Forestry Strategies for Climate Change Resilience in the Wabanaki-Acadian Forest Region

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1. Introduction

Climate change, resource exploitation, fragmentation, and development have already had profound and negative impacts on the Wabanaki forest region; as the climate continues to change, the forest will continue to experience changes in structure, composition, vigour, and resilience. As an organization dedicated to climate justice and caretakers of thousands of hectares of forestland in the Maritimes, Community Forests International actively develops and tests strategies to increase the climate change resilience and carbon storage capacity of the Wabanaki forest.

Ecological, or ecosystem-based, climate-focused forest management is an approach to forest stewardship that holds climate change resilience and carbon storage as its primary objectives, where biodiversity habitats are an important secondary objective and timber production is a by-product of active management. This document is intended to be a technical resource for forest managers, land stewards, forestry professionals, and anyone who is interested in assisting the forest to both better adapt to climate change and continue to mitigate the climate crisis. We provide a number of case studies from interventions that we have undertaken on the lands in our care. We hope that they will provide guidance for others to replicate similar strategies, and to build on this practice further while we all learn how to work with our forests for greater climate resilience.

Indigenous people interacted with the Wabanaki forest in reciprocal and resilient ways for thousands of years before colonization. Many of the ideas and methods we are attempting to describe here are echoes of the deeper history of forest care upheld by Mi'gmaq, Wolastoqey and Peskotomuhkati Nations to this day. Community Forests International looks up to those longer traditions humbly while reckoning with the new challenges that climate change is now placing on the forests we care for.

2. Climate Change Context

Climate change is causing rapid and serious disruptions to ecosystems worldwide, including local species losses, increases in disease, and mass declines of plants and animals. Warmer and drier conditions have increased tree mortality and disturbances in many temperate and boreal forests around the world.[1]

Boreal forests are highly vulnerable to the effects of climate change, since they are dominated by cold-tolerant species that are maladapted to warming conditions. The ecotones (transition zones) between boreal and temperate forests are particularly vulnerable to the effects of climate warming, since many tree species currently co-exist at their most northern and southern geographical range boundaries and species' geographic ranges are shifting as a result of climate change.[2]

3. Wabanaki-Acadian Forest Region

The Wabanaki forest takes its name from the Wabanaki Confederacy made up of the five original nations whose unceded ancestral territories span the region—the Abenaki, Penobscot, Peskotomuhkati, Wolastoqiyik, and Mi'gmaq Peoples. Wabanaki means "Dawnland", denoting the sun rising on the east coast of Turtle Island, and is an ecotonal forest between Appalachian hardwoods to the south and boreal forest to the north which covers the Maritime provinces of Canada, parts of southern Quebec, and parts of the New England states.

The Wabanaki forest has changed substantively in composition, age structure, and complexity since colonization.[3] In its pre-colonial condition, this area was likely dominated by late-successional forest types,[4] and contained only minor amounts of shorter lived, shade-intolerant early successional species.[5] This composition was largely driven by low severity, canopy gap-forming disturbances (like small wind events);[6] however, medium-to-high severity stand-replacing disturbances (principally from hurricanes, fires, and spruce budworm outbreaks) were also present across New Brunswick and Nova Scotia.[7]

Today, the composition of the contemporary Wabanaki forest in the Maritimes has shifted, now with greater proportions of economically important balsam fir and white spruce, as well as early successional species like red maple, white birch, and trembling aspen.[8] For decades, forestry in the region has prioritized high-yield harvesting over long-term sustainability, leading to degraded forests with fewer tree species and lower tree density compared to natural forests in similar environments.[9] In states like Maine, New Hampshire, and Vermont, up to 40% of forested land has been negatively affected by conventional forestry practices.[10] Similarly, in New Brunswick, old forests have declined 39% in the past 40 years alone, and over 3 million hectares have been degraded through intensive forestry practices during that time.[11]

In the Wabanaki forest, the greatest limiter of the survival and growth of cold-adapted boreal species like balsam fir is likely to be the combination of both increased temperature and reduced soil moisture,[12,13,14] and the related increases in frequency and intensity of fires,[15] hurricanes, and pest outbreaks.[16] As the climate continues to change, the vulnerability of the Wabanaki forest will only worsen – especially for those cold-adapted species that are so abundant across the region today. Although wind disturbance plays an important role in maintaining forest health by naturally shaping the structure, composition, and regeneration of a forest, major wind events are projected to increase in frequency and intensity throughout the Maritimes, which is likely to negatively affect standing forests. The simplified structure of much of the forest has also rendered the forest more vulnerable to the effects of climate change. As pest and pathogen outbreaks, wind storms and hurricanes, droughts and floods, and wildfires continue to increase, the forest's ability to protect communities, and perform important functions (like filter water and store carbon), will further erode. In parallel, the biodiversity crisis – the catastrophic declines in plant and animal life worldwide – will also only continue to worsen.

4. Climate-Focused Forest Management

Climate-focused forest management is an umbrella forest managment paradigm that incorporates future climate projections and plans for changes to the forest as a result of ongoing climate change. Within that larger paradigm, ecological, or ecosystem-based, climate-focused forest management prioritizes managing forests principally for increased adaptation to climate change and increased carbon storage capacity, all while restoring and maintaining biodiversity habitats and ecosystem services. Under this approach, forests regain complexity and diversified species composition, prioritizing (where ecologically appropriate) species that are projected to be resilient to climate change. Biodiversity habitats are also improved and restored,[17] while timber is generated only as a by-product of that management. Ecological climate-focused forestry, therefore, generates some wood products and revenues while also restoring the forest. Although these interventions are more complex than more conventional timber-focused activities, there are local harvesting contractors delivering these interventions profitably (e.g. ACFOR Forestry Inc.).

Depending on the objectives of the forest manager or land steward, the conditions of the forest, and projections for continued climate change, there are a number of specific strategies and approaches that can be used to increase the adaptive capacity and carbon storage capacity of a forest. These strategies generally fall into three categories – resistance, resilience, and transition,[18] where:

- Resistance strategies are adaptation strategies that seek to forestall impacts from climate change and protect highly valued resources (e.g. species at risk habitats, old forest). These practices seek to improve forest defenses against direct and indirect effects of rapid environmental changes.

- Resilience strategies are adaptation strategies that improve the capacity of ecosystems to return to desired conditions after disturbance.

- Transition (formerly known as “response”) strategies are adaptation strategies that facilitate transition of ecosystems from current to new conditions and intentionally accommodate change rather than resisting it, with an objective of enabling or facilitating forest ecosystems to respond adaptively as environmental changes accrue.

