Adapting U.S. Forest Service Methodology to Determine Minimum Standards for Verification and Delineation of Old-growth Eastern Hemlock Forests In Trent Lakes, Ontario

Forest Landscape Baselines #41

(**brief progress and summary reports**)

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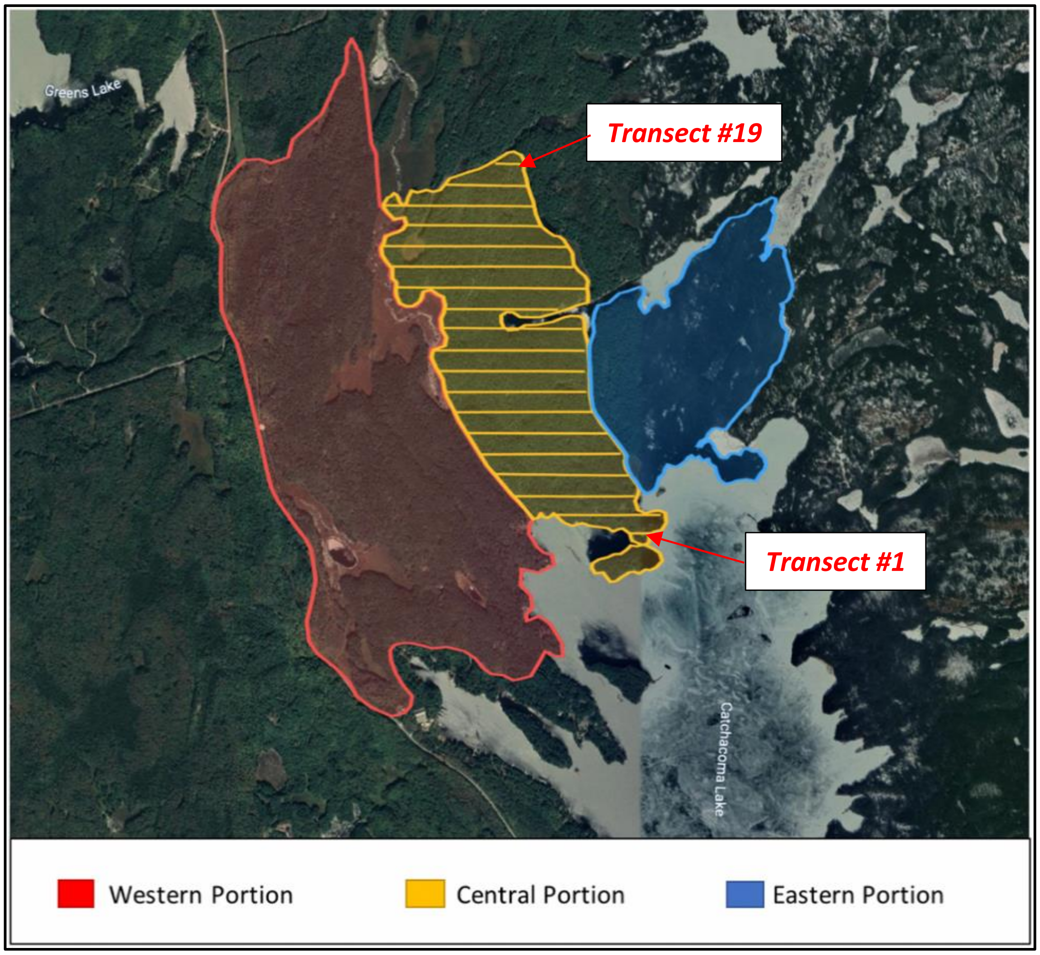

Figure 2. Map of the Catchacoma Forest Including Sample Transects in Central Catchacoma Forest, Trent Lakes, Ontario

Summary (MT-mother tree, or old-growth tree; OGF-old-growth forest) Minimum standards based on field data for the *Eastern Hemlock MT (Dominant)-Eastern White Pine MT (Sub-dominant) Community Type* include: (1) an eastern hemlock MT density of 20/ha, (2) an eastern white pine MT density of 13/ha, (3) a density of 36/ha for all MT species combined, (4) a deadwood density of 84/ha, (5) 9 t/ha for MT above-ground stored carbon, and (6) 7 t/ha of deadwood above-ground stored carbon. OGFs with no cut stumps have the highest level of ecological integrity, however, there will likely be many newly designated OGFs with a few cut stumps. Whether all or a sub-set of these minimum standards are applied to field data will be determined by the user. OGF field assessment studies should be part of an adaptive management process so that field data can be used not only to identify and delineate OGFs but can also be used to refine and further develop OGF minimum standards.

