CARBON STORAGE REDUCTION AND CO_2 PRODUCED BY LOGGING IN THE CATCHACOMA OLD-GROWTH FOREST

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Logging in the Catchacoma Forest, Peterborough County, October 2022

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Summary

Logging operations were carried out by the Bancroft Minden Forest Company in 2019-21 within Canada's largest known, unprotected stand of old-growth eastern hemlock—the Catchacoma Forest, located in northern Peterborough County, Ontario. Virtually nothing is known about how logging impacted the forest's above-ground carbon stores and subsequent production of CO_2, and more generally, how carbon stores in the Catchacoma Forest compare to other temperate forests across eastern North America. This is due to a lack of environmental impact analysis as part of the Ontario forest management planning process. To address this knowledge gap, a joint initiative between AFER and Youth Leadership in Sustainability (YLS) sampled trees, snags, logs, and stumps in logged and intact areas within the Western Portion of the Catchacoma Forest.

Logged areas stored an estimated 202 t C/ha before logging, which decreased to 82 t C/ha after logging. On average, above-ground carbon in intact areas (173 t C/ha) hold 111% more above-ground carbon than logged areas (82 t C/ha). This loss of tree biomass is equal to 441 t CO_2/ha, which is equivalent to ~1.24 million gallons of gasoline consumed for a 25 ha area logged. Biomass and carbon values were also compared to the Central Portion of the Forest (pristine), which stores a conservatively estimated 128 t C/ha. We also estimate (conservatively) that 291,739 t CO_2 would be released if contingency logging takes place as mapped and planned in the Forest – this is the equivalent of ~33 million gallons of gasoline consumed *(estimate does not include the required use of fossil fuel to carry out logging activities)****.***

A comparison of 55 temperate forest stands (old-growth and mature) across NE North America shows that the Western and Central Portions of the Catchacoma Forest fall within the top 15% and 36% of live carbon estimates, respectively. The results of this study demonstrate the significant carbon storage capacity of the Catchacoma Old-growth Forest and the severe detrimental impact that logging has on old-growth forest carbon stores including the production of atmospheric CO_2.

Introduction

During the current climate and biodiversity crises, the logging of old-growth (primary) forests is contributing to climate warming by removing and releasing vast quantities of stored carbon (Figure 1; Watson et al 2018; DellaSala et al 2022; Gilhen-Baker et al 2022). One such landscape is the nationally-significant, unprotected Catchacoma Old-growth Forest located in northern Peterborough County, Ontario (Figure 2), which is the largest documented old-growth eastern hemlock stand in Canada (~662 ha; Quinby 2019).

Figure 1. The Global Decline of Primary Forest and Non-Forest Ecosystems (Green) and Increase of Atmospheric CO_2 (Blue) from 1850-2020 (Makarieva et al. 2023)

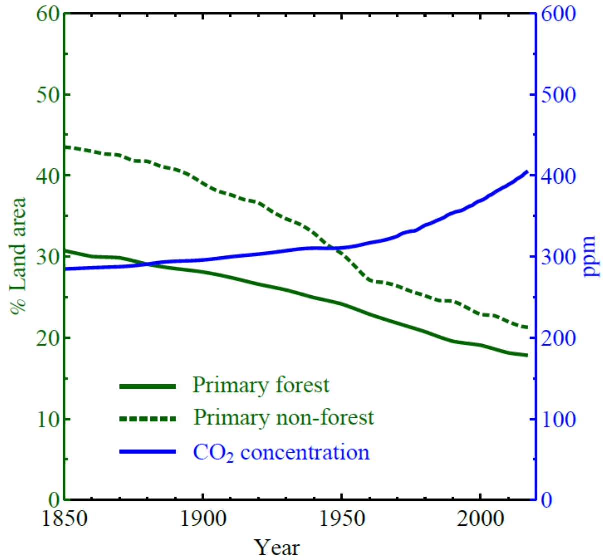
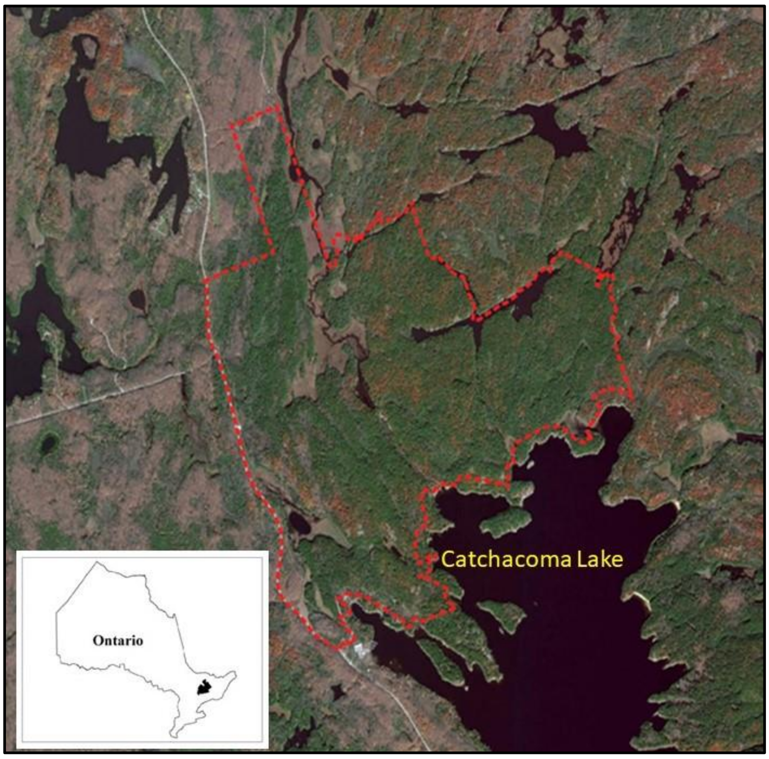


Figure 2. Location of the Catchacoma Old-Growth Forest, Peterborough County



In addition, Obrien et al. (2023) identified the Forest as a regionally significant site for wildlife connectivity and for forest carbon sequestration and storage. Despite these timely and invaluable biodiversity and climate cooling features, an amount between 25 and 50 ha of the forest was logged using the irregular shelterwood method from 2019 to 2021 by the Bancroft Minden Forest Company (BMFC), and future contingency logging has been allocated for this rare and unique site. Further investigation is required to determine the exact amount that was logged.

