuts of northwestern Ontario, Canada. https://loggingscars.wpengine.com/wp-content/uploads/MyUploads/LOGGING-SCARS-PROJECT-REPORT-FINAL-Dec2019-Summary-LR.pdf.

[iv] Pan, Y., Birdsey, R.A., Fang, J., Houghton, R., Kauppi, P.E., Kurz, W.A., Phillips, O.L., Shvidenko, A., et al. (2011). A large and persistent carbon sink in the world's forests. Science 333, 988–993.

[v] Sebastiaan Luyssaert, et al., "Old-Growth Forests as Global Carbon Sinks," p. 213-215. N. L. Stephenson, et al., "Rate of Tree Carbon Accumulation Increases Continuously With Tree Size," Nature 507(7490) (March 6, 2014).

[vi] Statement from Dr. Mark E. Harmon, Professor Emeritus to the United States House Natural Resources Committee Subcommittee on National Parks, Forests, and Public Lands Concerning the hearing on Climate Change and Public Lands: Examining Impacts and Considering Adaptation Opportunities, Committee Hearing Date: February 13, 2019 Testimony Date: February 21, 2019

[vii] Joshua Axelrod, "Pandora's Box: Clearcutting in the Canadian Boreal Unleashes Millions of Tons of Previously Uncounted Carbon Dioxide Emissions," NRDC, 2018, https://www.nrdc.org/ sites/default/files/pandoras-box-clearcutting-boreal-carbon-dioxide-emissions-ip.pdf.

[viii] Joshua Axelrod, "Pandora's Box: Clearcutting in the Canadian Boreal Unleashes Millions of Tons of Previously Uncounted Carbon Dioxide Emissions," NRDC, 2018, https://www.nrdc.org/ sites/default/files/pandoras-box-clearcutting-boreal-carbon-dioxide-emissions-ip.pdf.

[ix] Seton Stiebert et al., Emission Omissions: Carbon Accounting Gaps in the Built Environment, IISD (2019), https://www.iisd.org/sites/default/files/publications/emission-omissions-en.pdf.

[x] Statement from Dr. Mark E. Harmon, Professor Emeritus to the United States House Natural Resources Committee Subcommittee on National Parks, Forests, and Public Lands Concerning the hearing on Climate Change and Public Lands: Examining Impacts and Considering Adaptation Opportunities, Committee Hearing Date: February 13, 2019 Testimony Date: February 21, 2019

[xi] Ann Ingerson, Carbon Storage Potential of Harvested Wood: Summary and Policy Implications, Mitigation and Adaptation Strategies for Global Change, 16(3): 307-323 (2011).

[xii] Seton Stiebert et al., Emission Omissions: Carbon Accounting Gaps in the Built Environment, IISD (2019), https://www.iisd.org/sites/default/files/publications/emission-omissions-en.pdf.

Shortfalls in Canada's Climate Policies

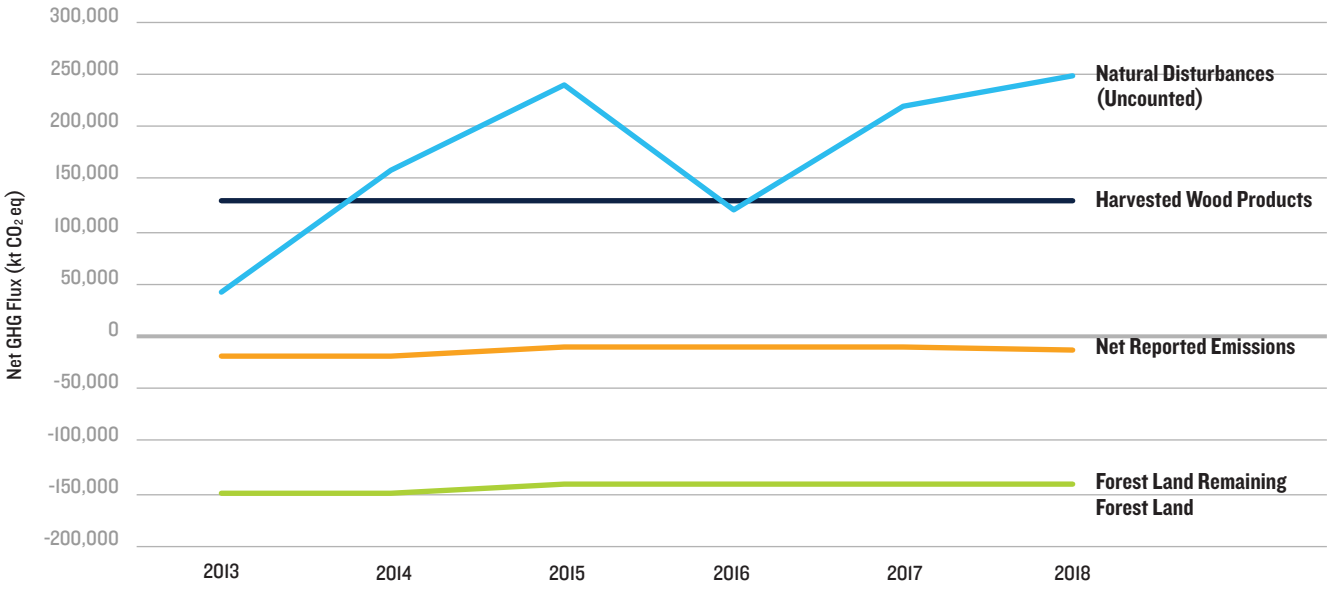
The Canadian government has made strong and unprecedented commitments to nature-based climate solutions. As part of this shift, it is pursuing the protection of 30 percent of its terrestrial areas by 2030[101] and a commitment under the Pan-Canadian Framework on Clean Growth and Climate Change to "protect[] and enhanc[e] carbon sinks including in forests, wetlands and agricultural lands."[102] These actions are a critical and positive development for both the global climate and the species that rely on intact boreal forests, and they signal the federal government's understanding of the boreal forest's key role in addressing the climate crisis. However, by failing to adequately account for and regulate the logging industry's carbon emissions, Canada is not creating the proper incentives for provinces and industry to meet these goals. Instead it is leaving the management of a significant carbon source in the hands of industry, trusting it will self-regulate. At the same time, policy platforms promoting harvested wood products as a climate solution threaten to undercut the very carbon storage goals they intend to achieve.

CANADA'S CARBON REPORTING

Each year, Canada is required to submit a National Inventory Report to the United Nations Framework Convention on Climate Change (UNFCCC), an account of the country's annual greenhouse gas emissions.[103] Canada includes estimated emissions from its managed forests under the category of Land Use, Land Use Change, and Forestry (LULUCF).[104] Canada, as allowed under IPCC rules, relies on modeled estimates rather than direct data.[105] In doing so, it adopts a number of problematic assumptions that downplay logging's full climate impacts. For example, the model does not incorporate the climate impacts of mosses lost during logging, and the model's assumptions around the rates of soil carbon loss may not account for industrial logging's full impact on the soil.[106] While the science around industrial logging's effect on soils is evolving, Canada has, in many cases, chosen to adopt more conservative assumptions or simply not incorporate these impacts. In addition, Canada's model relies on provinces' assumptions about the success of forest regeneration,[107] which studies have shown are not an accurate metric of actual forest regrowth. For instance, as discussed above, Canada's reporting does not capture the climate impact of the significant logging scars found in one study of 27 sites in Ontario,[108] an exclusion that may also apply to other parts of Ontario and other provinces.