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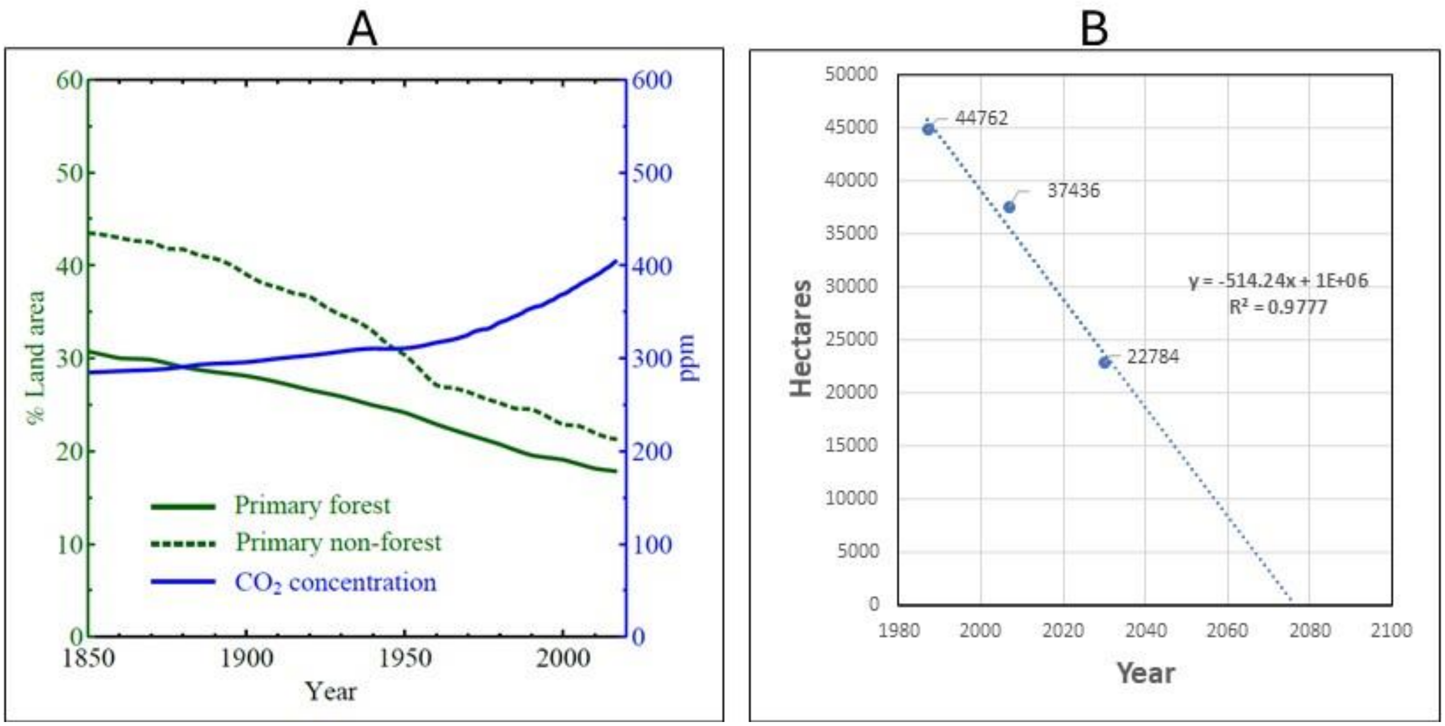
Introduction

The Problem

It is well known that increasing land use pressures are driving continuing global loss of primary old-growth forests (OGFs) throughout the world (Fig. 1-A; e.g., Dinerstein et al. 2019, 2020; Obrien et al. 2021; Makarieva et al. 2023, The White House 2023), including in Ontario, Canada (Fig. 1-B; e.g., Drever et al. 2010; Ross 2020; Henry and Quinby 2021, Quinby et al. 2022). To curb this trend, rapid and efficient survey methods are required to identify and protect these biodiverse and carbon-rich forested landscapes (Wirth et al. 2009). This includes developing minimum standards to be used to identify and accurately characterize old-growth forest features that distinguish these older forested ecosystems from younger forests and from other landscape vegetation types.

Figure 1. A-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)**; B-Decline of Eastern Hemlock Dominated Forest in Ontario's Area of Industrial Logging from 1987 to ~2075** (from Quinby (2024); FRI data)



Unlike the USA (Barnett et al. 2023, The White House 2023, USFS 2023) and the European Union (O'Brien et al. 2021, European Commission 2023, Mikolas et al. 2023) where federal and multi-federal action, respectively, are leading the effort to develop comprehensive standards for the assessment, identification, mapping, and protection of old-growth and other primary forests, the Canadian federal government has not yet initiated a national effort to develop such standards. To date, only six Canadian provinces – Newfoundland and Labrador, Nova Scotia, New Brunswick, Ontario, Saskatchewan, and British Columbia – have developed official operational definitions of old-growth forest, however, none of them have prepared minimum standards for the variety of old-growth forest types that occur in their province (Issekutz 2020).

The most significant achievement by the Ontario government has been the classification of old-growth forest community types that occur in the central and northern portions of the province, and the determination of the age-of-onset for each of these forest community types (OMNR 2003). Comprehensive old-growth forest standards include integrity, live old trees (age, density, carbon storage), snag density and carbon storage, and log density and carbon storage (USFS 2023). For Ontario, the only comprehensive OGF minimum standards we know of were produced using data (old trees, snags, logs) from 41 plots within 30 of the oldest and largest pristine old-growth red and eastern white pine forest stands in Temagami, Ontario ranging in size from 11 to 913 ha (Quinby and Giroux 1993).

Although only one stand (181 ha) was sampled for this study of the Central Catchacoma Forest (this report; Fig. 2) compared with the 30 stands sampled in Temagami, the sampling intensity of 142 plots/stand was much higher for this study compared to the mean of 1.4 plots/stand in Temagami (Quinby and Giroux 1993). These differences in number of stands sampled and sampling intensity can significantly affect results making comparisons dubious, which emphasizes the need for an accurate, robust, efficient, and consistent field protocol to assess for and describe OGFs in Ontario.