Although the *Crown Forest Sustainability Act* (Province of Ontario 1994) specifies consideration of all forest values, the Ontario government currently does not require an impact analysis of the effects of logging on carbon storage and dynamics as part of forest management planning. Thus, little is known about how much carbon was removed by logging from the Catchacoma Forest. For example, how much carbon was stored in the Forest before and after logging took place, and how much CO_2 was and will be emitted into the atmosphere due to logging?

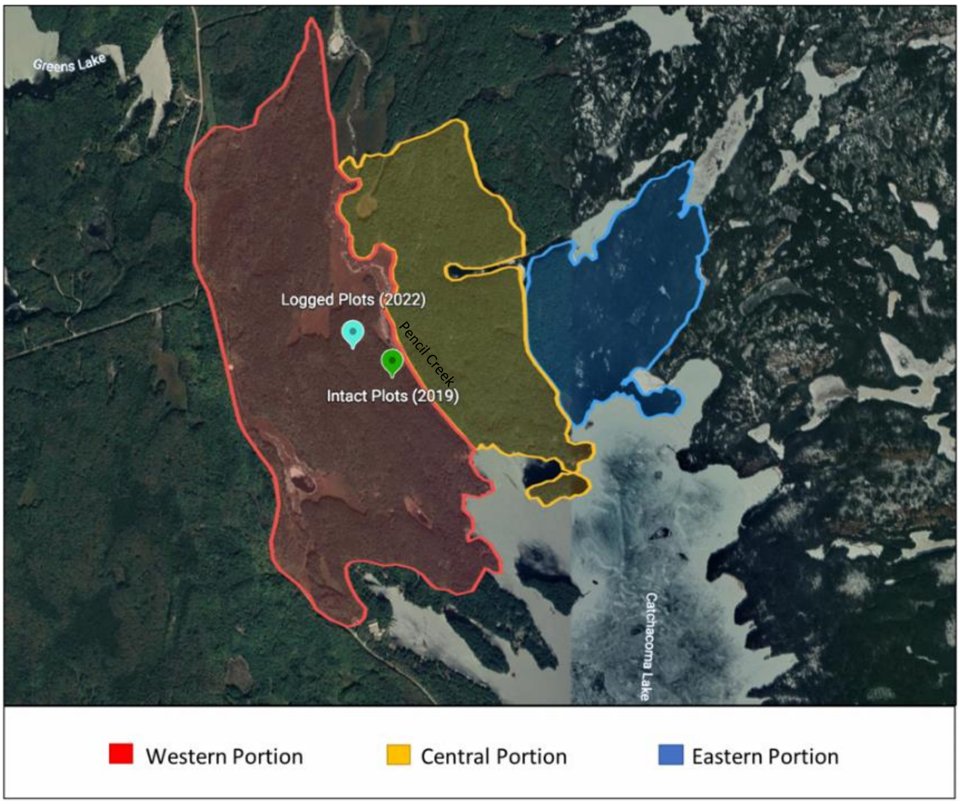
Similarly, little is known about how much carbon is stored in logged areas relative to intact portions of the Forest, and about how the Forest compares to other similar high-carbon forests in NE North America. To address this, AFER and the Peterborough Youth Leadership in Sustainability (YLS) class conducted sampling work in the Western Portion of the Catchacoma Forest in October of 2019 and 2022. Specifically, the purpose of this sampling was to (1) determine the amount of above-ground carbon stored in the logged and intact areas of the Catchacoma Forest, and to (2) estimate the amount of above-ground carbon that was removed by 2019-2021 logging operations in the Forest. Sampling was also conducted in the Central Portion of the Forest during the fall of 2022.

Methods

Sampling in the Western Portion of the Catchacoma Forest

Trees, snags, logs, and stumps were assessed in intact areas (six 500 m^2 plots) and logged areas (four 400 m^2 plots) in the Western Portion of Catchacoma Forest in 2019 and 2022, respectively. Figure 3 shows the general locations of these 2019 and 2022 plots and the boundaries of the Western, Central, and Eastern Portions of the Forest.

Figure 3. The Western, Central, and Eastern Portions of the Catchacoma Forest, and the General Locations of 2019 (Intact) and 2022 (Logged) Plots in the Western Portion



Diameter at breast height (DBH) was recorded for all trees and snags, and diameters at each end of all logs (>10 cm at the small end) were assessed in the 2019 and 2022 plots. These diameters were then used as input values with an online carbon calculator developed by the Association for Canadian Educational Resources (ACER 2022) to estimate: (1) above-ground biomass, (2) above-ground carbon, and (3) above-ground CO_2 stored in each tree, snag, and log of each plot. These values were then summed to determine the total amount of carbon and CO_2 stored in each plot.

ACER's Carbon Calculator generates above-ground biomass, carbon, and CO_2 estimates for native Canadian trees when users input the trees' species and DBH. The calculator determines these estimates using equations from Lambert et al. (2005) and Ung et al. (2008). These equations were derived from the relationships between the above-ground biomass (mass of foliage, branches, bark, trunk), DBH, and height of various Canadian tree species.