In addition, international accounting rules allow certain practices that distort the overall picture of land-based carbon flows (sources and sinks). For example, Canada's emissions from logging are obscured because they are buried within the net positive carbon balance achieved overall by its managed forests. In its National Inventory Report estimating 2018 emissions, despite clearcutting more than 400,000 hectares of forest that year, Canada

FIGURE I: CANADA'S REPORTED FORESTRY EMISSIONS



reported that its forests had a net removal of greenhouse gases of 14 million metric tons CO_2e (Figure 1).[109] Canada is giving itself carbon credit for the forests it doesn't cut in its healthiest forest areas, positioning its managed forests as a net carbon sink, even if each year logging ultimately adds to the carbon in the atmosphere relative to an unlogged forest. This 14 million metric tons are now being counted toward Canada's 2030 emissions target, in essence helping to offset emissions from other sectors, even while climate-critical intact forests are being lost.[110] Meanwhile, Canada does not include impacts from natural disturbances like fires and insects in this carbon calculation,[111] which, especially given the increase in these disturbances in many parts of the boreal forest, oversells the ability of the remaining unlogged forests to offset emissions (Figure 1).

FOREST CARBON REGULATIONS

The lack of adequate regulation of emissions from the forestry sector means the industry is offloading the social and economic cost of its sizable climate impact onto the rest of the world. Canada recently took significant steps to begin using market forces to regulate its greenhouse gas emissions, passing a national carbon tax in October 2018.[112] This Greenhouse Gas Pollution Pricing Act set the initial price of carbon at C$20 per ton in 2019 and will increase it to C$50 per ton by 2022, with revenue going mostly to provide rebates to Canadian citizens.[113] However, this carbon price does not apply to emissions from forest harvesting, leaving a significant gap in the emissions being regulated and ignoring a potentially meaningful source of revenue that could be used to help transition to a clean energy economy.

The absence of a carbon price on logging industry emissions also means that there are no direct financial incentives in place to drive climate-friendlier forestry or the protection of carbon-rich intact forests. While the federal government has discussed incentivizing forest protection through the sale of carbon offsets,[114] which allow a reduction in greenhouse gas emissions in one area to compensate for emissions made elsewhere, offsets alone will not be enough to meet international climate goals. This is because offsets treat reductions in forestry emissions as a replacement for decarbonization efforts when, in fact, Canada needs to both achieve a decarbonized energy economy and maximize the carbon storage in its forests.

ASSUMPTIONS ABOUT HARVESTED WOOD PRODUCTS

A pervasive and misguided narrative, based on selective science and misleading assumptions, has made its way into federal and provincial policy in Canada. According to this narrative, logging is unreservedly good for climate mitigation, in large part because of the carbon benefits of durable harvested wood products (HWPs).[115] For example, the Quebec government recently announced that, because HWPs like lumber and finished wooden furniture continue to store carbon while the forest regrows from logging, increasing the potential stored carbon, the province would be expanding industrial logging as a climate solution.[116] Similarly, the Ontario government has stated that "when carbon stored in harvested wood products is factored into carbon accounting, sustainably managed forests are always a carbon sink."[117]

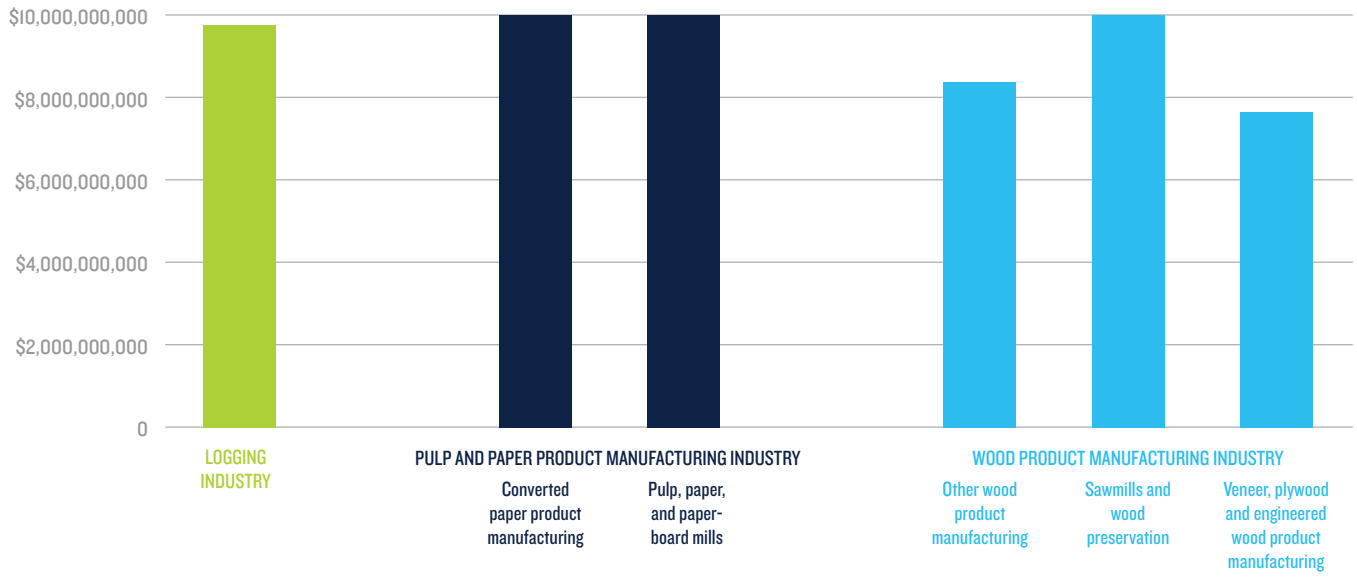
This narrative is also embedded in Canada's "Mid-Century Long-Term Low-Greenhouse Gas Development Strategy," which outlines policy pathways for reducing the country's greenhouse gas emissions 80 percent by 2050.[118] This document highlights HWPs as one emissions-reducing justification for continued intensive logging.[119] Canada's "Pan-Canadian Climate Framework," which outlines national and subnational policies to reduce Canada's greenhouse gas emissions, similarly emphasizes the role of industrial logging and HWPs in carbon storage and achieving its promised emissions reduction targets.[120]

However, these policies ignore an important caveat that appears throughout the scientific literature: HWPs provide a climate benefit only under very strict conditions, and these conditions are rarely grounded in real-world logging practices.[121] When forest products' complete life-cycle analysis, from cradle to grave, is conducted, the picture becomes far more complicated and the climate benefits tenuous.[122]

First, life-cycle analyses of HWPs often do not account for the carbon impact of the logging itself, instead assuming carbon neutrality in the logging process and perfect forest regeneration.[123] The IPCC states that HWPs can provide carbon storage benefits if their wood is harvested "equal to or below" the natural forest regrowth rate.[124] When this condition is not met, HWPs become a climate liability. In fact, according to a recent study, when making more reasonable assumptions about logging practices, HWPs end up having an even greater carbon impact than concrete.[125]

In addition, by the time a tree is logged, processed, and manufactured into a finished product, it has lost a significant amount of its stored carbon. Some studies have shown that as much as 40 percent of the tree's carbon remains in the biomass left as waste to decompose on the forest floor or burned for fuel.[126] Only about 20 percent of the tree's original carbon ultimately remains in the finished long-lived wood product.[127] HWPs are also relatively ineffective at retaining any remaining carbon in the long term.[128] After a century, the product may retain as little as 1 percent of the tree's original carbon.[129] Meanwhile, as allowed under IPCC rules, Canada does not actually count these inevitable emissions from HWPs at the time of logging, instead waiting to include them at a future date when the HWP is assumed to start emitting its carbon. This means these locked-in carbon emissions are not represented in the accounting for years, delaying a full picture of logging's climate impacts.