5. Strategies for Climate Resilience & Ecosystem Restoration

To deliver on our objective of increasing the climate change resilience and carbon storage capacity of the forests in our care, Community Forests International employs a variety of direct interventions. The exact intervention is determined on a stand-by-stand basis, principally by using our own climate-adaptive silviculture resources, *Managing Forestlands for Climate Change*,[19] but additionally we consult a few other resources that were developed for the Wabanaki forest region, including the:

- *Nova Scotia Silvicultural Guide for the Ecological Matrix,*[20]
- *Climate Change Response Framework* and associated Adaptation Workbook and strategies,[21,22,23,24] and occasionally the
- Northern Hardwoods Research Institute's *Silviculture Prescription System*.[25]

Increasing the resilience and carbon storage capacity of a forest stand often requires cutting some trees to free up resources (light, water, nutrients) for the remaining trees. The complexity comes in choosing which trees are cut and the pattern or spatial arrangement of cutting. Planting trees in different stand or forest conditions can also be used to accelerate the successional trajectory of the stand and augmenting its resilience.

Here, we profile three categories of climate-focused forestry interventions – these represent the most common interventions that we employ in our forests. For the most part, given our organizational objectives, when we employ these interventions, we are employing them as *Resilience* or *Transition* strategies. Due to the urgent need for intervention in the more vulnerable forests that we steward, we have focused our limited resources on intervening in the most vulnerable stands first and trying to make the most significant climate gains as quickly as possible. Our more intact forests, which likely have the most valuable habitats (for biodiversity and ecosystem services) may be candidates for *Resistance*-type interventions. They are less vulnerable at present to climate change (compared to most of the rest of our forest stands), and so we have not yet intervened in them.

5.1 Harvesting

Much of the Wabanaki forest has been altered to resemble boreal forests through past logging practices (a.k.a. borealization).[26] This has simplified the mix of tree species and overall forest structure, making these areas less resilient to climate change and weakening their ecological health.

When these simplified forests reach the pole stage (when young trees grow close together but haven't yet matured), they are at a high risk of being wiped out by insects, pathogens, strong winds, and wildfires – threats that are becoming more severe due to climate change.

Removing more than 40% of the tree cover in a forest – especially in timber-focused logging methods like thinning – greatly increases the risk of windthrow. This is because the remaining trees are suddenly more exposed and may not have sufficiently robust root systems to withstand strong winds.[27]

Some forests are already more vulnerable to windthrow, particularly those with:

- Shallow soils that don't provide deep anchoring for tree roots.
- Weak or poorly developed root systems, making trees less stable.
- Low structural diversity, where the trees are mostly the same size and species, which makes them more likely to fall in groups when disturbed.

To reduce these risks, it's better to use frequent, smaller-scale interventions that gradually increase tree variety and structural diversity without making the forest more fragile. These lighter interventions also help the forest store and absorb more carbon, strengthening its role in mitigating climate change.[28] Two harvesting methods that can be used to achieve these objectives are variants on an Irregular Shelterwood method – the Gap and Continuous Cover approaches.

Both Expanding Gap and Continuous Cover Irregular Shelterwood harvesting methods mimic the natural dynamics of mild-to-moderate wind disturbance in forests through careful harvesting to improve overall forest diversity and resilience to other disturbances (like pests, pathogens, and fire). They are commonly used to help regenerate and maintain forests that contain a mix of tree species with mid-to-high shade tolerance (trees that can grow in partial shade). These techniques allow managed forests to better mimic the natural diversity and complexity found in older, natural forests.[29]

Benefits and Drawbacks of Expanding Gap and Continuous Cover Irregular Shelterwood Harvesting Methods

Key Benefits:

- Retains desirable crop trees & improves their climate resilience.
- Increases stand complexity, wildlife habitats & carbon sequestration rates.
- Lowers the risk of major stand-replacing disturbances (e.g. big windstorms and fires).
- Reduced costs of implementation compared to broader uniform interventions.

Potential Drawbacks:

- Requires specialized operator knowledge.
- Slower growth response on softwood sites compared to broader uniform interventions.
- Maintains lower-value trees, complicating future interventions.

5.1.1 Expanding Gap Irregular Shelterwood

5.1.1.1 Specifications

Expanding Gap Irregular Shelterwood harvesting is a forestry technique designed to mimic the natural way wind historically disturbed middle-aged and mature forests in the Wabanaki region. Instead of cutting down all the trees in a stand at once (as is commonly done through "clearcutting", a conventional method that maximizes revenue instead), this intervention removes most of the trees within carefully spaced openings, or "gaps," where the gaps have diameters up to twice the height of an average tree in the stand. These gaps are placed unevenly throughout the treatment area (typically a stand or portion of a stand) and initially cover up to 25% of the area being managed (Fig. 1). These gaps are "expanded" upon in later entries by harvesting a ring (typically equal in volume removed to the first entry) around the gaps - these expansions are not necessarily circular, but can be irregularly-shaped based on features such as clusters of advanced regeneration, rare species, or seeps and watercourses. Some trees are retained permanently in both the gaps and the unharvested matrix of the stand, as sources or seed and biodiversity habitats, living out their entire lives as "retention" trees.

Figure 1. In an expanding gap irregular shelterwood system, initial gaps are harvested (top) in the first entry, and then expanded upon (bottom) in later entries. Permanent retention trees will live out their full lives in the gaps.

The objective of these openings is to encourage the growth of strong, healthy trees while maintaining important features that improve the forest's future condition. Frequent entries (as frequently as every 10-15 years) may be used to accelerate the stand transition to a more climate-adapted composition. To speed up this progression, new trees and shrubs can be planted in the gaps, supplementing the natural regrowth and shaping the composition of the next generation of trees (see **Enrichment Planting**).

Community Forests International uses this method to make forests more resilient to climate change, store more carbon, and restore biodiversity habitats and ecological function. This approach is particularly useful for forests that were previously planted with tree species that are maladapted to a warming climate.

There are several strengths to an irregular gap shelterwood, since it:

- Approximates the spatial patterns and impact of natural wind-based disturbance in this stand type.
- Is easy to implement with conventional logging equipment and can generate revenue.
- Retains desirable canopy structure and growing stock while building wind and fire resistance compared to conventional practices (under similar conditions).

The weaknesses of this approach are that it:

- Requires significant planning and flexibility for feasible implementation, also a large enough stand size to make it economical to float large equipment to.
- May not be aggressive enough to fully prevent negative climate and carbon storage impacts (i.e. transition the stand rapidly enough to a more resilient state to forestall some tree or species losses due to climate change).

5.1.1.2 Case Study – Whaelghinbran Forest

At our 318-ha Whaelghinbran forest, near Sussex, New Brunswick, there are a number of stands that were formerly pasture or crop land, that had been abandoned at different times and regenerated to white spruce, balsam fir, and white pine. One of the earliest old-field stands to be abandoned was subsequently harvested in the 1970s, then regenerated to balsam fir, poplar, and red maple. Parts of this stand had then been planted or pre-commercially thinned in the 1990s, and then saw some trembling aspen harvested in the early 2000s.