The stump diameters that were recorded in the 2022 logged plots were also used as input values with the ACER Carbon Calculator to estimate the above-ground biomass, carbon, and CO_2 that these logged trees stored at the time of logging. It is important to note that only aboveground biomass of trees, snags, and logs were assessed. Thus, the belowground carbon component (roots and soil carbon), which can be considerable, was not assessed, primarily due to the massive amount of time and effort required to sample soil and tree roots, and the destructive nature of excavating soil to expose tree root systems. Future work in the Catchacoma Forest to further refine carbon estimates should endeavor to obtain accurate assessments of belowground carbon.

It is also important to note that CO_2 storage (t/ha) is equivalent to 3.67 x carbon storage (t/ha). This is determined using the molecular weight of carbon and oxygen. Thus, when this report refers to above-ground stored carbon and CO_2, these are equivalent and not additive values.

Sampling in the Central Portion of the Catchacoma Forest

In addition to the permanent plots that were established and sampled in the Western Portion of Catchacoma Forest, mother trees (MTs; those that meet minimum old-growth standards) were surveyed in the Central Portion of the Forest in October 2022. MTs were assessed in 6 x 50 m plots located 50 meters apart along transects (running east-west) that covered the Central Portion (Figure 4). The quantity and species of MTs were recorded in 141 plots located along 19 transect lines. As DBH of MTs was not recorded in the field, conservative estimates for MTs were determined using species-specific minimum old-growth DBH values (Table 1; Quinby 2020). These DBH values were then used as input values with the ACER Carbon Calculator to determine conservative estimates for above-ground biomass, carbon, and CO_2 of the MTs in the 141 sampled plots.

Figure 4. 19 Transects Sampled with 141 Plots in the Central Portion, Catchacoma Forest

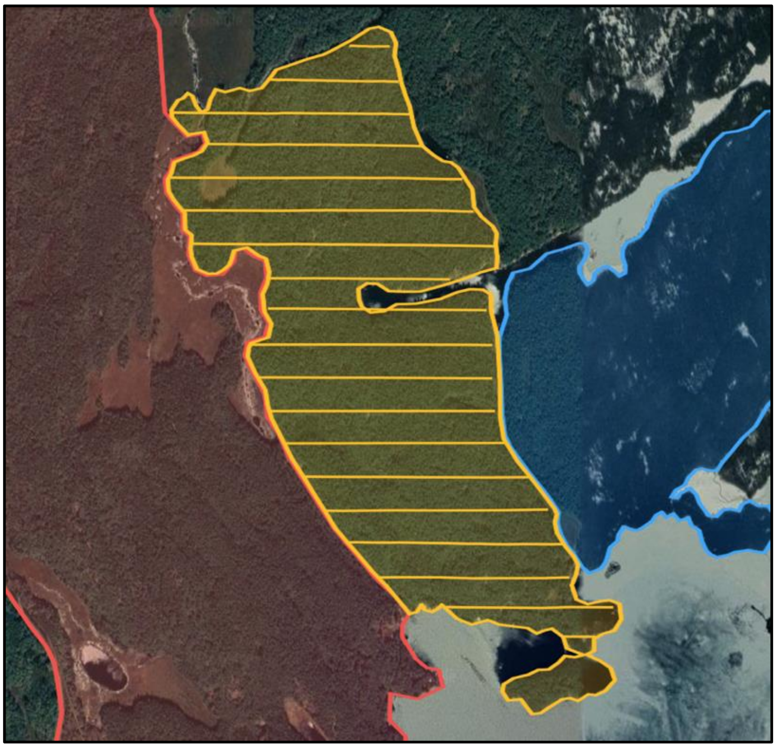


Table 1. Minimum Diameters for Old-growth Trees in the Central Portion, Catchacoma Forest

Species	Minimum Old-growth Age (yrs)	Minimum Diameter (cm)
Eastern Hemlock	140	40
Eastern White Pine	120	50
Red Maple	90	35
Red Oak	120	50
Red Pine	120	40
Sugar Maple	120	35
White Birch	100	35
White Cedar	110	30
White Oak	120	40
Yellow Birch	140	45

Results and Discussion

Carbon Removed by 2019-2022 Logging in the Western Portion

On average, plots stored 202 t C/ha (equal to 742 t CO_2/ha) before logging, which decreased to 82 t C/ha (equal to 301 t CO_2/ha) after logging (Figure 5a,b). In other words, an average of 120 t C/ha (equal to 441 t CO_2/ha) was removed from the Catchacoma Forest by logging operations in the form of above-ground biomass (Table 2). Figure 6 shows a variety of greenhouse gas (GHG) emitting equivalents of this quantity of CO_2 to put this value into a more tangible context (USEPA 2022).

Following its removal, this carbon began to transition back into the atmosphere at varying rates depending on whether the logged wood was used in short- or long-lived products. Carbon stored in short-lived wood products like paper typically transitions back into the atmosphere in ~2 years, whereas it can take upwards of ~100 years for carbon stored in long-lived wood products such as home infrastructure to transition back into the atmosphere (Skog and Nicholson 1998).