FIGURE 2: REVENUE FROM GOODS MANUFACTURED (CANADIAN DOLLARS)



Some HWPs can replace certain carbon-intensive building materials like concrete, bolstering their climate benefit. However, this depends on truly sustainable logging practices and should be incorporated into climate policy only after a robust, peer-reviewed analysis of the full carbon life cycle of Canadian boreal forest wood products. If the Canadian building sector is to move toward using more wood products, it has to start with an accurate assessment of what it would mean for emissions that come from forestry and the wood products it produces. Once the estimates of life-cycle emissions more accurately depict reality, it will then become clear which practices are truly part of the solution to address climate change.

It must also be taken into account that much of what the forest industry ultimately produces isn't actually long-lasting. Although Canada's carbon accounting does consider the differing lifespans of the sector's forest products, long-lived HWPs have received outsized weight in Canadian policy, particularly given the significant role shorter-lived products also play in the marketplace (Figure 2). More than 40 percent of the revenue from the manufacture of forest products in Canada comes from short-lived pulp and paper.[130] For example, the U.S. tissue industry is a significant importer of virgin forest fiber from Canada, purchasing more than 1.75 million tons of boreal pulp each year.[131] These products are used once and discarded, after which they add to the rising carbon concentration in the atmosphere. Since a significant amount of the logged material quickly ends up in landfills or sewers, where they emit carbon and methane, the logging industry's claims about their contributions to carbon storage obfuscate the actual life span of many of their products.

At the same time, biomass production and export is also growing in Canada,[132] further undermining industry arguments concerning their products' carbon storage capacity. Biomass, which consists of plants and plant by-products to be burned for fuel, is not a clean energy alternative to fossil fuels. When burned, biomass, at the point of combustion, usually has a carbon impact greater than that of coal and other fossil fuels[133] and creates a carbon debt that can last hundreds of years.[134]

While markets exist for tissue paper and biomass, this does not absolve the Canadian forest industry from responsibility for the impacts of delivering these products. Like the coal, oil, and natural gas companies that feed a global fossil fuel market, the forest industry is responsible for enabling those markets to exist and should take responsibility for the biodiversity and climate impacts of its activities and products.

Finally, it is important to note that even long-lived HWPs are not an immediate source of emissions reductions. Even if they meet the narrow conditions for acting as climate-friendly products, it takes decades to realize the climate benefits from HWPs given the long timescale of forest regrowth. Therefore, these benefits would come too late to contribute to the emissions pathways the IPCC has outlined for keeping warming below 1.5 °C. Forests left intact, however, continue to provide immediate climate benefits in the form of stored carbon, helping achieve this target within the needed time frame.

Recommendations

As the Canadian government pursues a more resilient, just, sustainable future, it will need to prioritize the protection of the boreal forest's value for the climate. Doing so means protecting remaining intact and primary forests and, where industrial logging does occur, incentivizing climate-friendlier practices. In addition to positioning Canada as a leader on nature-based climate solutions, these policy recommendations would provide numerous co-benefits, including advancing Canada's reconciliation commitments to Indigenous Peoples and biodiversity protections. These recommendations should also be included as part of a green recovery plan, as each presents opportunities for jobs and economic stimulus.

CANADA SHOULD FULLY ACCOUNT FOR THE LOGGING INDUSTRY'S EMISSIONS

Canada has committed to net zero emissions by 2050, in alignment with the IPCC's recommendations.[135] However, by undercounting forestry's emissions and exempting them from regulation, Canada could severely undermine this commitment. The federal government is continuing to hone its greenhouse gas accounting procedures, and as part of this effort it must accurately monitor how well forests are actually recovering from logging and incorporate these findings into its accounting practices. This should document impacts not only from reduced tree cover, but also from the potentially higher-than-reported rates of deforestation found in provinces like Ontario.

Canada needs to also account for the differences between the carbon-sequestering capabilities of the intact forest and the capabilities of second-growth forests, as well as the carbon debt incurred when carbon-rich natural landscapes are converted through logging to carbon-poor landscapes. This requires a better understanding of how both natural and human-caused disturbances impact soil carbon storage. Developing a more robust understanding of these dynamics will help ensure that Canada's accounting actually reflects the true carbon balance and does not inadvertently undermine the goals of the Paris Agreement. In addition, because Canada relies on a model rather than direct data for its reporting, the government should clearly communicate these uncertainties and urge provinces and industry to adopt the precautionary principle in their logging and forest management policies.

CANADA SHOULD REGULATE THE LOGGING INDUSTRY'S EMISSIONS

The Canadian government should integrate logging emissions into its national carbon pricing program under the Greenhouse Gas Pollution Pricing Act. Revenue generated from pricing forestry emissions should then be invested into reversing forest degradation; promoting climate-friendly forestry and forest adaptation to climate change; increasing research and monitoring; helping forestry-dependent communities, especially Indigenous communities, to expand economic alternatives; and developing industries around alternative, more sustainable materials to address global demand.

Where logging continues in non-intact forests, this regulation would provide incentives to both provincial governments and industry to adopt climate-friendlier forest management practices that reduce impacts on the ecosystem's stored carbon and improve regeneration. Such practices include adopting longer harvest rotations, avoiding full-tree logging, selective harvesting, and facilitating regeneration centered on biodiversity and climate considerations.

CANADA SHOULD PROTECT REMAINING INTACT FORESTS

The federal government has outlined a policy platform to promote nature-based climate solutions, including a commitment to invest C$3 billion over 10 years to plant two billion net additional trees across Canada.[136] While important, tree planting does not mitigate the damage done by clearcutting intact forests, which have a carbon benefit that is irreplaceable under any meaningful time frame. As a result, it is essential for the Canadian government to adopt robust protection for this globally vital ecosystem.

Under the Convention on Biological Diversity, Canada's federal government has committed to protecting 17 percent of its lands and inland waters by 2020, and has additionally promised to protect 25 percent by 2025, and 30 percent by 2030. These are strong and important commitments. With only about 10 percent of the boreal forest's carbon stores currently protected,[137] Canada needs to make the protection of intact regions in its managed forests a central element of meeting these commitments. In addition, where provinces are failing to protect critical boreal caribou habitat in intact forests, the federal government should employ laws, such as the Species at Risk Act, that enable them to step in and implement the needed safeguards.