This stand is predominately even-aged, with a high proportion of balsam fir and trembling aspen. Outside of the areas that were thinned, there is a high density of softwood species. Balsam fir is rapidly declining in vigor and condition, resulting in many small diameter dead snags and a few openings on exposed slopes where wind has caused patches of windsnap. There are low levels of regenerating balsam fir, red spruce, red oak, red maple, and white pine in the understory, along old extraction trails, and in small gaps related to past light harvesting. Several small seeps along the slope that descend into the brook have been heavily affected by machine traffic in the past, when wood products were removed from the stand. The canopy height is approximately 15 meters, except where residual white pine, hemlock, red and white spruce occur along seeps and harder-to-access slopes. In general, the stand is dominated by climate-vulnerable species, and suffers from low structural complexity.

The property is located in the Fundy Coastal Ecoregion. The soils across the stand are well-drained, coarse-textured, and of moderate productivity, and the stand enjoys a northwestern aspect, at mid slope in a well-protected valley. This means wind risk and drought risk are relatively low to moderate.

In 2022, we identified 28 hectares for a restoration intervention, and deliberated over several possible approaches, including continuous cover shelterwoods, strip cut shelterwoods, and group selection harvests to improve the stand structure and species composition. After inventorying this stand and delineating watercourse buffers, we determined that an expanding gap shelterwood harvest was the best choice to retain growing stock that we expected would continue to thrive on the site, as well as create the conditions desired to favour regeneration of mid-tolerant red oak and red maple. We expected that an expanding gap shelterwood would also create the soil disturbance necessary to favour red spruce and yellow birch regeneration – both these species are found in adjacent stands. In planning our intervention in the stand, imperfectly drained areas were excluded from the operable area, since many of these areas occurred in or near the regulated 30-meter stream buffer. Only 10 hectares of the original 28 hectares were operable after excluding restricted and sensitive areas. Gaps were planned at 60-meter intervals with an optimal diameter of 20 meters, giving us a total removal of 22 percent of the operable area and merchantable volume (including 5-meter-wide trails). The harvest was carried out with a tracked single grip Landrich harvester and 12-tonne forwarders, removing approximately 500 tonnes from the site, including from 2 hectares of road right-of-way. Most of that volume consisted of softwood studwood, pulp, and hardwood fuelwood, which was all sold locally.

We will return in future entries to expand on these initial openings (“gaps”). The re-entry period will depend upon how rapidly regeneration reaches full stocking and 2 meters in average height in the gaps, and whether the stand experiences additional natural disturbance (e.g. natural gaps forming or expanding from big windthrow events). At the time of writing three years after the intervention, the gaps already show promising levels of natural regeneration of desirable climate-resilient species.

5.1.1.3 Case Study – Cove Road Forest

Our 234-hectare Cove Road forest, near Oxford, Nova Scotia, contains a variety of forest stands with a history of intensive management for timber. One stand is comprised of planted jack pine, but neighboring stands contain white pine and red oak. Based on climate projections, we anticipated that without our intervention, the jack pine would eventually succumb to senescence or strong wind events, and would naturally succeed toward a mix of black spruce, red oak, and red maple. Red oak and red maple are both tree species that are projected to persist in the region under a warming climate and changing forest conditions.[30,31]

Because the jack pine plantation stand in the Cove Road Forest had already experienced spotty windthrow and because many young planted conifer stands were greatly disturbed by post-tropical storm Fiona in 2022, we chose to emulate gap-forming wind disturbance in this stand. To do this, we chose to test the Expanding Gap Irregular Shelterwood harvesting approach in the stand. This was an unconventional testing of the method, since this stand is younger than the method would be conventionally employed in, according to our climate-adaptive silviculture guidelines. (Although this may become more common going forward to restore plantations and transition them to a more climate-resilient condition). In this case, a high-retention, expanding gap, irregular shelterwood harvest was used to simulate and speed up the effects of large-scale wind disturbances, like hurricanes, that would naturally shape the forest over time.[32]

Approximately 12 hectares of the stand were treated using gaps that were each 18-20 meters in diameter, which created openings that were twice the height of the surrounding trees. These gaps were spaced roughly 60 meters apart, resulting in a total of 27 gaps across the harvest area. To connect these gaps, trails were planned at 4 meters wide, but since the actual trail footprint ended up being smaller than expected, only 18-20% of the total area was actually cut across the site, which is lower than we initially estimated.

The gaps were created using a Rottne H8 thinning harvester, equipped with a Logmax 3000 cut-to-length, single-grip harvesting head. The harvest focused on removing species with low resilience (mainly planted jack pine) and trees with poor form or defects, following our own criteria for acceptable and unacceptable growing stock.[33]

All the harvested wood was left on-site within the gaps to increase coarse woody debris (fallen branches and logs) and carbon storage. The operator also intentionally scarified (disturbed the soil) in some areas to promote regeneration, particularly because ericaceous species, like lambkill (*Kalmia angustifolia*) and blueberries (*Vaccinium sp.*), can prevent desired tree species from becoming established.

We instructed the harvesting contractor to leave behind permanent retention trees—any individual trees within the gaps from species that are climate-resilient or particularly well suited to the site, such as white pine, red maple, and black spruce. These trees will live out their full life cycle as sources of seed and habitats in the gaps.

This site lacked enough climate-resilient tree species to regenerate naturally, so we expect to plant additional trees in the harvested gaps to help guide the stand toward a healthier, more resilient mix of species over time (see **Enrichment Planting**).

5.1.2 Continuous Cover Irregular Shelterwood

5.1.2.1 Specifications

The Continuous Cover Irregular Shelterwood method (Fig. 2) is similar to the Expanding Gap Irregular Shelterwood in that it prioritizes repeated, light entries to remove shorter-lived and maladapted species and to free up resources for longer-lived, mid-to-shade tolerant species. However, unlike an Expanding Gap Irregular Shelterwood, this intervention is applied in situations where horizontal stand structure is relatively uniform or windthrow hazard is lower.[34] When there is an objective to increase the structural complexity of the stand, then it is especially desirable to implement the Continuous Cover Irregular Shelterwood irregularly across the stand area. To do this, low-value or climate-vulnerable trees can be harvested somewhat patchily, and harvesting can be skipped in areas with desirable advanced natural regeneration, rare species, culturally important species or artifacts, or where there are patches of high-value crop trees. For our objectives, we typically do not harvest more than 1/3 of the area (including trails), to maintain at least moderate shade across the stand and encourage shade-tolerant species to regenerate.

Figure 2. In a continuous cover irregular shelterwood, a network of trails provides harvest access to the entire stand, except areas that are "skipped" for a variety of reasons – for example, to increase structural complexity or protect rare species. Even the accessible area is harvested irregularly, depending on species distributions and objectives for the stand.