Table 2. The Above-Ground Biomass, Carbon, and CO_2 Removed by Logging in Catchacoma Forest

Plot #	Total Above-Ground Biomass of Logged Trees (t/ha)	Total Above-Ground Carbon Stored in Logged Trees (t/ha)	Total Above-Ground CO_2 Sequestered in Logged Trees (t/ha)
1	289	144	530
2	216	108	397
3	201	101	370
4	255	128	466
Mean	**240**	**120**	**441**

Figure 5. Above-Ground Carbon and CO_2 Storage Before and After Logging

(a) Carbon Storage **(b) CO_2 Storage**

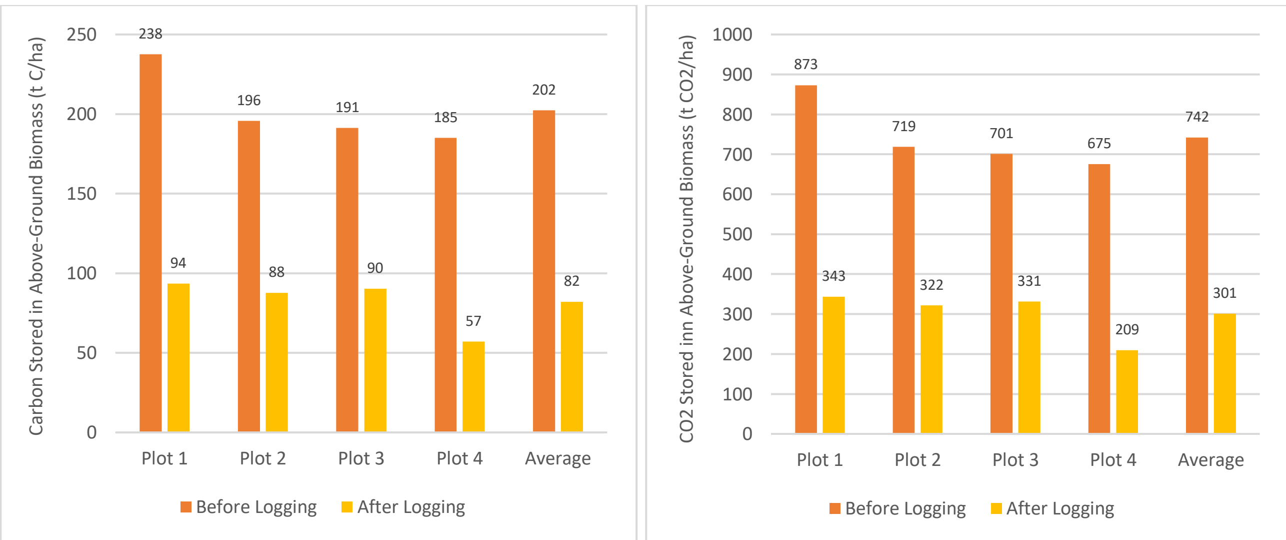


Figure 6. GHG-Emitting Equivalents of the CO_2 (441 t/ha) Released by 2019-2021 Logging