Modifying Management of the Catchacoma Forest, Canada's Largest Old-growth Eastern Hemlock Ecosystem

In July of 2021 the Director, Southern Region of the Ministry of Northern Development, Mines, Natural Resources and Forestry (MNDMNRF), responded to written concerns from the Catchacoma Forest Stewardship Committee supporting protection of the Catchacoma Forest, Canada's largest eastern hemlock OGF (CFSC 2021). In the response, the Director stated that the "*Ministry is committed to having old growth conditions and values continue in Ontario's Crown forest in order to conserve biodiversity at levels that maintain or restore ecological processes*", to "*enhanc[ing] old-growth considerations in the FMP* [forest management plan] [and] …*to contribute to constructive and cooperative dialogue*". To address these concerns and objectives, the Director prepared orders (Rew 2021) to be followed by the Bancroft District MNDMNRF and Bancroft Minden Forest Company (BMFC; logging licensee) that addressed logging, climate change, carbon storage, and old-growth verification and delineation.

<u>Logging</u>

- A 1-year logging moratorium (delay) was placed on harvesting of blocks 2749 and 3710 to allow additional research and values collection work.
- Following the moratorium and once other criteria (see climate change and old growth below) are met, block 2749 will become available for harvest and block 3710 will remain in contingency.
- If block 2749 is logged, it should be done using the selection system not the shelterwood system to manage for old growth values to be included in revised "*Silviculture Ground Rules [SGR]*" for the final FMP submission.
- An administrative amendment to the FMP will be required once all conditions described above are fulfilled before logging may proceed in these blocks.

<u>Climate Change and Carbon Storage</u>

- The planning team shall prepare a summary of the components of the forest management plan (FMP) that supports climate change mitigation and adaptation to be added to the FMP supplementary documentation. This direction must be satisfied prior to allowing logging to proceed in blocks 2749 and 3710.
- The MNDMNRF Southern Region Office will work with the Ministry's Science & Research Branch for provincial assessment of forest carbon stocks to enhance knowledge and understanding of logging impacts on forest carbon and to inform the development of future forest management plans.

<u>Old-growth Verification and Delineation</u>

- MNDMNRF "*will develop technical guidance for old-growth verification and delineation based on a thorough literature review and considering AFER* [Ancient Forest Exploration & Research] *reports and data, input from sustainable forest licensees and other stakeholders*."
- "*The Planning Team shall identify hemlock stands older than 130 years from the Operational Planning Inventory and create a map that portrays these areas. This map will be included in the final FMP to be considered for the old growth selection system SGR*."

Summary of Old-growth Standards and Protocols Work (prior to June 2024)

The following is based on the abstract from Quinby and Marcus (2024). We used systematic rectangular plot placement along evenly spaced east-west transects at a 2% sampling intensity for the 181 ha old-growth eastern hemlock-dominated Catchacoma Forest (largest of its type in Canada (Quinby 2019a)) to sample for mother trees (or large, old trees that meet minimum diameters (Quinby 2019b)) and cut stumps. All eastern hemlock-dominated forests in Ontario could be gone by 2075 given current trends, which demands rapid assessment for these endangered ecosystems. This methodology facilitates more efficient coverage of larger areas compared to assessing randomly placed and intensively sampled plots typically used for long-term ecological studies by ~ 15X.

Mother trees (MTs) are the largest and oldest trees on a landscape (Quinby 2019b) and can act as central biodiversity hubs or keystone ecological structures (Liu et al. 2019). As the key component of an old-growth forest, old-growth trees can also be considered MTs, however, not all MTs are old-growth trees. For example, large old trees in urban-suburban areas and on agricultural lands can act as keystone ecological structures providing unique habitat value to insect, bird, and small mammal species despite the absence of old-growth forest conditions (Lindenmayer and Laurance 2017, Liu et al. 2019).

Three hotspots that support the highest MT densities and MT species richness were identified with GIS and only one cut stump was found for a density of 0.006 stumps/ha. Four MT forest types were characterized including: *Eastern Hemlock-Dominant* (47%), *White Pine-Dominant* (26%), *Other MT Species-Dominant* (9%), and *Eastern Hemlock-White Pine Co-dominants* (8%). MTs were absent from roughly 10% of the study area. Compared to five other studied forests with MT data, highest MT densities were found in the eastern hemlock-dominated Catchacoma Forest (123-194/ha), second highest MT densities were associated with an eastern hemlock-dominated forest in Connecticut, USA (125/ha). The Canadian federal government has not initiated a national effort to develop old-growth standards including field assessment protocols; and densities and biomass standards for MTs, snags, logs, and integrity (cut stumps) have yet to be developed by the Government of Ontario.

Our results, including a field protocol, represent a first step towards establishing old-growth forest standards for old-growth eastern hemlock forests in Ontario's *Great Lakes-St. Lawrence Forest*, and potentially beyond. Given the continuing decline of old-growth forests, standards should also be developed for the many other forest types in the *Great Lakes-St. Lawrence Forest*. Ontario's primary contribution to the Global Safety Net (GSN, Dinerstein et al. 2020) is the large extent of roadless areas and high carbon storage in its terrestrial ecosystems. The Catchacoma Forest, with its roadless area and its documented high carbon content is precisely the type of unprotected landscape sought for protection by the GSN, yet it remains unprotected.