5.1.2.2 Case Study – Jungle Road Forest

Our Jungle Road forest is a 186-hectare property near Oxford, NS. In 2024, we partnered with the Nova Scotia Family Forest Network and ACFOR Forestry Inc. to complete a high-retention continuous cover irregular shelterwood (HC-IS) intervention across 26 hectares. This part of the property was an early-successional forest, which contained two distinct vegetation types - IH5 (Trembling aspen – White ash / Beaked hazelnut / Christmas fern) and IH4 (Trembling aspen / Wild raisin / Bunchberry).[35]

The objective of the HC-IS was to accelerate the transition from an early-successional condition to late-successional vegetation types. In the case of the IH5 vegetation type, the objective was to facilitate transition to MW1 (Red spruce – Yellow birch / Evergreen wood fern) or TH3 (Sugar maple – White ash / Christmas fern). In the case of the IH4 vegetation type, the objective was to facilitate transition to MW1 (Red spruce – Yellow birch / Evergreen wood fern) or TH6 (Red oak – Yellow birch / Striped maple / Partridge-berry) cover. Where the species mix was more favourable, we left pockets untreated. After identifying one black ash (a rare and culturally significant species prized by the Wabanaki Nations) in the stand, we buffered the tree with a 30 m radius circle and excluded that area from harvest.

For the HC-IS, the target was maximum 33% volume removal (including trails), with a residual canopy closure of 60% or greater to discourage aspen regeneration. Our instructions to the contractor for the harvest were to:

- Not create gaps unless desirable advanced regeneration was already present.
- Create crown openings primarily around crop trees of desirable species.
- Maintain some untreated pockets focused on areas with a more desirable species mix, areas of high biodiversity value, pockets of advanced regeneration, or pockets of imperfect drainage.
- Target 10-25% of the area in this untreated condition, with leave areas a minimum 0.1 ha (0.25 acre) in size.
- Retain unmerchantable stems in the understory wherever they were not competing with a crop tree. This will help provide a secondary source of shade for controlling aspen regeneration.
- Retain all legacy, diversity, and mast-producing growing stock trees.
- Retain all standing dead trees (snags) if possible.

The soil types for this area (ST9, ST3-L, ST3) were at moderate-to-very high risk for rutting, compaction, and erosion, especially in areas that were imperfectly drained. To protect soils from negative impacts during harvesting, we instructed the contractor to:

- Stay on higher ground and avoid travel in depressions or wet pockets (we provided an indicator species fact sheet to help identify these areas).
- Avoid unnecessary machine travel and do not shift trails if damage occurs. Instead, reinforce main trails with slash and/or corduroy to prolong use.
- Reinforce side trails with slash as needed to avoid one-pass damage.
- Minimize mineral soil exposure, especially on slopes. If rutting occurred on slopes, stabilize with slash and/or water bars.
- Shut down operations when needed (e.g., after significant rain events) or stockpile harvested wood adjacent to trails until conditions allow for extraction.

During implementation, the contractor stopped harvesting and forwarding in the central southern section of the stand due to soil disturbance caused by a combination of site characteristics, periods of heavy rain, topography and long forwarding distances. At our request, the contractor left products in sensitive areas at the stump to minimize compaction. In areas with sensitive soils where some travel was necessary, the harvester and porter laid slash and low-grade products in the trail as reinforcement. In the end, the contractor only implemented the harvest across 21.7 hectares. There is a possibility that we may enrichment plant (see **Enrichment Planting**) the area with red spruce, yellow birch, and possibly sugar maple (in nutrient-rich microsites), but the need for this will be determined by post-harvest regeneration surveys.

5.2 Tending

Tending interventions, like various types of thinning, are activities that are applied to younger stands that have not yet reached biological maturity. (Actually, these interventions were developed to increase growth in stands that haven't yet reached economic maturity, for timber objectives – but similar practices can still be used to address climate objectives). Forests that already have shallow roots, thin soils, or low species diversity are naturally at higher risk of excessive windthrow. To reduce this risk, these forests need light, frequent thinnings rather than heavy cutting. Repeated light tending treatments, like thinning, allow the remaining trees to slowly acclimate to increased wind exposure, whereas heavy cutting would open the stand too rapidly to big wind disturbances and risk the entire stand blowing down. Frequent, light thinnings also show promise in supporting the resilience of stands to a variety of stressors that are increasing due to climate change (e.g. wind, drought, fire).[36]

Both Crop Tree Release (CTR) thinning (a.k.a. "Free Thinning,") and Pre-Commercial Thinning (PCT) are interventions used to tend young forest stands by thinning (cutting) out undesired trees in favour of freeing up resources (light, nutrients, water) for the remaining target crop trees. CTR is a selective approach to managing young forests, focusing on individual high-value trees rather than thinning an entire stand (Fig. 3). It differs from PCT, which is applied evenly across the entire stand and prioritizes increased and even growth of all crop trees in the stand (Fig. 4).

CTR offers several advantages over traditional thinning methods (like PCT), particularly in even-aged forests dominated by fast-growing, shade-intolerant hardwoods like aspen, birch, and cherry.[37] CTR is often used in shade-tolerant hardwood forests, where the goal is to produce high quality logs rather than just increasing timber volume. Unlike uniform thinning (like PCT), CTR leaves much of the stand untouched, allowing certain trees to die off naturally while still providing important habitat (e.g. mast trees, snags) for wildlife. By carefully thinning around a limited number of high-value crop trees, CTR may enhance wind resistance and carbon storage more effectively than heavier thinning treatments like PCT.[38,39]

Since Community Forests International prioritizes climate resilience, carbon storage, and biodiversity, we have adapted this method into Climate Crop Tree Release (CCTR)—a version of CTR that emphasizes climate-adapted species as crop trees. CTR is especially beneficial for mid-tolerant species like white pine, red oak, and red maple—helping them grow by reducing competition from faster-growing trees. For example, research shows that CTR can help selected red oak trees survive climate stress, in particular by improving their resilience to drought.[40] It also allows trees to develop larger, fuller crowns, which improves wind resistance and carbon storage. Since both CTR and PCT produce similar growth responses over time,[41] we usually choose CTR over PCT for climate-focused stand tending, because CTR introduces greater irregularity and complexity into the stand, and retains higher initial stand-level carbon.

5.2.1 Climate Crop Tree Release

In a typical CTR, you choose up to 400 crop trees per hectare (depending on species, density, shade tolerance, and site conditions), then “release” those crop trees on three sides. This means cutting the competing trees (those that impede the crown) on three sides of the crop tree, to free up space, light, and resources for the crop tree.

In some jurisdictions, like through the Association for Sustainable Forestry in Nova Scotia, CTR is eligible for a subsidy. Typically, the requirement is to release 125 crop trees per hectare in CTR interventions, which translates to about 9-meter spacing between trees if evenly distributed. Subsidies for CTR most often are aimed at growing high-quality hardwood sawlogs – so in shade-tolerant hardwood stands this is the minimum density of crop trees needed to prevent severe epicormic branching (and to grow straight, knot-free logs).

In applying this treatment more broadly for climate resilience (hence, Climate CTR) – potentially replacing even- aged tending treatments like PCT – we adjust crop tree spacing based on average stand height. Taller trees need more space and fewer trees per hectare, while shorter trees can accommodate a higher density of crop trees in the treated stand.