CANADA SHOULD PRIORITIZE INDIGENOUS-LED LAND MANAGEMENT

Strong Indigenous land rights are not only critical to Indigenous self-determination and empowerment, but are also correlated with better protections for forest carbon and healthier forest ecosystems, including higher biodiversity.[138] In Canada, Indigenous Peoples have been at the forefront of more effective, sustainable land management, including through Indigenous-led protected areas and Guardians programs.[139] Their leadership is critical not only to empowering Indigenous Nations to determine their own futures, but also to ensuring that the forest is managed sustainably for the climate and biodiversity.

The Canadian government has taken positive initial steps to support Indigenous leadership, giving C$25 million to fund a pilot Indigenous Guardians Network and C$175 million in part to fund over 60 Indigenous-led protection initiatives.[140] While this funding is significant, it is a fraction of what Indigenous communities need to safeguard their traditional territories and manage the remaining intact boreal forests. Additional funding for Indigenous-led management should come from diverted logging subsidies for non-Indigenous-led operations, carbon pricing, and other sources to support this critical work.

Conclusion

Forests are our best natural allies, and if the world is going to reduce its emissions rapidly enough to avoid exceeding 1.5 °C of warming, we need all the help we can get. Focusing exclusively on energy decarbonization, while vital, misses a critical piece of the climate puzzle. In addition to phasing out fossil fuel emissions, countries must protect their carbon-rich ecosystems and enhance their ability to sequester carbon. To this end, countries with large remaining intact forest areas must do everything in their power to conserve and enhance these essential climate regulators. Doing so will not only protect our climate but help stem the global loss of species. We can no longer simply value forests such as the boreal for their supply of toilet paper, newsprint, and lumber, nor can the logging industry continue its current unsustainable practices.

Canada is the steward of a significant portion of the world's most carbon-dense, intact ecosystem, and it therefore has an essential role to play. It has made significant commitments that position the country to be a key leader on nature-based climate solutions. But with the ongoing, significant loss of intact boreal forests from industrial extraction and the failure to transition to climate-friendlier logging practices, time is running out. The Canadian boreal's carbon stores can be a critical resource or a devastating carbon bomb in the fight to protect our future. It's time for Canada to close the logging loophole, step into the climate leadership role it claims, and fully prioritize this global climate linchpin, safeguarding the forest in its indispensable role as one of the world's greatest climate allies.

ENDNOTES

1 Readily accessible fossil fuel reserves contain 2.7 trillion tons of CO_2. Richard Heede and Naomi Oreskes, "Potential Emissions of CO_2 and Methane From Proved Reserves of Fossil Fuels: An Alternative Analysis." *Global Environmental Change* 36 (January 2016): 12-20, https://www.sciencedirect.com/science/article/pii/S0959378015300637. Forests store three trillion tons of CO_2. Yude Pan et al., "A Large and Persistent Carbon Sink in the World's Forests," *Science* 333 (January 2011): 988–993, https://science.sciencemag.org/content/333/6045/988.abstract.

2 Valentin Bellassen and Sebastiaan Luyssaert, "Carbon Sequestration: Managing Forests in Uncertain Times," *Nature* 506, no. 7487 (February 2014), https://www.nature.com/news/carbon-sequestration-managing-forests-in-uncertain-times-1.14687.

3 Intergovernmental Panel on Climate Change (hereinafter IPCC), *Special Report: Global Warming of 1.5 °C*, 2018, https://www.ipcc.ch/sr15/.

4 Richard A. Houghton and Alexander A. Nassikas, "Negative Emissions From Stopping Deforestation and Forest Degradation, Globally," *Global Change Biology* 24, no. 1 (January 2018): 350-359, https://onlinelibrary.wiley.com/doi/abs/10.1111/gcb.13876. William J. Ribble et al., "World Scientists' Warning of a Climate Emergency," *BioScience* 70, no. 1 (January 2020): 8-12, https://academic.oup.com/bioscience/article/70/1/8/5610806. IPCC, *Special Report: Global Warming of 1.5 °C*.

5 Peter Lee, "The Boreal Forest: Trouble in Canada's Great Wilderness," in *State of the Wild 2010–2011: A Global Portrait,* Eva Fearn, ed. (Washington, DC: Island Press, 2010), 140.

6 Ross W. Gorte, *Carbon Sequestration in Forests*, Congressional Research Service, 2009, https://fas.org/sgp/crs/misc/RL31432.pdf. Matt Carlson, Jeff Wells, and Dina Roberts, *The Carbon the World Forgot*, Boreal Songbird Initiative and Canadian Boreal Initiative, 2009, https://www.borealbirds.org/sites/default/files/pubs/report-full.pdf.

7 Joshua Axelrod, "FYI: How NRDC Calculated Forest and Fossil Fuel Carbon Equivalencies," NRDC, March 2018, https://www.nrdc.org/sites/default/files/media-uploads/carbon_comparison_background_v1.1.pdf.

8 Gorte, *Carbon Sequestration in Forests*. Carlson, Wells, and Roberts, *The Carbon the World Forgot*.

9 National Forestry Database (Canada), "Forest Area Harvested on Private and Crown Lands," http://nfdp.ccfm.org/en/data/harvest.php (accessed June 4, 2020).

10 Natural Resources Canada, "Statistical Data: Trade," https://cfs.nrcan.gc.ca/statsprofile/trade/ca (accessed June 7, 2020). Jennifer Skene and Shelley Vinyard, *The Issue With Tissue: How Americans Are Flushing Forests Down the Toilet*, NRDC, February 2019, https://www.nrdc.org/resources/issue-tissue-how-americans-are-flushing-forests-down-toilet.

11 Intact forest landscapes are defined as "an unbroken expanse of natural ecosystems within the zone of current forest extent, showing no signs of significant human activity, and large enough that all native biodiversity, including viable populations of wide-ranging species, could be maintained." W. Smith and R. Cheng, *Canada's Intact Forest Landscapes Updated to 2013*, Global Forest Watch, 2016.

12 Ibid.

13 National Forestry Database (Canada), "Forest Area Harvested on Private and Crown Lands."

14 Natural Resources Canada, "Clearcutting in the Forest," http://www.nrcan.gc.ca/node/9513 (accessed June 7, 2020).

15 Joshua Axelrod, "Pandora's Box: Clearcutting in the Canadian Boreal Unleashes Millions of Tons of Previously Uncounted Carbon Dioxide Emissions," NRDC, updated March 2018, https://www.nrdc.org/sites/default/files/pandoras-box-clearcutting-boreal-carbon-dioxide-emissions-ip.pdf.

16 Ibid.

17 Ibid.

18 See, e.g., Derek Nighbor, Susan Yurkovich, and Denis Lebel, "Climate Change Is a Call to Action for Canada's Forestry Industry," *Globe and Mail*, October 5, 2019, https://www.theglobeandmail.com/opinion/article-climate-change-is-a-call-to-action-for-canadas-forestry-industry/. Forest Products Association of Canada (hereinafter FPAC), "Climate Change," https://www.fpac.ca/sustainable-forestry/30by30/ (accessed May 26, 2020). Ontario Forest Industries Association (hereinafter OFIA), "Climate Change Champions," http://www.ofia.com/tackle-climate-change/climate-change-champions.html (accessed May 26, 2020). Curt Stevens, "Opinion: Canada's Forest Industry Ready to Help Fight Against Climate Change," *Vancouver Sun*, November 26, 2015, http://www.vancouversun.com/business/opinion+canada+forest+industry+ready+help+fight+against+climate+change/11546996/story.html.