Purpose

The purpose of this report is twofold: (1) to present evidence-based, quantitative, multi-metric OGF descriptions and minimum standards for old-growth eastern hemlock forest communities found in the Central Catchacoma Forest, and (2) to map MT forest community types, MT density and carbon storage, and deadwood density and carbon storage to show variations of metric abundances across the Central Catchacoma Forest landscape.

Methods

> "*The most common approach to defining mature and old-growth forests is to place them in a successional continuum of increases in tree size, biodiversity, habitat niches, and structural diversity with forest age*", however, "*There does not seem to be a readily-available [remote sensing] method to map mature and old-growth stands across a landscape with a high degree of accuracy… [this] will likely require additional [field] measurements*" (Gray et al. 2023).

To supplement remote sensing information available for the Catchacoma Forest region, we conducted rapid field assessments of primary old-growth forest features including MTs, snags (>10 cm DBH; >2 m H), logs (1 m L; >10 cm D), and cut stumps within 142 plots. Sample plots were placed systematically along evenly spaced east-west transects every 50 m at a 2% sampling intensity for the 181 ha Central Catchacoma Forest (Fig. 2).

The focus only on structural characteristics of OGF community types (*Franklin Method*; Appendix A) is based on easily measurable OGF structural features including old live trees, snags, and logs originally developed by Franklin et al. (1981; 1986) (Obrien et al. 2021) and is currently used by the USFS for OGF inventories (2023). Franklin et al. (1981; 1986) consider OGFs to be free from the impacts of logging and therefore the Franklin Method does not include a measure of ecological integrity. In contrast, given the pervasiveness of logging in southern and central Ontario, we included the easily measured field metric called *cut stumps* to assess for the degree of ecological integrity of a potential OGF.

For simplicity and in recognition of the wide variation of deadwood abundance on the Catchacoma Forest landscape, we combined *snags* and *logs* into a single *deadwood* category. The *Acer Carbon Calculator* (ACER 2022) was used to determine carbon storage in live and dead wood. A weighted mean of the minimums for the six metrics for all four MT community types (mature forest samples excluded) was used to determine *minimum standards*. *Thiessen polygons* (ESRI ArcGIS 2024) were used to create the map of forest community type populations, defined as “connected groups of polygons of the same MT community type including those with minimal diagonal connections at the corners” (Figure 3).

Following data collection modelled on the Franklin Method, we evaluated two potential statistical metrics to determine OGF minimum standard values. One method uses “range minimums” (e.g., Quinby and Giroux 1993) whereas the Franklin Method uses the “percentile” method. These two methods each using the six primary OGF metrics were compared, however, instead of the 25th percentile used by USFS (2023), we used the 12.5 percentile in order to be more inclusive of potential OGF landscapes, given their known scarcity.

ESRI (2024) *natural neighbor* analysis (one iteration) was used to produce spatially continuous maps of MT density and above-ground carbon as well as deadwood density and above-ground carbon for the study area. This analysis has been described by ESRI (2024) as an

> “*interpolation tool* [that] *finds the closest subset of input samples to a query point and applies weights to them based on proportionate areas to interpolate a value… interpolated heights are guaranteed to be within the range of the samples used. It does not infer trends and will not produce peaks, pits, ridges, or valleys that are not already represented by the input samples.*”

Results

The study area (181 ha, 453 ac) was composed of an old-growth eastern hemlock (70% plot frequency)-eastern white pine (59%)-red maple (18%) upland forest ecosystem, which is likely a rare forest type (Quinby and Marcus 2024). Roughly 90% of the study area was occupied by OGF, 10% was composed of mature forest, and 96% of the area is pristine (unlogged). The spatial distribution of MT community types and the mature forest type are shown on Fig. 3. Four of the sample plots closest to the northern shoreline of Catchacoma Lake – the southern boundary of the study area, and one plot mid-way on the western boundary had one or more cut stumps. The stumps along the southern boundary are likely associated with cottager activity given the numerous cottages along the lake’s northern shoreline. At a finer scale within the 181 ha landscape, we found four MT community types (Fig. 3; Table 1) from most to least abundant: (1) *Eastern Hemlock-dominant* (47%), (2) *White Pine-dominant* (26%), (3) *Other MT Species-dominants* (9%), and (4) *Eastern Hemlock-White Pine co-dominants* (8%). Mature forests where MTs were absent made up 10% of the study area.

Figure 3. Mother Tree and Mature Forest Community Types in the Central Catchacoma Forest
(no MTs = mature forest; He = eastern hemlock; Pw = eastern white pine; dots = sample locations)