This means that while the standard 125 crop trees per hectare is a guideline, the actual spacing and density should remain flexible. The goal is to prioritize the highest-value trees and climate-resilient species in the stand as crop trees, even if these trees are irregularly distributed across the stand. This irregular approach allows land stewards to adapt the treatment based on site conditions and tree species characteristics rather than strictly following a fixed number of trees per hectare.

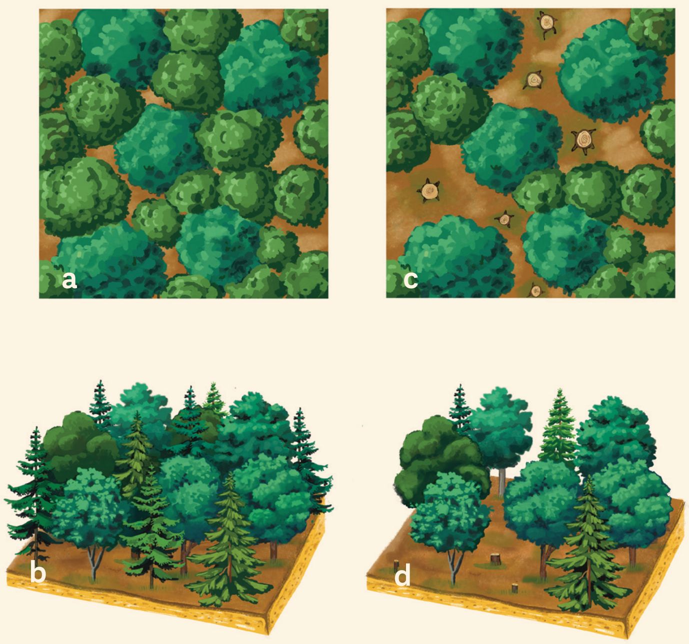


Figure 3. In a crop-tree release, desirable crop trees are identified before harvest (a, b) and released by cutting competing trees on three sides (c, d). This introduces irregularity into the stand.

Benefits and Drawbacks of Crop Tree Release

Key Benefits:

- Retains desirable, climate-resilient crop trees,
- Adds structural diversity, improving wildlife habitats and stand complexity.
- Lowers the risk of major stand-replacing disturbances (e.g. big windstorms and fires).
- Maintains/ enhances carbon sequestration rates and storage.
- Supports mast tree retention, aiding biodiversity.
- Reduced treatment costs compared to broad thinning interventions.

Potential Drawbacks:

- Requires skilled operators with specialized training.
- Slower growth response on softwood sites compared to PCT.
- Retains more lower-value trees, complicating future interventions.

5.2.1.1 Specifications

We have trialed the Climate Crop Tree Release (CCTR) treatment at several Community Forest International's sites including at our Cove Road (NS), Melrose Hill (NS), Midgic (NB), and Pearsonville (NB) sites. Our focus in these trials is on improving pole-aged stands of different compositions, by adhering when appropriate to the traditional specifications of choosing 125 crop trees per hectare (to access subsidies when available, and for ease of comparison across CCTR interventions).

Community Forests International's key modifications for CCTR as a climate-focused alternative to traditional CTR include:

1. Prioritizing climate-resilient species when selecting crop trees, rather than just focusing on high-value timber.

2. Targeting removal of low-resilience species and trees with poor form or defects, based on Community Forests International's guidelines for acceptable and unacceptable growing stock.[42,43]

3. Adjusting crop tree density based on height and stand age, ensuring younger or taller stands receive appropriate spacing.

4. Varying intervention intensity – less intense (fewer crop trees, fewer removals) for shade-tolerant species, more intense (more crop trees, more removals) for mid-tolerant species or taller stands.

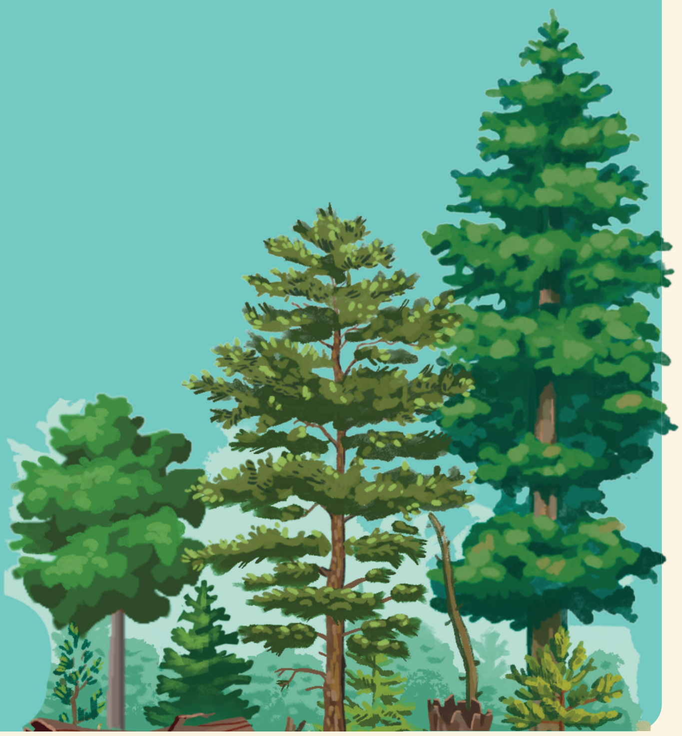
5. Ensuring that the next intervention (such as a selection harvest or shelterwood) supports regeneration, avoiding commercial thinning where possible.

Community Forests International staff collect site inventory data for each property's management plan before implementing interventions, and this data is collected again in 10 years when the plans require revision. At that time, we assess carbon stock changes since the CCTR, along with any impacts from natural disturbances that may affect species composition and climate resilience projections. We determine whether and when additional interventions are warranted, including strategies to enhance carbon sequestration and storage, as well as those that move carbon into other ecosystem pools (e.g. by increasing coarse woody debris). These future interventions should also aim to create greater irregularity in stand structure and vegetation distribution, boosting both the climate resilience and wildlife habitat value of the stand.

5.2.1.2 Case Study – Cove Road Forest

Our largest trial of this technique is at our Cove Road forest, where we implemented a CCTR in 2023 across more than 50 hectares of young black spruce and jack pine plantation. Implementing a CCTR in a softwood plantation is a somewhat unconventional (or at least largely untested) application of this approach, since CTRs have most traditionally been used in tolerant hardwood forests, where the goal is to produce high-quality logs rather than just increasing timber volume. Our objective here, however, was to introduce irregularity into an even-aged and highly climate-vulnerable stand, and CCTR was our preferred method of accomplishing this.