441 tons CO_2 /ha
Removed and released by logging in the Catchacoma Forest

=

95 vehicles
(gasoline-powered), driven for one year

or

1,093,892 miles
driven by an average gasoline-powered vehicle

or

487,588 pounds
of coal burned

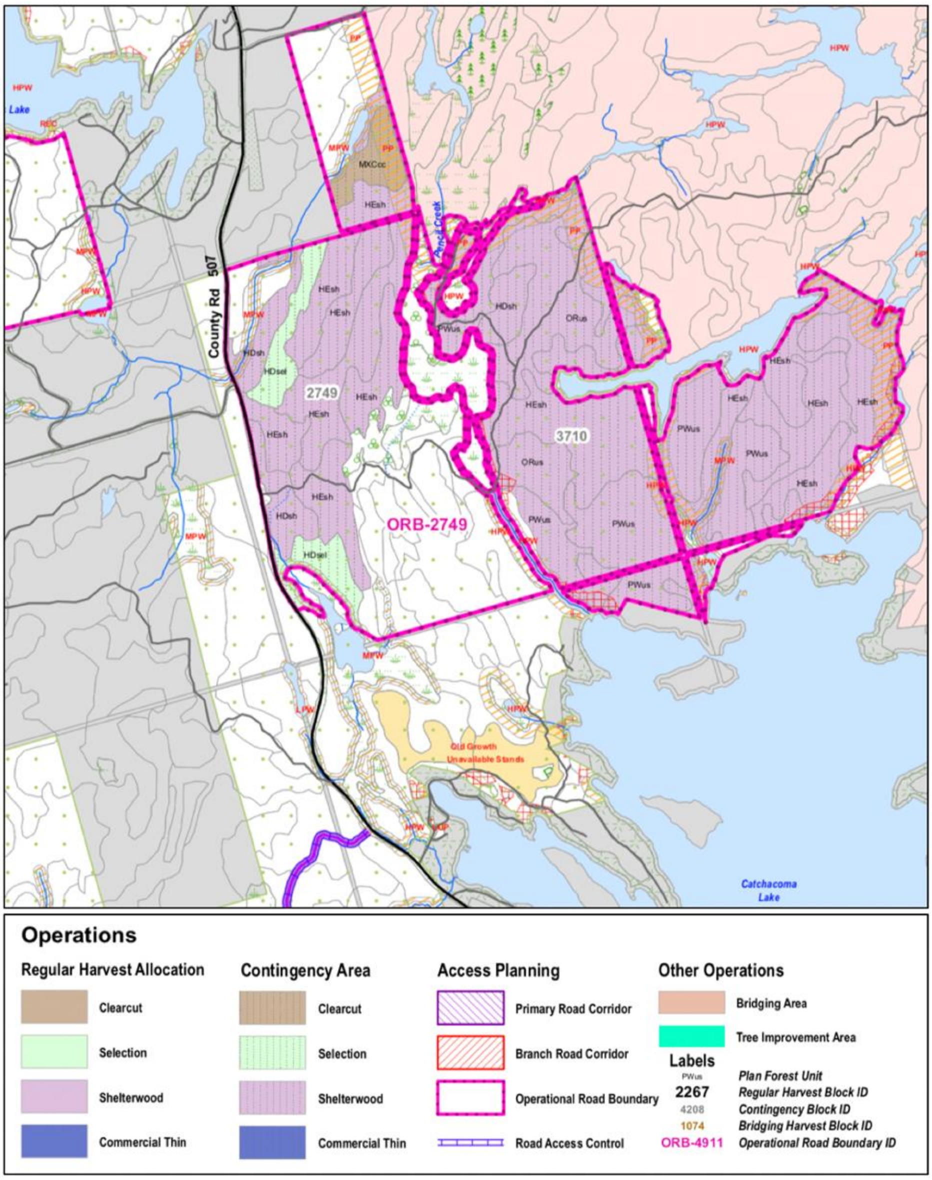
or

49,589 gallons
of gasoline consumed

Carbon Removed by Proposed Future Logging

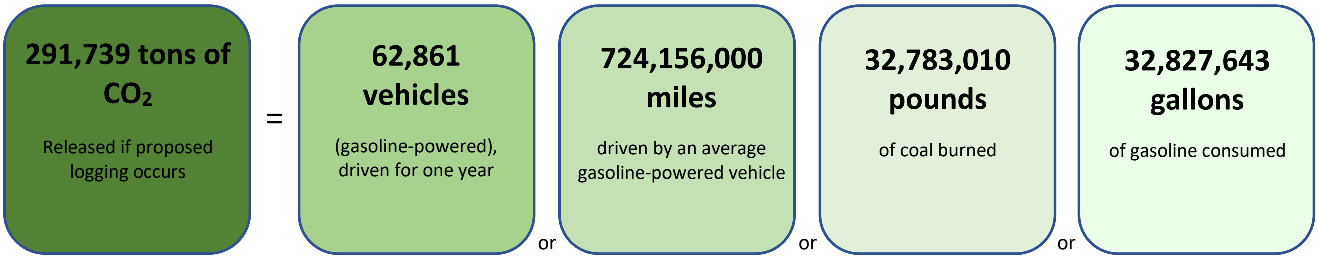
In addition to the recent logging that took place in the Catchacoma Forest in 2019-2022, potential upcoming logging is scheduled in the 2021-2031 Bancroft Minden Forest Management Plan (BMFMP). Figure 7 is a map from the 2021-2031 BMFMP that outlines the proposed areas for contingency logging in the Catchacoma Forest (blocks 2749 and 3710). Together, these blocks make up ~70% of the total area of the forest (~463 ha).

Figure 7. Proposed Contingency Logging in the Catchacoma Forest (pink with vertical lines; per the 2021-2031 BMFC Forest Management Plan)



If the proposed logging area (~463 ha) is logged in a fashion similar to the four logged plots sampled in 2022 (441 t of above-ground CO_2 removed per ha; Table 1; Figure 5b), then 291,739 t CO_2 would be removed from the Forest by this proposed logging. This value is an underestimate as it does not include the CO_2 produced from the use of fossil fuels in logging activities or the carbon released from logging-induced disturbances to the soil. Figure 8 shows various greenhouse gas emitting equivalents of this quantity of CO_2 to put this value into context (USEPA 2022).

Figure 8. GHG-Emitting Equivalents of the CO_2 (291,739 t) Released by Proposed 2021-2031 Contingency Logging



Carbon Storage in Logged Areas Versus Intact Areas, Western Portion

The total carbon/CO_2 stored in above-ground biomass (trees, snags, and logs) of logged plots (2022) and intact plots (2019) was determined using the ACER Carbon Calculator. Figure 9 compares the mean aboveground carbon stored in logged areas (82 t C/ha) to the intact areas (173 t C/ha), and equivalent stored CO_2 in logged areas (301 t CO_2/ha) to intact areas (635 t CO_2/ha).

Figure 9. Mean Carbon and CO_2 Stored in Remaining Above-Ground Biomass of Logged Areas Following Logging Compared to Intact Areas