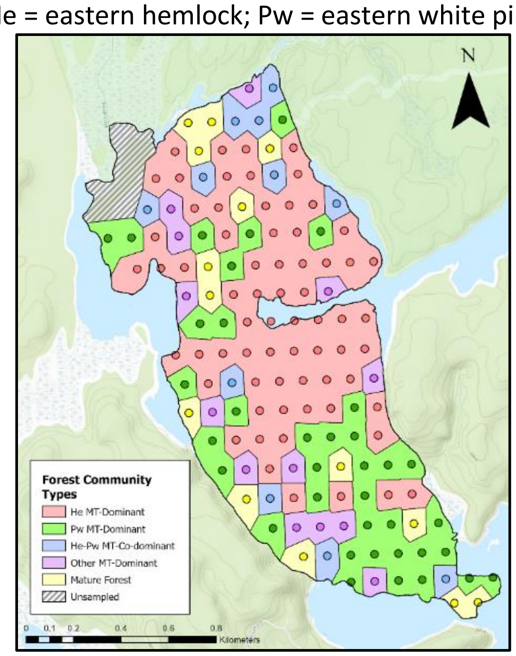


Table 1. Primary Characteristics (Metrics) of Old-growth Forest Community Types in Central Catchacoma Forest, Ontario

Mother Tree (MT) and Mature Forest Types	Primary Old-growth Forest Metrics					
	Living Trees				Dead Trees	
	All Mother Tree Density (mean; #/ha; range)	Hemlock Mother Tree Density (mean; #/ha; range)	White Pine Mother Tree Density (mean; #/ha; range)	Mother Tree Above-ground Carbon (mean; t/ha; range)	Deadwood Density (mean; #/ha; range)	Deadwood Above-ground Carbon (mean; t/ha; range)
Hemlock MT-Dominated (n=67; 47%; 85 ha; 4 populations)	193 (33 - 533) *(highest)*	154 (33 - 400) *(highest)*	17 (0 - 100)	66 (6 - 187) *(highest-tied)*	473 (0 - 967)	45 (0 - 137)
Other MT Species-Dominated (n=13; 9%; 16.3 ha; 9 populations)[#]	169 (33 - 433)	23 (0 - 67)	31 (0 - 133)	66 (7 - 184) *(highest-tied)*	490 (333 - 867)	64 (22 - 286) *(highest)*
Hemlock-White Pine MT Co-Dominated (n=11; 8%; 14.5 ha; 9 populations)	133 (67 - 333)	58 (33 - 133)	58 (33 -133)	54 (28 - 131)	485 (133 - 867)	47 (5 - 137)
White Pine MT-Dominated (n=37; 26%; 47 ha; 11 populations)	123 (33 - 300)	21 (0 - 100)	88 (33 - 200) *(highest)*	56 (10 - 151)	567 (133 - 1100) *(highest)*	44 (14 - 122)
Mature Forest (n=14; 10%; 18 ha; 9 populations)	0 *(lowest)*	0 *(lowest)*	0 *(lowest)*	0 *(lowest)*	431 (33 - 1033) *(lowest)*	34 (1 - 96) *(lowest)*
Old-growth Forest Plots (n=128)	165 (33 - 533)	94 (0 - 400)	43 (0 - 200)	62 (6 - 187)	503 (0 - 1100)	47 (0 - 287)
Central Catchacoma (all plots; n=142)	149 (0 - 533)	85 (0 - 400)	39 (0 - 200)	56 (0 - 187)	496 (0 - 1100)	46 (0 - 286)

NOTES: [#] other **mother tree species** include red pine, northern white cedar, sugar maple, red maple, yellow birch, white birch, red oak, white oak, poplar

Table 1 provides an overview of six primary characteristics, or metrics, of these four MT community types and a mature forest type found in the Central Catchacoma Forest (see Appendix B for maps of MT density and above-ground carbon as well as deadwood density and above-ground carbon). Of the four MT community types, the *Eastern Hemlock-Dominant Type* has the highest density of hemlock MTs (mean, 154/ha, up to 400/ha) as well as for all MT species combined (mean, 193/ha, up 533/ha). Along with the *Other MT Species Type*, the *Eastern Hemlock MT Type* has the highest MT above-ground stored carbon (mean, 66 t/ha, up to 187 t/ha). However, it also has the lowest deadwood density (mean, 43/ha) and along with the *White Pine MT Type*, it has the lowest above-ground carbon storage (mean, 45 t/ha).

The *Other MT Species Type* has the second highest density of all MT species combined (mean, 169/ha, up to 433/ha). In addition to eastern hemlock MTs and eastern white pine MTs, this type includes nine other MT species: red pine, northern white cedar, sugar maple, red maple, yellow birch, white birch, red oak, white oak, and poplar. In addition to the *Hemlock MT Type*, the *Other MT Species Type* has the highest MT above-ground carbon storage, and it has by far the greatest amount of above-ground carbon in the deadwood component (mean, 64 t/ha, up to 286 t/ha). Along with the *White Pine Type*, the *Other MT Species Type* has the lowest hemlock MT densities (mean, 23/ha), and also has a very low white pine MT density (mean, 31/ha).

The *Hemlock-White Pine MT Type* is intermediate in rank for all six OGF metrics. However, the *White Pine MT Type* has the highest value for white pine MT density (mean, 88/ha, up to 200/ha) and for deadwood density (mean, 567/ha, up to 1,100/ha). The *White Pine MT Type* also has the lowest density for all MT species combined (123/ha). The *Mature Forest Type* has the lowest values for all OGF metrics.

The range minimum was selected as the metric to represent the minimum standard for *Old-growth Eastern Hemlock Dominant-Eastern White Pine Sub-dominant Forests* since the 12.5 percentile method overestimated MT and deadwood density and underestimated eastern hemlock and eastern white pine MT densities (Table 2) as shown by comparison with reference data. A minimum of 20 hemlock MTs/ha for the range minimum method (Table 2) is more similar to the MT density minimum standards reported by others compared to a minimum of 8 hemlock MTs/ha obtained for the 12.5 percentile method (Table 2).