19 See, e.g., Malcolm, "Forest Harvesting and the Carbon Debt in Boreal-Eastern Canada." Trevor Hesselink, *Boreal Logging Scars: An Extensive and Persistent Logging Footprint in Typical Clearcuts of Northwestern Ontario, Canada*, Wildlands League, December 2019, https://loggingscars.wpengine.com/wp-content/uploads/MyUploads/LOGGING-SCARS-PROJECT-REPORT-FINAL-Dec2019-Summary-LR.pdf. Seton Stiebert et al., *Emission Omissions: Carbon Accounting Gaps in the Built Environment*, IISD (2019), https://www.iisd.org/sites/default/files/publications/emission-omissions-en.pdf. Harmon, M.E. 2019. Have product substitution carbon benefits been overestimated? A sensitivity analysis of key assumptions. *Environmental Research Letters* 14: Article 065008.

20 Axelrod, "Pandora's Box." Malcolm, Holtsmark, and Piascik, "Forest Harvesting and the Carbon Debt."

21 Liberal Party of Canada, "Natural Climate Solutions," https://www2.liberal.ca/our-platform/natural-climate-solutions/ (accessed May 31, 2020).

22 Bronson W. Griscom et al., "Natural Climate Solutions," *PNAS* 113, no. 44 (2017): 11645-11650.

23 Liberal Party of Canada, "Liberals Move Forward to Plant Two Billion Trees," September 27, 2019, https://www.liberal.ca/liberals-move-forward-to-plant-two-billion-trees/.

24 Ibid.

25 See Hesselink, *Boreal Logging Scars*.

26 Axelrod, "Pandora's Box."

27 Barry Saxifrage. "As Canada's Forests Become Carbon Bombs, Ottawa Pushes the Crisis off the Books," *Canada's National Observer*, March 30, 2020, https://www.nationalobserver.com/2020/03/30/opinion/canadas-forests-become-carbon-bombs-ottawa-pushes-crisis-books.

28 Ibid.

29 See, e.g., Carl Meyer, "Wood Pellets From Clear-Cut, Old-Growth Forests May Not Be Carbon Neutral," *Canada's National Observer*, May 12, 2020, https://www.nationalobserver.com/2020/05/12/news/wood-pellets-clear-cut-old-growth-forests-may-not-be-carbon-neutral.

30 Natural Resources Canada, "Boreal Forest," https://www.nrcan.gc.ca/our-natural-resources/forests-forestry/sustainable-forest-management/boreal-forest/13071 (accessed June 7, 2020).

31 Indigenous Leadership Initiative, "People of the Boreal," https://www.ilinationhood.ca/our-stories/people-of-the-boreal/ (accessed June 7, 2020). PEW, "Indigenous Leadership Driving Boreal Forest Conservation in Canada," November 11, 2014, https://www.pewtrusts.org/en/research-and-analysis/articles/2014/11/11/indigenous-leadership-driving-boreal-forest-conservation-in-canada.

32 Jeffrey V. Wells and Peter J. Blancher, "Global Role for Sustaining Bird Populations," in *Boreal Birds of North America: A Hemispheric View of Their Conservation Links and Significance*, Jeffrey V. Wells, ed. (Berkeley and Los Angeles: University of California Press, 2011). Jennifer Skene, *Cutting It Close: How Unsustainable Logging In Canada's Boreal Forest Threatens Indigenous Rights, Wildlife, and the Global Climate*, NRDC, July 2018, https://www.nrdc.org/sites/default/files/cutting-it-close-logging-canadas-boreal-report.pdf.

33 Carlson, Wells, and Roberts, *The Carbon the World Forgot*.

34 Recent studies of global boreal forest carbon stock put the total at 1,095 gigatons. Corey J. A. Bradshaw and Ian G. Warkentin, "Global Estimates of Boreal Forest Carbon Stocks and Flux," *Global and Planetary Change* 128, no. 27 (May 2015). Twenty-eight percent of all boreal forests are found in Canada, so NRDC calculated that approximately 306.6 gigatons of carbon are found in the boreal forest of Canada. For a more detailed discussion of how NRDC calculated this number and its comparison to oil reserves, see Axelrod, "FYI: How NRDC Calculated."

35 Gorte, *Carbon Sequestration in Forests*.

36 Ibid. Carlson, Wells, and Roberts, *The Carbon the World Forgot*.

37 Gorte, *Carbon Sequestration in Forests*.

38 Ibid.

39 Maara S. Packalen, Sarah A. Finkelstein, and James W. McLaughlin, "Carbon Storage and Potential Methane Production in the Hudson Bay Lowlands Since Mid-Holocene Peat Initiation," *Nature Communications* 5 (2014), https://www.nature.com/articles/ncomms5078.

40 "Significant human footprint" is used here to mean "all human activities that are known to cause physical changes in a forest that lead to a decline in ecological function." James E. M. Watson et al., "The Exceptional Value of Intact Forest Ecosystems," *Nature Ecology & Evolution* 2 (April 2018): 599-610, https://www.nature.com/articles/s41559-018-0490-x?draft=marketing. As defined by the Secretariat of the Convention on Biological Diversity (CBD), a primary forest is one that "has never been logged and has developed following natural disturbances and under natural processes, regardless of its age." This includes forests that have been used "by indigenous and local communities living traditional lifestyles relevant for the conservation and sustainable use of biological diversity." Secretariat of the CBD, "Forest Biodiversity Definitions," https://www.cbd.int/forest/definitions.shtml (accessed May 31, 2020).

41 Watson et al., "The Exceptional Value of Intact Forest Ecosystems." Ian D. Thompson et al., "An Operational Framework for Defining and Monitoring Forest Degradation," *Ecology and Sociology* 18, no. 2 (2013): 20, https://www.ecologyandsociety.org/vol18/iss2/art20/.

42 Ibid. Primary forests contain "natural forest dynamics, such as natural tree species composition, occurrence of dead wood, natural age structure and natural regeneration processes." Food and Agriculture Organization of the United Nations (FAO), *Global Forest Resources Assessment 2020 Terms and Definitions*, 2020, http://www.fao.org/3/I8661EN/i8661en.pdf.

43 Watson et al., The Exceptional Value of Intact Forest Ecosystems." National Academies of Sciences, Engineering, and Medicine, *Negative Emissions Technologies and Reliable Sequestration: A Research Agenda,* 2019, https://www.nap.edu/read/25259/chapter/1#ii. John E. Fa et al., "Importance of Indigenous Peoples' Lands for the Conservation of Intact Forest Landscapes," *Frontiers in Ecology and the Environment* 18, no. 3 (April 2020): 135-140. https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1002/fee.2148.

44 Griscom et al., "Natural Climate Solutions."

45 Watson et al., The Exceptional Value of Intact Forest Ecosystems."

46 Ibid. Malcolm, Holtsmark, and Piascik, "Forest Harvesting and the Carbon Debt."

47 Erica Newman, "Disturbance Ecology in the Anthropocene," *Frontiers in Ecology and Evolution* (May 2019), https://www.frontiersin.org/articles/10.3389/fevo.2019.00147/full.