Prior to the plantation, that stand likely supported a mixed species composition, and so the plantation represented a reduction in diversity and simplification of the stand. In addition, both black spruce and jack pine are cold-adapted boreal species and are projected to fare poorly as the climate continues to warm. As a result, we chose to release naturally occurring climate-adapted regeneration by cutting the competing planted black spruce and jack pine. There was sufficient natural regeneration in the stand that we were able to release red maple, red oak, and white pine, and occasionally red spruce, yellow birch, and sugar maple. Infrequently, when no climate-adapted species were present, we chose a well-formed black spruce or white birch for release, to meet the minimum silviculture funding requirements. The average stand height was 7 meters, and so we adhered closely to the silviculture funding criteria and mapped 125 crop trees per hectare for release. In this case, the contractor used a manual chainsaw crew to complete the intervention.



5.2.1.3 Case Study – Pearsonville 2 Forest

In 2024, we implemented a CCTR at our Pearsonville 2 forest, near Sussex, NB, in a 7.7 ha stand. This was comprised of young intolerant hardwoods with lesser amounts of shade-tolerant softwood and hardwood species scattered throughout. The entire Pearsonville 2 property had been clearcut 26 years prior. This stand had been pre-commercially thinned in 2008, leaving minor amounts of long-lived, mid-to-shade tolerant hardwoods throughout the stand (especially yellow birch) – these species became the focus (target species for retention) of our CCTR intervention. Although there was little regeneration in the stand given its high crown closure and relatively young age, there were a few patches with a small number of regenerating sugar maple, white ash, and red spruce in the understory. Protecting this regeneration was a priority during the CCTR, since it represents the next cohort of trees to grow in the stand.

Before the intervention, the stand height was approximately 10-12 m. During the intervention, we flagged 459 high-value crop trees for release, equating to slightly more than 9 m spacing (approximately 107 trees per hectare) throughout.

Unlike the intervention at our Cove Road forest, this CCTR was completed using an excavator-mounted shear head on a small tracked harvester. As a result, meeting the maximum 33% basal area removal target (required to access silviculture funding) was challenging, in comparison with a manual thinning treatment. However, the contractor did an admirable job minimizing site disturbance and adequately releasing crop trees as marked throughout the stand with little crop tree damage.

Completing this intervention with mechanized equipment, rather than a manual chainsaw crew, was something of an experiment. Manual crews are increasingly hard to find, whereas mechanized options are becoming more available. In this case, the work was completed in a timely fashion and to our specifications; however, the per-hectare cost of such a mechanized treatment is considerably higher than for a manual crew. Although we ultimately were unable to access silviculture funding to support this intervention, this was not clearly attributable to the use of the machine, and we generally considered this experiment a success.

5.2.2 Climate Pre-Commercial Thinning

Pre-commercial thinning (PCT) is typically used as a systematic tending intervention for young single cohort (a.k.a. single-aged) stands, where a portion of the stems are cut just as the stand enters the stem exclusion stage of development. Applying PCT too early can backfire – removing competitors too soon can trigger a surge of fast-growing, shade-intolerant species (like aspen and birch), which can once again suppress crop trees rather than support them.[44] PCT is applied uniformly across the stand and perpetuates a single-cohort condition – it is most commonly used in the Maritimes to tend natural or planted stands that have emerged after major stand-replacing disturbances (e.g. clearcuts, fire). This approach frees up light, nutrients, and water for the remaining trees, allowing them to grow more rapidly; often, PCT prioritizes leaving (releasing) species that are valued for timber.

The variant on PCT that we employ prioritizes species for retention that are projected to be climate-adapted, irrespective of their value for timber products – hence, climate-focused precommercial thinning (CPCT). Although CCTR is our preferred method for tending young stands to increase their climate change resilience, we have pragmatically implemented CPCT in a couple of our forests. This is for a few reasons – first, we've implemented a CPCT in cases where we determine that the stand isn't holding quite enough climate-adapted trees to ensure top-quality outcomes from a CCTR. In these cases, we judged that a CPCT would provide a good initial intervention to increase the disturbance-resilience of the stand and to kick-start a shift in species composition – the next intervention might be more suited to a CCTR, to further shift the stand's resilience. Second, we want to compare the outcomes of the two treatments, to test these assumptions – to do so, we actually need to implement CPCT in some stands. Third, PCT is often more readily funded by provincial silviculture programs (certainly in New Brunswick) – and so, we have in a few cases chosen CPCT so as to access funding and also to ensure we have a few sites to compare against our CCTR interventions.

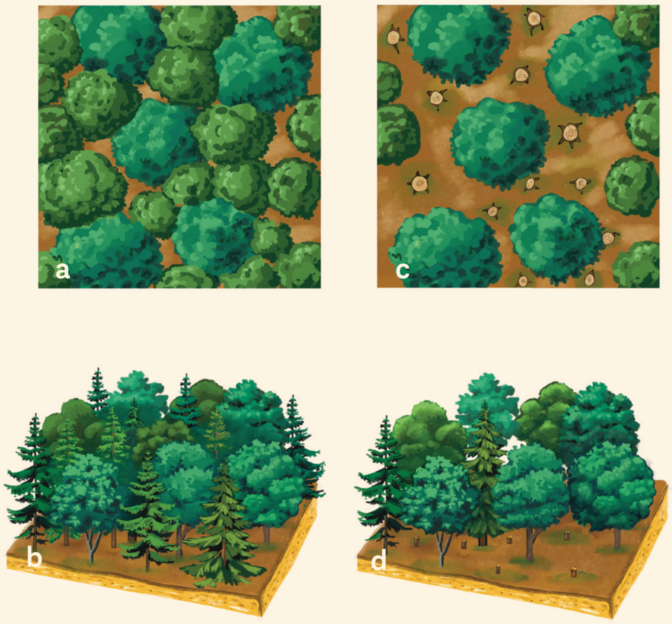


Figure 4. In a pre-commercial thinning, desirable crop trees are spaced uniformly across the stand, so that the stem density is greatly reduced from before thinning (a, b) to after thinning (c, d). This perpetuates a single-cohort condition.

5.2.2.1 Specifications

In New Brunswick, PCT is frequently implemented to meet provincial silviculture funding criteria, which requires that crop trees are uniformly spaced at 2 meters (plus or minus 0.5 m), with densities between 2800 and 3500 stems per hectare. The program specifications and objectives are rigidly aimed at ensuring consistent wood supply from private lands, with all other values and objectives for thinning being secondary. In Nova Scotia, the technical specifications in provincial funding programs are similar to those in New Brunswick, but the subsidy programs have more constrained timing considerations and funding access parameters. Programs in Nova Scotia, however, have greater flexibility in the technical criteria, such that multiple values and objectives are accommodated. For example, the specifications for PCT in hardwood stands target older and taller stands to ensure that species composition and high-value trees are placed in priority above volumetric growth (timber) objectives. Hardwood stands must be a minimum of 6 meters tall before PCT funding will be approved. The program does, however, place limitations on the number of entries that will be funded, and restricts any conversion of failed plantations to natural stands (if attempting to meet non-timber objectives). The program prioritizes past investments in plantations to perpetuate timber objectives.