Table 2. Minimum Standards for Old-growth Eastern Hemlock Dominant-Eastern White Pine Sub-dominant Forests, Ontario

OGF Metric	Minimum Standard	
	12.5 Percentile	Range Minimum*
Density		
All MT Species	67/ha	36/ha
Eastern Hemlock MTs	8/ha	20/ha
Eastern White Pine MTs	6/ha	13/ha
Deadwood (Snags & Logs)	296/ha	84/ha
Above-ground Carbon		
All MT Species	21 t/ha	9 t/ha
Deadwood (Snags & Logs)	23 t/ha	7 t/ha

NOTES: * means of the values for the four fine-scale MT community types shown in Table 1

Quinby and Giroux (1993) found a minimum of 9 - 15 MT/ha for *Old-growth Red and Eastern White Pine Forests* in Temagami, Ontario (Appendix C) and the USFS (2023, 2024) found a minimum of 25 MT/ha (FIA Forest Type 105; 141+ yrs. tree age/40 cm dbh; Appendix D) for *Old-growth Eastern Hemlock Dominant Forests* in the U.S. Forest Service Eastern Region. In addition, for the percentile method a minimum density for all MT species combined of 67/ha is unrealistically high given that the two dominant MT species combined for 14 MT/ha, which makes up only 21% of the all MT species category. Clearly, 21% of the all MT species category is not dominance by hemlock and white pine.

In summary, minimum standards for the *Eastern Hemlock MT (Dominant)-Eastern White Pine MT (Sub-dominant) Community Type* (Table 2) include at least: (1) an eastern hemlock MT density of 20/ha, (2) an eastern white pine MT density of 13/ha, (3) a density of 36/ha for all MT species combined, (4) a deadwood density of 84/ha, (5) 9 t/ha for MT above-ground stored carbon, and (6) 7 t/ha of deadwood above-ground stored carbon. The application of these minimum standards should be part of an adaptive management process so that field data can be used not only to identify and delineate OGFs but can also be used to refine minimum OGF standards.

Discussion

Forest ecologists and managers worldwide have been working on the "wicked problem" (Gray et al. 2023) of how to define, describe, and inventory OGFs since at least 1930, about a century ago, when Hough (1936) of the U.S. Forest Service conducted the first known study of an OGF (Henry and Quinby 2021) located in Pennsylvania's Tionesta Forest. Fifty years later the first set of quantitative, measurable, multi-metric OGF definitions and minimum standards was produced (Franklin et al. 1981; Franklin et al. 1986 (Franklin Method)) (Obrien et al. 2021).

For 40 years the Franklin Method has been available as a model for application and adaptation to any forested region.

However, other than for the United States (USFS 2023) and for the Temagami Region of Ontario (Quinby and Giroux 1993), few have applied this method beyond those regions. The U.S. Forest Service has applied the Franklin Method systematically to create OGF minimum standards for multiple regions including more than 200 different OGF community types (USFS 2023). These definitions and standards were a necessary step and tool for conducting a national inventory of OGFs as part of the U.S. national OGF protection policy briefly described below (The White House 2023).

> "***Earth Day 2022 Executive Order*** *on* ***Strengthening the Nation's Forests, Communities, and Local Economies****… to conserve and restore America's mature and old growth forests… At the President's direction, the Forest Service and the BLM completed the first-ever nationwide inventory of old and mature forests, and developed definitions for over 200 forest types in the United States…* [for a] *total of 112 million acres*."

In other parts of the world, including Ontario, the lack of quantitative, science-based OGF definitions are often the rationale for putting off the development of effective policies and on-the-ground protection for OGFs (Obrien et al. 2021). However, as stated by Mosseler et al. (2003):

> "*The lack of an all-encompassing, consensual, and uniform definition of an old-growth forest should not… be used as an excuse for either disregarding old growth as a conservation issue or avoiding the development of appropriate public policy*."

To facilitate OGF identification and protection, some have suggested the use of an *OGF Index* (Mosseler et al. 2003, Obrien et al. 2021, Gray et al. 2023) that: (1) could accommodate additional quantifiable forest metrics in addition to MTs, deadwood, and integrity (e.g., cut stumps), (2) would be adaptable recognizing that OGFs are dynamic systems as well as our increasing knowledge of OGFs over time, (3) would be used to evaluate potential OGF stands, (4) could identify true OGFs as well as provide a forest quality ranking using index results, (5) would provide the basis for setting priorities for OGF protection and management at scales from local to global, and (6) could be applied worldwide.

Our *OGF Rapid Assessment Protocol* and *OGF Minimum Standards* meet these six potential *OGF Index* criteria and when applied they also provide the foundation for a geographic database to support spatial analyses and long-term ecological studies. However, given the continuing decline of OGFs worldwide, minimum standards should also be rapidly developed and applied for the many other OGF community types found in Ontario, and beyond.