48 See L. A. Vernier et al., "Effects of Natural Resource Development on the Terrestrial Biodiversity of Canadian Boreal Forests," *Environmental Review* 22 (2014): 457-490. Yan Boucher and Pierre Grondin, "Impact of Logging and Natural Stand-Replacing Disturbances on High-Elevation Boreal Landscape Dynamics (1950–2005) in Eastern Canada," *Forest Ecology and Management* 263, no. 1 (January 2012): 229-239. https://www.sciencedirect.com/science/article/abs/pii/S0378112711005597. National Forestry Database (Canada), "Forest Area Harvested on Private and Crown Lands."

49 National Forestry Database (Canada), "Forest Area Harvested on Private and Crown Lands."

50 Ibid.

51 Committee on the Status of Endangered Wildlife in Canada (hereinafter COSEWIC), *COSEWIC Assessment and Status Report on the Caribou* Rangifer tarandus*, Newfoundland Population, Atlantic-Gaspésie Population, Boreal Population*, 2014, https://www.sararegistry.gc.ca/virtual_sara/files/cosewic/sr_Caribou_NF_Boreal_Atlantic_2014_e.pdf. Vernier et al., "Effects of Natural Resource Development."

52 See, e.g., Cree First Nation of Waswanipi, "The Mishigamish Protected Area Proposal," March 2018, https://www.eeyouconservation.com/wp-content/uploads/2018/03/Mishigamish.pdf. Jennifer Skene, "Waswanipi Cree Protest Logging in Last Intact Forest," NRDC, September 2018, https://www.nrdc.org/experts/courtenay-lewis/waswanipi-cree-protest-logging-last-intact-forest. Jon Thompson, "The Never-Ending Fight to Save One Ontario Forest," TVO, October 12, 2018, https://www.tvo.org/article/the-never-ending-fight-to-save-one-ontario-forest.

53 Environment Canada, *Report on the Progress of Recovery Strategy Implementation for the Woodland Caribou (*Rangifer tarandus caribou*), Boreal Population in Canada for the Period 2012–2017*, Species at Risk Act Recovery Strategy Series, 2017, http://registrelep-sararegistry.gc.ca/default.asp?lang=En&n=7037FCE4-1.

54 COSEWIC, *COSEWIC Assessment and Status Report on the Caribou*, p. xvii. Environment Canada, "Species Profile: Caribou Boreal Population," https://wildlife-species.canada.ca/species-risk-registry/species/speciesDetails_e.cfm?sid=636 (accessed May 31, 2020).

55 Environment and Climate Change Canada, *Action Plan for the Woodland Caribou (*Rangifer tarandus caribou*), Boreal Population, in Canada*, Species at Risk Act Action Plan Series (2018), http://www.registrelep-sararegistry.gc.ca/virtual_sara/files/plans/Ap-WoodlandCaribouBorealPopulationFederalActions-v00-2018Feb-Eng.pdf.

56 COSEWIC, *COSEWIC Assessment and Status Report on the Caribou*, p. 59.

57 Environment and Climate Change Canada, *Woodland Caribou, Boreal Population (*Rangifer tarandus caribou*): Amended Recovery Strategy 2019,* Species at Risk Act Recovery Strategy Series, 2019, https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/recovery-strategies/woodland-caribou-boreal-2019.html.

58 Ibid., p. ii.

59 Jeff Wells, "Overlap Between Carbon Stores and Intact Boreal Woodland Caribou Ranges in Canada's Boreal Forest," in *Encyclopedia of the World's Biomes* Vol. 1 (Amsterdam: Elsevier 2020), 279-286.

60 Mark Hebblewhite, "Billion Dollar Boreal Woodland Caribou and the Biodiversity Impacts of the Global Oil and Gas Industry," *Biological Conservation* 206 (February 2017): 102-111. https://www.sciencedirect.com/science/article/abs/pii/S0006320716310308.

61 Sebastiaan Luyssaert, et al., "Old-Growth Forests as Global Carbon Sinks," *Nature* 455, no. 7210 (2008). J. James and R. Harrison, "The Effect of Harvest on Forest Soil Carbon: A Meta-analysis," *Forests* 2016, no. 7 (2016): 308. Axelrod, "Pandora's Box."

62 Axelrod, "Pandora's Box."

63 Ibid.

64 Ibid.

65 Thomas Buchholz et al., "Mineral Soil Carbon Fluxes in Forests and Implications for Carbon Balance Assessments," *GCB Bioenergy* 6, no. 4 (July 2014): 305-311.

66 Ibid. James and Harrison, "The Effect of Harvest on Forest Soil Carbon."

67 James and Harrison, "The Effect of Harvest on Forest Soil Carbon."

68 Ibid. Buchholz et al., "Mineral Soil Carbon Fluxes in Forests and Implications for Carbon Balance Assessments."

69 Sylvie Gauthier et al., "Fire Frequency and Forest Management Based on Natural Disturbances," in *Ecosystem Management in the Boreal Forest* (Québec, Presses de l'Université du Québec, 2009), 59-60. NRDC, "How the Growing Industrial Footprint in Canada's Boreal Forest Undermines Climate Protection," webinar, May 9, 2019, https://www.youtube.com/watch?v=CLxRIcdFwro.

70 But see N.L. Stevenson et al., "Rate of Tree Carbon Accumulation Increases Continuously With Tree Size," *Nature* 507 (2014): 90-93, https://www.nature.com/articles/nature12914.

71 See Malcolm, Holtsmark, and Piascik, "Forest Harvesting and the Carbon Debt." Bjart Holtsmark, "Harvesting in Boreal Forests and the Biofuel Carbon Debt," *Climatic Change* 112 (2012): 415-428, https://link.springer.com/article/10.1007/s10584-011-0222-6. Axelrod, "Pandora's Box."

72 Luyssaert et al., "Old-Growth Forests as Global Carbon Sinks."

73 N.L. Stevenson et al., "Rate of Tree Carbon Accumulation Increases Continuously With Tree Size.

74 See, e.g., Forest Products Association of Canada (FPAC), "Flushing Out the Truth About Our Canadian Forests," March 5, 2019, https://www.fpac.ca/flushing-out-the-truth-about-our-canadian-forests/ (accessed June 21, 2020). Natural Resources Canada, "Is Timber Being Harvested Sustainably?" https://www.nrcan.gc.ca/our-natural-resources/forests-forestry/timber-being-harvested-sustainably/16494 (accessed June 21, 2020).

75 Ibid.

76 Natural Resources Canada, "Deforestation in Canada: Key Myths and Facts," https://www.nrcan.gc.ca/our-natural-resources/forests-forestry/wildland-fires-insects-disturban/deforestation-canada-key-myths-and-facts/13419 (accessed May 26, 2020).

77 Sylvie Gauthier et al., "Boreal Forest Health and Global Change," *Science* 349, no. 6250 (August 21, 2015): 820, https://science.sciencemag.org/content/349/6250/819.full?ijkey=9E/LoNrjj1ASk&keytype=ref&siteid=sci.

78 Hesselink, *Boreal Logging Scars*.

79 Ibid.

80 Ibid.

81 Ibid.

82 Ibid.

83 Ibid., p. 51.

84 Ibid., p. 64.

85 Ecosystem services are the benefits an ecosystem provides to society, including carbon regulation, water filtration, and hunting opportunities. Sylvie Gauthier et al., "Boreal Forest Health and Global Change."