(a) Carbon Storage **(b) CO_2 Storage**

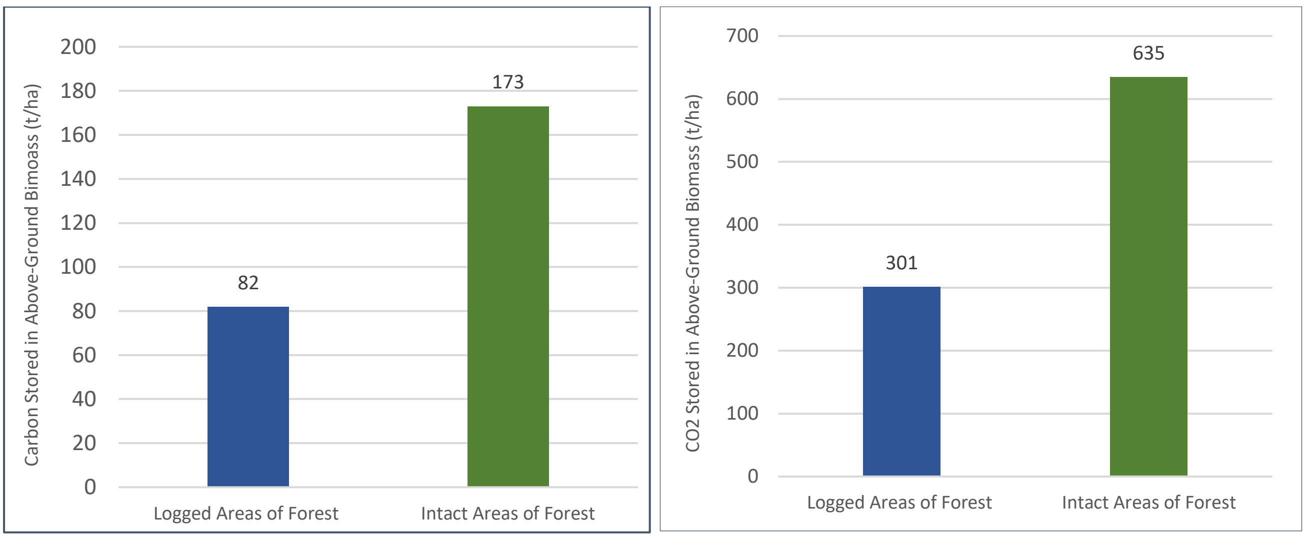


Figure 9 reveals that intact areas within the Western Portion of the Catchacoma Forest hold 111% more above-ground carbon than areas that were logged in 2019-2021. This demonstrates the significant amount of carbon that was removed from Catchacoma Forest by 2019-2021 logging operations.

It is important to note that while this report explores one way that logging impacts forest carbon (e.g., the cutting and removal of carbon storing trees), logging can also impact forest carbon stores in a variety of other ways. For example, logging can create unnaturally large gaps and/or higher gap densities in the canopy that result in increased solar radiation penetration to the forest floor, increasing temperatures in cut areas (Gray et al. 2002; Miller et al. 2007; Forrester et al. 2012). Unpublished AFER field data from the 2022 field season shows that this temperature increase can be as much as 13°C higher in cut areas compared to intact areas in the Catchacoma Forest.

Increased temperatures in forests can have significant impacts on carbon cycling processes (Anderson-Teixeira et al. 2021). For example, increased temperatures at the forest floor can accelerate dead wood decomposition rates, which increases CO_2 production and emission into the atmosphere (Forrester et al. 2012; Kahl et al. 2015). As well, higher temperatures caused by increased solar radiation exposure can increase risk of forest fires by creating hot, dry conditions that are made more hazardous by the flammable slash left on the forest floor by logging (Watson et al. 2018, Martin et al. 2021). When forest fires occur, they can release huge quantities of stored carbon in gaseous form from forested landscapes (Anderson-Teixeira et al. 2021).

Carbon Storage in the Western Portion Versus the Central Portion

Above-ground Biomass of Mother Trees (MTs) in the Central Portion

No historical logging was detected in the Central Portion of the Forest. Table 3 shows the minimum, maximum, and mean above-ground biomass (t/ha) of MTs based on the 141 sampled plots in the Central Portion of Catchacoma Forest. Above-ground MT biomass ranged from 0 to 374 t/ha, with a mean of 112 t/ha in these plots.

Table 3. Mean, Minimum, and Maximum MT Above-ground Biomass (t/ha) for 141 Plots in the Central Portion, Catchacoma Forest

Category	Mother Tree Above-Ground Biomass (t/ha)
Minimum	0
Mean	112
Maximum	374

Total Above-ground Biomass (live and dead wood) in the Central Portion

Using the proportion of MTs to total biomass (trees, snags, logs) found in the six intact plots sampled in the Western Portion of the Forest in 2019, we estimated total above-ground biomass (t/ha) in the central portion (e.g., biomass of all trees, snags, and logs as opposed to just mother trees). Table 4 shows that on average, above-ground biomass of MTs in 2019 intact plots accounted for 45% of total above-ground biomass. Applying this proportion to MTs in the Central Portion, we determined that the total above-ground biomass of the Central Portion ranged from 0 to 831 t/ha, with a mean of 249 t/ha.

Table 4. Mother Tree Biomass as a Percent of Total Above-Ground Biomass (Trees, Snags, Logs) in the Six Intact Plots Sampled in 2019

Plot 1#	Total Above-Ground Biomass (Trees, Snags, Logs) (t/ha)	Total Mother Tree Above-Ground Biomass (t/ha)	Mother Tree Above-Ground Biomass, as a Percent of Total Above-Ground Biomass (%)
1	324	133	41
2	363	194	53
3	558	237	42
4	286	89	31
5	174	97	56
6	368	174	47
Mean	346	154	**45**

Carbon Storage in the Central Portion Versus the Western Portion

Using the accepted assumption that carbon content makes up approximately 50% of above-ground tree biomass (Jana et al. 2009, Paladinić et al. 2009, Hetland et al. 2016, Salas Macias et al. 2017), we determined carbon storage in the Central and Western Portions of the Catchacoma Forest from their above-ground biomass values (Table 5).

Table 5. Mean Above-ground Biomass, Carbon, and CO_2 (t/ha) in the Intact Western Portion (6 plots) and Central Portion (141 plots) of the Catchacoma Forest

Location	Mean Above-Ground Biomass (t/ha)	Mean Above-Ground Carbon (t C/ha)	Mean-Above Ground CO_2 (t CO_2/ha)
Western Portion (6 intact plots)	345	172.5	632.4
Central Portion (141 intact plots)	249	124.5	456.4

When comparing tree biomass and carbon in the Western Portion of the Catchacoma Forest to the Central Portion, it is important to note that different sampling methods (originally for different purposes) were used for these two areas. Establishing the samples (141 plots) along the transect lines systematically across the entire Central Portion (2% sample by area) allowed for a much more accurate estimation of the mean and variation of MTs and their biomass within that portion.

In comparison, establishing six circular plots in the Western Portion provided a less accurate estimation of the mean and variation of tree biomass, as these plots were specifically selected to represent areas that were “typical” of the intact forest in that portion, and less time was available for that assessment resulting in fewer samples. Thus, the results for the Western Portion are biased towards the higher density portions of that part of the Forest. In the future, the entire Western Portion should be sampled using the method applied in the Central Portion in order to obtain a more accurate estimate of mean and variation of above-ground biomass and carbon.