Whether the minimum standards for all six of the OGF metrics used in this study or some sub-set of them must be met to classify a landscape as Hemlock OGF should be addressed with future studies but ultimately will be determined by the user. MT community type data at the finer scale (1:1.3 vs 1:181) can likely be used to create OGF minimum standards for additional eastern hemlock community types. The primary concern is the variation in sample sizes for community types ranging from 11 to 67 plots. At minimum, those stands that meet the standard for all MT species combined (density or carbon content) but do not meet the minimum deadwood standards (density or carbon content) could be classified as "young OGFs" (Franklin et al. 1986), and those that meet both MT and deadwood standards could be classified as "ancient OGFs" (Quinby 2020b).

As long as OGFs that remain are maintained, scientists and managers will be able to sample, study, learn, and benefit from them. And, as stated by the U.S. Forest Service (2023), "*a continual adaptive management process integrating new science, local conversations, and social processes will refine old-growth… definitions over time*". The problem is that OGFs are also a valuable timber resource that continues to be logged resulting in their severe and rapid continuing decline. Ultimately, if they are not spared from exploitation, their biodiversity, ecological functionality (e.g., energy flow, nutrient cycling, hydrological cycle), and carbon storage will be severely degraded leading to potential extinction (Oxford and Google 2024).

Their loss is a major disadvantage to society since these unique, natural ecosystems provide us with a source of information about how the oldest, most adaptive, and evolved forests in the world work. Delaying their protection will not allow for the future studies that are required to understand and effectively manage for sustainable forested landscapes and the benefits that they provide.

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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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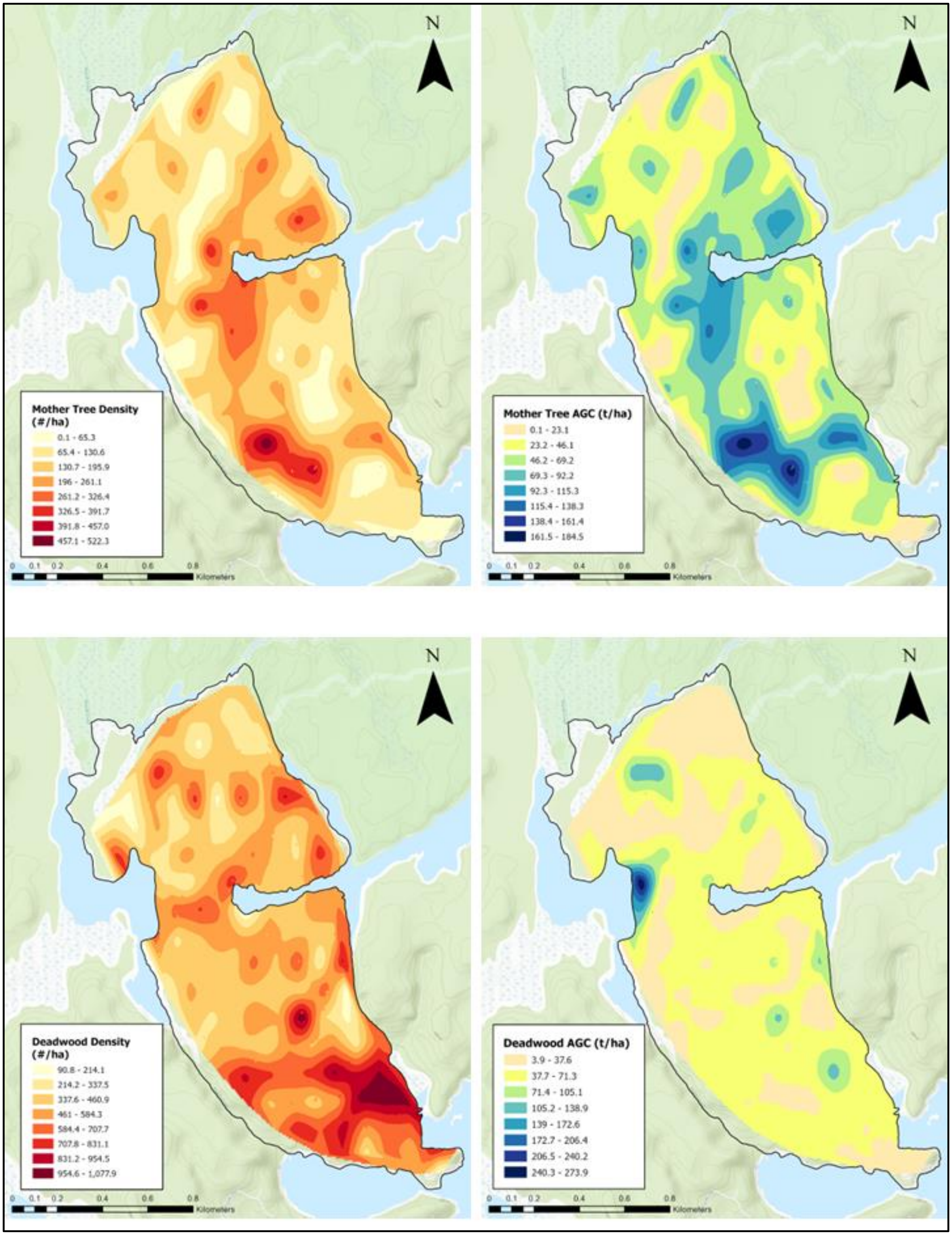
Appendices (A, B, C, D)

Appendix A. Douglas Fir and White Fir Old-growth Forest Characteristics and Minimum Standards (Franklin et al. 1986)