86 Yves Bergeron and Nicole J. Fenton, "Boreal Forests of Eastern Canada Revisited: Old Growth, Nonfire Disturbances, Forest Succession, and Biodiversity," *Botany* 90 (2012); 509-523. See, e.g., Ontario Ministry of Natural Resources, *Silvicultural Effectiveness Monitoring Manual for Ontario*, 2001, https://dr6j45jk9xcmk.cloudfront.net/documents/3110/silvicultureeffectmanual.pdf.

87 Bergeron and Fenton, "Boreal Forests of Eastern Canada Revisited." Gauthier et al., "Boreal Forest Health and Global Change." Jean-Pierre Jetté et al., "Ecological Issues Related to Forest Management," in *Ecosystem Management in the Boreal Forest* (Québec, Presses de l'Université du Québec, 2009), 1-10.

88 Yves Bergeron and Nicole J. Fenton, "Boreal Forests of Eastern Canada Revisited."

89 Dominick Thom et al., "The Climate Sensitivity of Carbon, Timber, and Species Richness Covaries With Forest Age in Boreal-Temperate North America," *Global Change Biology* 25, no. 7 (July 2019), https://onlinelibrary.wiley.com/doi/abs/10.1111/gcb.14656. Brendan Mackey et al., "Untangling the Confusion Around Land Carbon Science and Climate Change Mitigation Policy," *Nature Climate Change* 3 (2013): 552-557, https://www.nature.com/articles/nclimate1804?page=2.

90 Peter Potapov et al., "The Last Frontiers of Wilderness: Tracking Loss of Intact Forest Landscapes from 2000 to 2013," *Science Advances* 3, no. 1 (2017), https://www.researchgate.net/publication/312391376_The_last_frontiers_of_wilderness_Tracking_loss_of_intact_forest_landscapes_from_2000_to_2013. Watson et al., "The Exceptional Value of Intact Forest Ecosystems." Dominick Thom et al., "The Climate Sensitivity of Carbon, Timber, and Species Richness Covaries With Forest Age in Boreal-Temperate North America."

91 Carter Stone, Andrew Hudak, and Penelope Morgan, "Forest Harvest Can Increase Subsequent Forest Fire Severity," *Proceedings of the Second International Symposium on Fire Economics, Planning, and Policy: A Global Vie*w (2004): 532, https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1198&context=usdafsfacpub. Jonathan R. Thompson, Thomas A. Spies, and Lisa M. Ganio, "Reburn Severity in Managed and Unmanaged Vegetation in a Large Wildfire," *Proceedings of the National Academy of Sciences* 104, no. 25 (June 19, 2007): 10746, https://www.pnas.org/content/104/25/10743. Curtis M. Bradley, Chad T. Hanson, and Dominick A. DellaSala, "Does Increased Forest Production Correspond to Higher Fire Severity in Frequent-Fire Forests of the Western United States?" *Ecosphere* 7, no. 10 (2016): 1-13, https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/ecs2.1492.

92 Watson et al., "The Exceptional Value of Intact Forest Ecosystems."

93 Ibid. Malcolm, Holtsmark, and Piascik, "Forest Harvesting and the Carbon Debt."

94 See James K. Agee and Carl N. Skinner, "Basic Principles of Forest Fuel Reduction Treatments," *Forest Ecology and Management* 211, no. 1-2 (2005), https://www.fs.fed.us/psw/publications/skinner/psw_2005_skinner(agee)001.pdf. Scott L. Stephens et al., "The Effects of Forest Fuel-Reduction Treatments in the United States," *BioScience* 2, no. 6 (June 2012), https://www.fs.fed.us/psw/publications/fettig/psw_2012_fettig001(stephens).pdf.

95 Stone, Hudak, and Morgan, "Forest Harvest Can Increase Subsequent Forest Fire Severity." Thompson, Spies, and Ganio, "Reburn Severity."

96 D. J. McRae et al., "Comparisons Between Wildfire and Forest Harvesting and Their Implications in Forest Management," *Environmental Reviews* 9, no. 4 (December 2001): 223–260, https://www.researchgate.net/publication/237154364_Comparisons_between_wildfire_and_forest_harvesting_and_their_implications_in_forest_management.

97 Ibid.

98 Thomas A. Deluca and Celine Boisvenue, "Boreal Forest Soil Carbon: Distribution, Function, and Modelling," Forestry: An International Journal of Forest Research, 85, no. 2 (2012): 161-184, https://academic.oup.com/forestry/article/85/2/161/527316.

99 E. S. Kasischke & M. R. Turetsky, "Recent Changes in the Fire Regime Across the North American Boreal Region: Spatial and Temporal Patterns of Burning Across Canada and Alaska," *Geophysical Research Letters* 33, no. 9 (May 2006), https://www.researchgate.net/publication/298985452_Recent_changes_in_the_fire_regime_across_the_North_American_boreal_region_-_Spatial_and_temporal_patterns_of_burning_across_Canada_and_Alaska.

100 Gauthier et al., "Boreal Forest Health and Global Change."

101 Liberal Party of Canada, "Natural Climate Solutions."

102 Government of Canada et al., "Pan-Canadian Framework on Clean Growth and Climate Change," 2016, p. 21, www.canada.ca/content/dam/themes/environment/documents/weather1/20170125-en.pdf.

103 *United Nations Framework Convention on Climate Change*, May 9, 1992, 31 I.L.M. 849 (entered into force 21 March 1994), Art. 4.1.

104 Natural Resources Canada, "Indicator: Carbon Emissions and Removals," https://www.nrcan.gc.ca/our-natural-resources/forests-forestry/state-canadas-forests-report/how-does-disturbance-shape-canad/indicator-carbon-emissions-removals/16552 (accessed October 29, 2019).

105 Environment and Climate Change Canada, *2020 National Inventory Report*, 2020, https://unfccc.int/documents/224829.

106 See Deluca and Boisvenue, "Boreal Forest Soil Carbon."

107 Environment and Climate Change Canada, *2020 National Inventory Report*. J. M. Metsaranta et al., "Uncertainty of Inventory-Based Estimates of the Carbon Dynamics of Canada's Managed Forest (1990–2014)," *Canadian Journal of Forest Research* 47 (2017): 1082-1094, https://www.nrcresearchpress.com/doi/pdf/10.1139/cjfr-2017-0088.

108 Hesselink, *Boreal Logging Scars*.

109 Environment and Climate Change Canada, *2020 National Inventory Report*.

110 Ibid.

111 Ibid.

112 Dana Nuccitelli, "Canada Passed a Carbon Tax That Will Give Most Canadians More Money," *The Guardian*, October 26, 2018, https://www.theguardian.com/environment/climate-consensus-97-per-cent/2018/oct/26/canada-passed-a-carbon-tax-that-will-give-most-canadians-more-money.

113 Ibid.

114 Environment and Climate Change Canada, *Carbon Pollution Pricing: Options for a Federal GHG Offset System*, 2019, https://www.canada.ca/content/dam/eccc/documents/pdf/climate-change/pricing-pollution/Options-GHG-Offset-System.pdf.