5.2.2.2 Case Study – Pearsonville 2 Forest

In 2024, we completed a CPCT on a 5.9-hectare stand in our Pearsonville 2 forest. Although the entire property had been clearcut 26 years prior, as the forest regenerated naturally, there were some slight differences in composition among stands. Unlike the stand in which we implemented a CCTR, this stand was not pre-commercially thinned in 2008 – as a result, this stand retained more shade-intolerant species and pockets of balsam fir.

The stand contains a single cohort (a.k.a. single-aged) with areas of advanced balsam fir left from a previous harvest and an average height of 11.7 meters. Well-formed red maple and any shade-tolerant species were the priority for retention in the CPCT; however, white birch was abundant and good specimens were inevitably retained during the thinning. Given the high crown closure and relatively young age of the stand, there was little regeneration present, although there were areas with a small number of red spruce and yellow birch in the understory. Preserving these regenerating trees was a high priority during the intervention.

Like the CCTR in another stand at Pearsonville 2, this CPCT was completed using an excavator-mounted shear head on a small tracked harvester. We were pleased with how the machine performed, even though it was considerably more expensive than a comparable manual crew using spacing saws.

5.3 Planting

In the Maritimes, a long history of intensive forest management for timber production has resulted in clearcutting being used as the most common harvesting method, both on public (Crown) and private lands. As a result, clearcut properties are commonly found across the landscape. Although natural regeneration is frequently adequate after clearcutting (depending on the site, of course), this regeneration tends to be dominated by early-successional species like poplar, grey and white birch, pin cherry, red maple, white spruce, and white pine. These and other species, like balsam fir, also often grow rapidly from advanced regeneration that were present before the clearcut. Vigorous natural regeneration is a good thing; however, most of these species are generally considered to be maladapted to the effects of climate change – representing, therefore, a less-than-ideal species composition for the regrowing forest. Given that vulnerability and the urgent need to mitigate climate change, those naturally-regenerating species may not offer the most rapid or secure trajectory for restoring a clearcut into a growing forest. Planting climate-adapted species, where appropriate, can augment the resilience of the growing forest and accelerate its return to a healthy condition.

Community Forests International developed a forest restoration program in 2013, to secure clearcuts and other degraded forests, and to steward them to a more climate-adaptive state. Although clearcuts are seemingly abundant across the landscape, finding suitable ones in strategic locations for our program requires a considerable amount of searching and evaluating through our professional networks and realtor connections. After acquiring and planting a diversity of tree seedlings to begin the forest restoration process we undertake additional weeding and tending activities as needed. Once the property has been replanted, we monitor the regrowing forest and move it into the more advanced stream of ongoing climate-focused management.

5.3.1 Mixed Species Planting

5.3.1.1 Specifications

Once we have identified promising sites for purchase and restoration, we evaluate a whole series of site features (site access, past harvesting practices, road condition, slash load, regeneration abundance, and site topography, etc.) to determine a reasonable purchase price and the feasibility of re-planting. After securing the property, we re-plant the degraded area with a mix of native Wabanaki tree species (Fig. 5). Typically, we plant 2000 trees per hectare, and as much as possible those trees are planted based on compatible microsites to ensure optimal survival and growth. For high-value trees, like hardwoods, we often install protective tubes to prevent deer browse.

Such a complex program inevitably has challenges. Finding reliable local sources of seedlings, especially of climate-resilient species, is a perennial challenge. This has been especially marked since the federal government's Two Billion Trees program has funded many tree planting projects in the region, but nursery capacity and growing timelines have lagged behind the increased need for seedlings. Securing adequate clearcut land for a reasonable price is also a regular challenge, since we balance a desire to restore degraded lands equally with a desire to not unduly financially incentivize further degradative harvesting practices.

Figure 5. Tree planters are critical to the success of our mixed species planting and enrichment planting programs.

Our best practices – not always practically feasible, but still our preferred approach – include:

- Planting clearcut sites that are at least two years old (very recent clearcuts can be inhospitable to planted seedlings).

- Not using traditional site preparation methods (e.g. disking, barrels and chains), although we have trialed alternative site preparation activities. For example, we used an excavator-mounted mulcher to redistribute the slash that was preventing natural regeneration and expose the soil beneath. We also used the excavator bucket to mound soil to create plantable microsites and mitigate some of the damage caused by severe rutting.

- Preferentially planting sites that do not have adequate regeneration or are not stocked with adequate regeneration of climate-adapted species.

- Varying the planting density to reflect the site - if it has more acceptable natural regeneration in some areas, then the planting density can be lower.

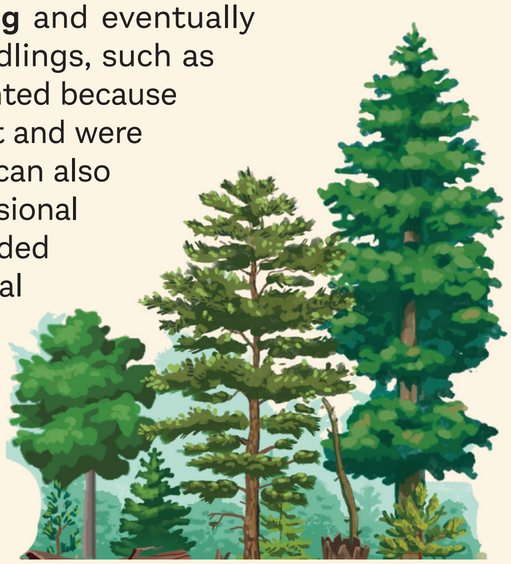
After delivering this program for over 12 years and planting over 2 million trees on approximately 1800 ha of degraded land, we have also identified some aspirational objectives for the program. We intend to continue improving our approach to restoration by eventually:

- Producing site reports that include soil classification, ecoregion (climate implications on species selection), probable stable late-successional forest condition, and that note the most likely climate risks and mitigation/adaptation pathways.

- Sub-dividing the site to a “stand” level for species and planting specifications regarding density, species, and spatial pattern.

- Noting necessary restoration activities for immediate planting success, and then restoration activities to mitigate future climate- and disturbance-related risks (e.g. infrastructure repair or decommissioning, site damage, riparian buffers, structural enhancements, etc.).

As our replanted sites grow and thrive, they enter into the stream of climate-focused forest management, which includes **Tending** and eventually **Harvesting** interventions described above. Many seedlings, such as early-successional species (like white spruce), were planted because they were suited to the harsh conditions of the clearcut and were relatively easy to obtain from nurseries. These species can also act as nurse trees for regenerating mid- and late-successional species, which is a helpful role in restoring these degraded lands. However, many of these planted early-successional trees are unlikely to be resilient to the effects of climate change over the medium to long-term. As a result, some of these maladapted planted trees may be culled at a later date, as we return to manage the growing forest for increased resilience and carbon storage.