Stand characteristic	Douglas-fir on western hemlock sites (western hemlock, Pacific silver fii)	Douglas-fir on mixed conifer sites (white fir, Douglas-fir)	Douglas-fir on mixed evergreen sites (tanoak, Douglas-fir)	Sierra mixed-conifer forests (white fir)
Live trees	Two or more species with wide range of ages and tree sizes	Two or more species with wide age range and full range of tree sizes	Douglas-fir and evergreen hardwood species (tanoak, Pacific madrone, and canyon live oak) associates (40 to 60% of canopy)	Two or more with wide age range and full range of tree sizes
	Douglas-fir ≥20 per ha of trees >81 cm in diameter or > 200 years old	Douglas-fir, ponderosa pine, or sugar pine ≥20 per ha of trees >76 cm in diameter or >200 years old	Douglas-fir or sugar pine ≥15 per ha of trees 78 1 cm in diameter or >200 years old	Douglas-fir, sugar pine, or ponderosa pine ≥20 per ha of trees 781 cm in diameter or 7200 years old
	Tolerant associates (western hemlock, western redcedar, Pacific silver fir, grand fii, or bigleaf maple) 130 per ha or trees >41 cm in diameter	Intermediate and small size-classes are typically white fir, Douglas-fir, and incense-cedar, singly or in mixture	Intermediate and small size-classes may be evergreen hardwoods or include a component of conifers (e.g., Douglas-fir or white fir)	Intermediate and small size-classes are typically white fir with incense-cedar or both in some stands
Canopy	Deep, multilayered canopy	Multilayered canopy	Douglas-fii emergent above evergreen hardwood canopy	Multilayered canopy
Snags	Conifer snags 110 per ha that are >51 cm in diameter and >4.6 m tall	Conifer snags 23.7 per ha that are >51 cm in diameter and >4.6 m tall	Conifer snags ≥3.7 per ha that are >51 cm in diameter and >4.6 m tall	Conifer snags ≥7.4 per ha that are >51 cm in diameter and 74.6 m tall
Logs	Logs ≥34 metric tons per ha including 10 pieces per ha ≥61 cm in diameter and >15 m long	Logs ≥22 metric tons per bit including 5 pieces per ha >61 cm in diameter and 715 m long	Logs ≥22 metric tons per ha including 5 pieces per ha >61 cm in diameter and >15 m long	Logs ≥22 tons per ha including 5 pieces per ha ≥61 cm in diameter and >15 m long

Appendix B. Density (no./ha) and Above-ground Carbon Storage (t/ha) for All Mother Tree Species and Deadwood (Snags and Logs) in the Central Catchacoma Forest



Appendix C. Eastern White and Red Pine Old-growth Forest Characteristics and Minimum Standards (Quinby and Giroux 1993)

	White Pine-Deciduous	White Pine-Mixed	White Pine-Conifer	White Pine-Red Pine	Red Pine-Conifer
Old Live Trees Density	>10 trees/ha >140 years old	>10 trees/ha >140 years old	>10 trees/ha >140 years old	>15 trees/ha >140 years old	>9 trees/ha >140 years old
Associates >1 m2/ha basal area)	sugar maple, red maple, yellow birch, white cedar	white birch, red pine, white cedar, balsam fir, red maple	red pine, white cedar, black spruce, white birch	white birch, balsam fir, white cedar, white spruce	white pine, black spruce, white cedar, white birch
Canopy	white pine emergent above deciduous	multilayered canopy	multilayered canopy	multilayered canopy	mainly a single layered canopy
Snags	all species >70/ha, >10 cm DBH and 2 m tall	all species >30/ha, >10 cm DBH and 2 m tall	all species >60/ha, >10 cm DBH and 2 m tall	all species >50/ha, >10 cm DBH and 2 m tall	all species >30/ha, >10 cm DBH and 2 m tall
Logs	23 metric tons/ha, 10 pieces/ha 51 cm diam and 8 m long	23 metric tons/ha, 10 pieces/ha 51 cm diam and 8 m long	23 metric tons/ha, 10 pieces/ha 51 cm diam and 8 m long	23 metric tons/ha, 10 pieces/ha 51 cm diam and 8 m long	23 metric tons/ha, 10 pieces/ha 51 cm diam and 8 m long

Appendix D. Minimum Standards for Mother Tree DBH, Density, and Age for FIA Forest Type 105 (Eastern Hemlock Type; USFS 2023)

Table 17.—Eastern Region old-growth community types, corresponding FIA forest types, and large tree diameter and density and stand age minima

Old-growth Type	FIA Forest Type Code	Tree Diameter (inches)	Trees per acre	Stand Age
Beech maple basswood	805	16	10	141
Northern hardwood	520, 801, 802, 809	16	10	141
Dry oak	162, 163, 165, 167, 182, 184, 404, 405, 501, 502, 506, 507, 509, 510, 513, 515	16	20	101
Mesic northern oak	503, 504, 505, 511, 512, 516	20	5	161
Wetland hardwood	701, 702, 703, 704, 705, 706, 707, 708, 709	18	10	121
Conifer northern hardwood	104, 105, 401	16	10	141
Northern pine	101, 102, 103	12	20	101
Montane spruce	121, 123, 124, 128, 129	15	10	141
Sub-boreal spruce/fir	122, 125	12	10	141
Other	All others	14	10	101