115 See, e.g., Government of Ontario, "Managed Forests and Climate Change," July 17, 2014, updated April 17, 2020, https://www.ontario.ca/page/managed-forests-and-climate-change. Québec Ministère des Ressources Naturelles et de la Faune, *Forests: Building a Future for Québec* (2008), p. 18, mern.gouv.qc.ca/english/publications/forest/consultation/green-paper.pdf. Environment and Climate Change Canada, *Canada's Mid-Century Long-Term Greenhouse Gas Development Strategy*, 2016, https://unfccc.int/files/focus/long-term_strategies/application/pdf/canadas_mid-century_long-term_strategy.pdf.

116 Martin Croteau, "Québec Permettra Plus de Coupes Forestières Pour Réduire les GES," *La Presse*, September 30, 2019, https://www.lapresse.ca/actualites/environnement/201909/30/01-5243494-quebec-permettra-plus-de-coupes-forestieres-pour-reduire-les-ges.php.

117 Ontario Ministry of Natural Resources and Forestry, "Ontario's Crown Forests: Opportunities to Enhance Carbon Storage?" 2016, https://ero.ontario.ca/notice/012-8685.

118 Environment and Climate Change Canada, *Canada's Mid-Century Long-Term Greenhouse Gas Development Strategy*.

119 Ibid., pp. 57-61.

120 Government of Canada et al., *Pan-Canadian Framework*.

121 John Muir Project, "Over 200 Top U.S. Climate and Forest Scientists Urge Congress: Protect Forests to Mitigate Climate Crisis," press release, May 13, 2020, https://johnmuirproject.org/2020/05/breaking-news-over-200-top-u-s-climate-and-forest-scientists-urge-congress-protect-forests-to-mitigate-climate-crisis/. Seton Stiebert et al., *Emission Omissions: Carbon Accounting Gaps in the Built Environment*, International Institute for Sustainable Development, April 2019, https://www.iisd.org/sites/default/files/publications/emission-omissions-en.pdf.

122 Ibid. Stith T. Gower, "Patterns and Mechanisms of the Forest Carbon Cycle," *Annual Review of Environment and Resources* 28 (November 2003): 194. https://www.annualreviews.org/doi/abs/10.1146/annurev.energy.28.050302.105515. Malcolm, Holtsmark, and Piascik, "Forest Harvesting and the Carbon Debt."

123 Seton Stiebert et al., *Emission Omissions: Carbon Accounting Gaps in the Built Environment*.

124 Gert Jan Nabuurs et al., "Forestry," in *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, B. Metz et al., eds. (New York: Cambridge University Press, 2007), p. 550.

125 Stiebert et al., *Emission Omissions*.

126 Ann Ingerson, "Carbon Storage Potential of Harvested Wood: Summary and Policy Implications," *Mitigation and Adaptation Strategies for Global Change* 16, no. 3 (March 2011): 307-323, https://link.springer.com/content/pdf/10.1007/s11027-010-9267-5.pdf.

127 Stiebert et al., *Emission Omissions*. Ann Ingerson, "Carbon Storage Potential of Harvested Wood." Timo Pukkala, "Carbon Forestry Is Surprising," *Forest Ecosystems* 5, no. 11 (February 2018), https://forestecosyst.springeropen.com/articles/10.1186/s40663-018-0131-5.

128 Ann Ingerson, "Carbon Storage Potential of Harvested Wood." Timo Pukkala, "Carbon Forestry Is Surprising," *Forest Ecosystems* 5, no. 11 (February 2018), https://forestecosyst.springeropen.com/articles/10.1186/s40663-018-0131-5.

129 Ingerson, "Carbon Storage Potential of Harvested Wood."

130 Natural Resources Canada, "Statistical Data: Domestic Economic Impact," https://cfs.nrcan.gc.ca/statsprofile/economicimpact/ca (accessed May 26, 2020).

131 Skene and Vinyard, *The Issue With Tissue*.

132 Malcolm, Holtsmark, and Piascik, "Forest Harvesting and the Carbon Debt."

133 K. Pingoud, T. Ekholm, and I. Savolainen, "Global Warming Potential Factors and Warming Payback Time as Climate Indicators of Forest Biomass Use," *Mitigation and Adaptation Strategies for Global Change* 17, no. 4 (January 2012): 369-386, https://cris.vtt.fi/en/publications/global-warming-potential-factors-and-warming-payback-time-as-clim. E. D. Schulze et al., "Large-Scale Bioenergy From Additional Harvest of Forest Biomass Is Neither Sustainable Nor Greenhouse Gas Neutral," *GCB Bioenergy* 4, no. 6 (November 2012): 611-616, https://www.chathamhouse.org/sites/default/files/publications/research/2017-02-23-woody-biomass-global-climate-brack-final2.pdf.

134 Malcolm, Holtsmark, and Piascik, "Forest Harvesting and the Carbon Debt."

135 Carl Meyer, "Liberals Commit to Carbon-Pollution Target of Net-Zero by 2050," *National Observer*, December 5, 2019, https://www.nationalobserver.com/2019/12/05/news/liberals-commit-carbon-pollution-target-net-zero-2050.

136 Liberal Party of Canada, *Planting Two Billion Trees and Using the Power of Nature to Fight Climate Change*, September 2019, https://2019.liberal.ca/wp-content/uploads/sites/292/2019/09/Planting-two-billion-trees-and-using-the-power-of-nature-to-fight-climate-change.pdf. Morgan Lowrie, "Trudeau Vows to Use Trans Mountain Pipeline Revenues to Plant 2 Billion Trees," *Global News*, September 27, 2019, https://globalnews.ca/news/5960379/trudeau-plant-trees-climate-change/.

137 Jeff Wells, "Overlap Between Carbon Stores and Intact Boreal Woodland Caribou Ranges in Canada's Boreal Forest".

138 Caleb Stevens et al., *Securing Rights, Combating Climate Change: How Strengthening Community Forest Rights Mitigates Climate Change*, World Resources Institute, July 2014, https://www.wri.org/publication/securing-rights-combating-climate-change. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, *Global Assessment Report on Biodiversity and Ecosystem Services*, 2019, https://www.ipbes.net/global-assessment-report-biodiversity-ecosystem-services. Government of Canada, "Canada Target 1 Challenge," https://www.canada.ca/en/environment-climate-change/services/nature-legacy/canada-target-one-challenge.html?fbclid=IwAR2eFXUx5oGlzLuZzwkDNLIWSQkWqSnz36F9TipLfcS9L7u4UAJqk8IkZQs#events (accessed July 9, 2020).

139 "Indigenous-Led Conservation," Indigenous Leadership Initiative, https://www.ilinationhood.ca/ (accessed July 11, 2020).

140 Government of Canada, "Indigenous Guardians Pilot Program," https://www.canada.ca/en/environment-climate-change/services/environmental-funding/indigenous-guardians-pilot-program.html (accessed October 29, 2019). Environment and Climate Change Canada, "Canada's $175 Million Investment in Nature Kicks Off Conservation Projects in Every Province and Territory," press release, August 19, 2019, https://www.canada.ca/en/environment-climate-change/news/2019/08/canadas-175-million-investment-in-nature-kicks-off-conservation-projects-in-every-province-and-territory.html.