5.3.1.2 Case Study – Neil Whan Restoration Forest

Neil Whan Restoration Forest, near Sackville, NB, is the first reforestation site that Community Forests International ever purchased and replanted. This 28.3 ha property was clearcut in 2014, then purchased by Community Forests International and replanted over two planting seasons (2014 and 2015). This property is located in the Eastern Lowlands ecoregion of New Brunswick. Based on the current surrounding forests' composition, prior to harvest the property was probably dominated by immature and mature softwoods (certainly black and possibly white spruce), mixed with small amounts of intolerant hardwoods (mostly trembling aspen, grey and white birch, and red maple). To accelerate the recovery of the property, we planted approximately 56,000 trees. We planted a mix of Wabanaki forest species that were appropriate for the site conditions, but that would still encourage increased climate resilience in the new forest – red spruce, Eastern hemlock, white pine, and lesser amounts of larch, Eastern white cedar, and black spruce. Later monitoring assessments found that the property was a little under-stocked, so we fill-planted the property with 5000 seedlings in autumn 2020, including 1750 white pine, 1750 red spruce, 950 white spruce, 500 Eastern hemlock, 90 red oak, and 90 sugar maple.

5.3.2 Enrichment planting

5.3.2.1 Specifications

In addition to mass planting a mix of native Wabanaki forest tree species on clearcut lands, we also fill plant such species in other degraded forests that we steward. These forests are usually degraded from past intensive harvesting, have regenerated poorly, and/or are over-stocked with maladapted species. Enrichment planting with climate-resilient species encourages greater diversity of species and encourages a rapid transition to a resilient forest composition. Depending on the conditions of the site, some intermediary intervention – light spacing or weeding, for example – may be necessary to free up spaces for enrichment planting. The exact planting itself can vary widely, depending on the conditions of the site – we have enrichment-planted in our Midgic forest and in a low-productivity area in our Jungle Road forest (as well as trialed direct seeding in some gaps at Jungle Road), and all of these activities have required somewhat different preparations and species.

5.3.2.2 Case Study – Midgic Forest

The Midgic property, near Sackville, NB, is a 30-hectare degraded forest that was donated to Community Forests International in 2020. The surrounding properties contain red spruce, white spruce, balsam fir, poplar, and red maple. The Midgic property had been harvested heavily in the past and is generally in a forested condition, although degraded and with poor regeneration. Approximately one-third was clearcut in 2014. In 2023, we undertook to augment the regenerating clearcut, first by cleaning (with a spacing saw) some shrubs, raspberries, and young intolerant hardwood trees, and then by planting 10,000 tree seedlings in those areas. We chose red spruce (4500 seedlings), white pine (4500), red oak (820), sugar maple (90), and bur oak (90) to enrich the species composition and climate resilience of the site.

6. Glossary

Acadian forest is a commonly used name in the Maritime provinces for the Wabanaki forest.

Adaptation strategies are pathways to reduce and dispense the hazards that will likely influence our ability to achieve forest management goals under climatic change - these strategies involve monitoring and anticipating change and undertaking actions to avoid negative consequences and to take advantage of potential benefits of those changes.

Appalachian forest is a hardwood-dominated forest type that is found scattered throughout the Wabanaki forest region, characterized principally by southerly-affiliated hardwood species (e.g. sugar maple, yellow birch) and lesser amounts of conifers like eastern hemlock and white pine.

Boreal forest is the dominant forest type across much of Canada, characterized by species that are adapted to cold temperatures (e.g. white and black spruce, trembling aspen) and vast wetland complexes.

Climate-focused forest management (a.k.a. climate-smart forestry) is a management philosophy that builds on the concepts of ecological forest management, but with a stronger focus on climate and ecosystem services. It aims to connect mitigation with adaptation measures, enhance the resilience of forest resources and ecosystem services, and use wood resources sustainably to substitute non-renewable, carbon-intensive materials.

Early-successional species (a.k.a. pioneer species) are those that colonize and grow well in recently disturbed sites. These species tend to have life-history traits that allow them to colonize and thrive such conditions – for example, rapid growth, tolerance for heat and exposure, prolific seed production.

Ecological forest management (a.k.a. ecological forestry) is a management philosophy that emphasizes the conservation of native biodiversity and ecological integrity, and achieves a sustained yield of goods and services to to meet the needs and objectives of land owners and society.

Ecotone is a multi-dimensional transition zone between adjacent ecological systems, having a set of characteristics uniquely defined in space and time, and by the strength of the interactions between those systems.

Late-successional species (a.k.a. climax or late-seral species) are those that grow in the later stages of succession, typically with limited resources (especially light).

Resilience strategies are adaptation strategies that improve the capacity of ecosystems to return to desired conditions after disturbance.

Resistance strategies are adaptation strategies that seek to forestall impacts and protect highly valued resources - these practices seek to improve forest defenses against direct and indirect effects of rapid environmental changes.

Transition strategies are adaptation strategies that facilitate transition of ecosystems from current to new conditions and intentionally accommodate change rather than resisting it, with a goal of enabling or facilitating forest ecosystems to respond adaptively as environmental changes accrue.

Wind Disturbance refers to any impact on forests caused by wind including uprooting (windthrow) or breaking (windsnap) of individual trees or groups of trees.

Windsnap refers to trees broken off at the stem by wind, where the roots stay anchored in the ground but some portion of the above-ground trunk is snapped off.

Windthrow refers to trees that are completely uprooted by wind, often with the entire tree tipped over and the roots exposed up out of the soil.

7. Native Tree Species' Common and Latin Names

Common Name	Latin Name
American Basswood	*Tilia americana*
American Beech	*Fagus grandifolia*
American Mountain Ash	*Sorbus americana*
Balsam Fir	*Abies balsamea*
Balsam Poplar	*Populus balsamifera*
Black Ash	*Fraxinus nigra*
Black Cherry	*Prunus serotina*
Black Spruce	*Picea mariana*
Black Willow	*Salix nigra*
Bur Oak	*Quercus macrocarpa*
Butternut	*Juglans cinerea*
Eastern Hemlock	*Tsuga canadensis*
Eastern Larch	*Larix laricina*
Eastern White Cedar	*Thuja occidentalis*
Grey Birch	*Betula populifolia*
Ironwood	*Ostrya virginiana*
Jack Pine	*Pinus banksiana*
Large Tooth Aspen/Poplar	*Populus grandidentata*
Mountain Maple	*Acer spicatum*
Mountain Paper Birch	*Betula cordifolia*
Pin Cherry	*Prunus pensylvanica*
Red Maple	*Acer rubrum*
Red Oak	*Quercus rubra*
Red Pine	*Pinus resinosa*
Red Spruce	*Picea rubens*
Serviceberry	*Amelanchier canadensis*
Silver Maple	*Acer saccharinum*
Striped Maple	*Acer pensylvanicum*
Sugar Maple	*Acer saccharum*
Trembling Aspen/Poplar	*Populus tremuloides*
White Ash	*Fraxinus americana*
White Birch	*Betula papyrifera*
White Elm	*Ulmus americana*
White Pine	*Pinus strobus*
White Spruce	*Picea glauca*
Yellow Birch	*Betula alleghaniensis*

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