When comparing biomass and carbon estimates in the Western and Central Portions of the Forest, it is also critical to emphasize that DBH values were recorded in the field for plots in the Western Portion but not for those in the Central Portion, where only trees meeting minimum old-growth diameters were tallied. As such, minimum diameters for old-growth tree species (Quinby 2020) were used to estimate diameters of MTs in the Central Portion. Thus, use of these minimum diameters generated conservative estimates of MT metrics when used with the ACER Carbon Calculator. If DBH of MTs had been recorded in the field, total biomass and carbon estimates for the Central Portion would have been higher than the value reported (124.5 t C/ha).

Comparison of NE North American Temperate Forest Stands

Table 6 compares live above-ground carbon estimates (t/ha) of 55 temperate forest stands located in NE North America (SE Canada and NE United States), including two portions of the Catchacoma Old-growth Forest (Western and Central portions). Since most studies determined live above-ground biomass rather than total (live and dead wood) above-ground biomass, Table 6 is comprised of live above-ground carbon estimates. Carbon content (50% of aboveground biomass) was calculated from studies that documented above-ground biomass and not carbon storage.

Above-ground live carbon estimates ranged from 7 - 453 t C/ha (mean = 96 t C/ha) across the 55 temperate forest stands shown in Table 6. Stands in the table are organized from highest carbon estimates to the lowest. The Western and Central Portions of the Catchacoma Forest fall within the top 15% and 36% of carbon estimates in the table, respectively. The top 10% of carbon storage estimates all belong to temperate forest stands located in the NE United States, which is generally further south than Canadian stands and where the growing season is longer, facilitating greater biomass accumulation.

On average, old-growth temperate forests located in NE North America (from Table 6; n=17; mean = 182 t C/ha) stored 122% more carbon than the most carbon-rich mature stands (n=17, mean = 82 t C/ha, t=0.0014 (highly significant)). Clearly, old-growth forests in NE North America contain more than twice the amount of tree biomass compared to the most biomass-rich mature forests, which also means that old-growth forests are far superior to mature forests in terms of carbon storage and CO_2 sequestration.

As shown by this case study of the Catchacoma Forest, old-growth forests are the crown jewel of terrestrial carbon storage and sequestration, with mature forests also contributing significantly to this ecosystem service that is so important for keeping the climate cool. In addition to their fiber value, all other values of forested ecosystems (including carbon storage) are supposed to be assessed, evaluated, and considered by the forest management planning process in Ontario (Province of Ontario 1994).

Until federal and provincial policies reflect the fact that the managed forests of Canada and Ontario are now a source of atmospheric carbon rather than a sink due to forest management practices (ECCC 2021, Saxifrage 2021), forest carbon management in Ontario will continue to be mis-managed (Skeen 2021). During this current existential crisis of global climate warming, this is unacceptable according to most scientists and the public at large.

Table 6. Comparison of Aboveground Live Carbon Estimates for 55 Eastern North American Temperate Forest Stands, Ranked High to Low (t C/ha; sub-dominant tree species in parentheses)

Location	Forest Type	Above-ground Carbon in Live Biomass (t C/ha)	Reference
Michigan, USA	**Old-growth** *Tsuga canadensis* Forest	453	Woods (2014)
Michigan, USA	**Old-growth** *Acer saccharum* Forest	442	Woods (2014)
Michigan, USA	**Old-growth** Mixed Hardwood-Conifer Forest	339	Woods (2014)
Tennessee, USA	**Old-growth** *Tsuga canadensis* (*Halesia Carolina, Fagus grandifolia, Acer saccharum*)	220	Burrascano et al (2013)
Tennessee, USA	**Old-growth** *Tsuga canadensis* (*Fagus grandifolia, Acer saccharum*)	199	Burrascano et al (2013)
Mid-Atlantic US	**Old-growth** *Quercus alba (Quercus prinus, Liriodendron tulipifera, Tsuga canadensis, Acer saccharum, Quercus rubra)*	154[1]	McGarey et al (2015)
Vermont, USA	**Old-growth** *Acer saccharum (Fraxinus americana)*	139	Burrascano et al (2013)
West Catchacoma Forest, Ontario, Canada	**Old-growth** *Tsuga canadensis*	**136[2]**	**this study**
Maine/New Hampshire, USA	**Old-growth** *Tsuga canadensis (Picea* sp.*, Albies* sp.*)*	132	Burrascano et al (2013)
Michigan, USA	**Old-Growth** *Acer saccharum (Betula alleghaniensis, Tsuga canadensis)*	131	Burrascano et al (2013)
Panuke Lake, Nova Scotia, Canada	**Old-growth** *Tsuga canadensis (Picea rubens)*	116	Stewart et al (2003)
Michigan, USA	Mature *Acer saccharum (Betula alleghaniensis, Tsuga canadensis)*	115	Burrascano et al (2013)
Sporting Lake, Nova Scotia, Canada	**Old-Growth** *Tsuga canadensis (Pinus strobus, Picea rubens)*	111	Stewart et al (2003)
Vermont, USA	**Old-growth** *Tsuga canadensis (Picea* sp.*, Abies* sp.*)*	111	Burrascano et al (2013)
Maine/New Hampshire, USA	**Old-Growth** *Acer saccharum (Fagus grandifolia, Betula* sp.pl.)	104	Burrascano et al (2013)
Grand Anse, Nova Scotia, Canada	**Old-growth** *Acer saccharum (Betula alleghaniensis, Acer rubrum)*	104	Stewart et al (2003)[3]

[1] This value is an average of carbon estimates from 25 old-growth temperate forest stands across the Mid-Atlantic US
[2] Carbon stored in above-ground biomass of live trees was averaged for 6 intact plots in the western portion to determine this value.
[3] Forest stands were quantified in terms of volume, and so equations and dominant-species-specific parameters from Boudewyn et al (2007) were used to convert from volume (m3/ha) to biomass (t/ha)

Location	Forest Type	Above-ground Carbon in Live Biomass (t C/ha)	Reference
Happy Valley, Ontario, Canada	Temperate Forest	102	Puric-Mladenovic et al (2016)[4]
Scanlon Creek, Ontario, Canada	Temperate Forest	99	Puric-Mladenovic et al (2016)
North River, Nova Scotia, Canada	**Old-growth** *Acer saccharum (Betula alleghaniensis)*	99	Stewart et al (2003)
Central Catchacoma Forest, Ontario, Canada	**Old-Growth** *Tsuga canadensis*	**98.2**[5]	**this study**
Baldwin, Ontario, Canada	Temperate Forest	94	Puric-Mladenovic et al (2016)
Newmarket, Ontario, Canada	Temperate Forest	94	Puric-Mladenovic et al (2016)
Joker's Hill, Newmarket, Ontario, Canada	Temperate Forest	88	Puric-Mladenovic et al (2016)
Stratford, Ontario, Canada	Temperate Forest	87	Puric-Mladenovic et al (2016)
Appalachian Plateau, Eastern USA	Temperate Deciduous Forest	86	Botkin et al (1993)
Georgina Island, Ontario, Canada	Temperate Forest	84	Puric-Mladenovic et al (2016)
Newmarket, Ontario, Canada	Temperate Forest	81	Puric-Mladenovic et al (2016)
New York, USA	Mature *Betula alleghaniensis (Fagus grandifolia, Picea rubens, Tsuga canadensis)*	74	Burrascano et al (2013)
New York, USA	Mature *Betula alleghaniensis (Fagus grandifolia, Piecea rubens, Tsuga canadensis)*	72	Burrascano et al (2013)
Newmarket, Ontario, Canada	Temperate Forest	69	Puric-Mladenovic et al (2016)
King City, Ontario, Canada	Temperate Forest	68	Puric-Mladenovic et al (2016)
Campbellville, Ontario, Canada	Temperate Forest	68	Puric-Mladenovic et al (2016)
Newmarket, Ontario, Canada	Temperate Forest	63	Puric-Mladenovic et al (2016)
Southern Ontario, Canada	Temperate Forest	56	Puric-Mladenovic et al (2016)

[4] This study investigated above- and below-ground live carbon. 16.6% of total studied live carbon is below-ground, and so 16.6% was subtracted from the total studied carbon to arrive at above-ground live carbon.
[5] The proportion of live above-ground biomass to total biomass (live and dead) for intact plots in the western portion of Catchacoma Forest was applied to the total biomass of the central portion to determine this value

Location	Forest Type	Above-ground Carbon in Live Biomass (t C/ha)	Reference
Quebec, Canada	*Acer saccharum*-Dominant Temperate Hardwood Forest	53	Duchesne et al (2016)
Bruce Peninsula, Ontario, Canada	Temperate Forest	53	Puric-Mladenovic et al (2016)
Southern Ontario, Canada	Temperate Forest	46	Puric-Mladenovic et al (2016) [4]
Piedmont Province Lowlands, Eastern USA	Temperate Deciduous Forest	45	Botkin et al (1993)
Northeastern USA	Temperate Deciduous Forest	45	Botkin et al (1993)
Quebec, Canada	Temperate Deciduous Forest	43	Nelson (2010)
Adirondack Mountains, New York, USA	Temperate Deciduous Forest	42	Botkin et al (1993)
Quebec, Canada	Temperate Mixedwood Forest	41	Nelson (2010)
Quebec, Canada	*Betula Alleghaniensis*-Dominant Temperate Mixedwood Forest	41	Duchesne et al (2016)
Quebec, Canada	Mixedwood Deciduous Forest	40	Nelson (2010)
Quebec, Canada	Northern Temperate Mixedwood Forest	39	Nelson (2010)
Quebec, Canada	Mixedwood Conifer Forest	38	Nelson (2010)
Eastern USA	Temperate Deciduous Forest	38	Botkin et al (1993)
Quebec, Canada	Northern Temperate Conifer Forest	34	Nelson (2010)
Laurentian Highlands, New York, USA	Temperate Deciduous Forest	34	Botkin et al (1993)
Eastern USA	Temperate Deciduous Forest	32	Botkin et al (1993)
Southern Ontario, Canada	Temperate Forest	31	Puric-Mladenovic et al (2016)
Quebec, Canada	Northern Temperate Forest	30	Boudreau (2008)
Eastern USA	Temperate Deciduous Forest	29	Botkin et al (1993)
Southern Ontario, Canada	Temperate Forest	13	Puric-Mladenovic et al (2016)
Northeastern USA	Temperate Deciduous Forest	7	Botkin et al (1993)

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AFER's Mission and Guiding Principles

AFER is a non-profit scientific organization with a mission to carry out research and education that leads to the identification, description and protection of ancient (pristine) forested landscapes, including old-growth forests. The earth-stewardship principles that guide our work include the following.

- Many forest ecosystem types are now endangered. We consider these ecosystems and other ancient forests to be non-renewable resources, which is not consistent with the practice of mining or logging them.
- We consider biodiversity conservation needs at local, provincial, federal and international scales.
- We support the Government of Canada's commitment to increase protected areas to 30% of the Canadian land base by the year 2030.
- We support the *New York Declaration on Forests* to end natural forest loss by 2030.

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