Tree Seed Working Group
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Association canadienne de génétique forestière

ASSISTED MIGRATION

Featured in this Issue

Armchair report

Happy New Year, all the best for 2026. Following our workshop this summer Fabienne and I expanded our TSWG team to include Darren Derbowka of the National Tree Seed Centre and Kerry McLaven of the Forest Gene Conservation Association of Ontario. Welcome to the team and Thank you for your contributions. Contributing is the only way to keep this working group alive and relevant, so providing tree seed related articles, meeting summaries, updates and queries is the best way others can contribute. Our team has also discussed other extension possibilities like webinars, but currently focused on extending information from our summer workshop and producing this News Bulletin. Our next project will be to invite our audience to participate in a survey to inform us of your tree seed science and technology priorities moving forward.

The theme of this News Bulletin is **Assisted Migration** although I view this as a genetics topic. Assisted migration is very topical around the globe and without a dedicated National forum we decided to focus on this topic for News Bulletin 77. Assisted Migration is a powerful tool for growing resilience in our forests, but as many of our contributors have noted it is one of many tools available. A wide variety of authors have contributed and in BC it isn't theoretical, it's how operational tree genetic resource deployment happens. Hopefully the articles help demystify the concepts, provide status of various initiatives and helps to form a call to action for those on the sidelines. Some other jurisdictions are also working on assisted migration initiatives, but too early to report, so hopefully we can get future updates on those projects. For me, the research has pointed out one very simple principle: **there is far more risk involved in doing nothing than doing something!**

Articles contained in this edition supplement contributions on this topic in edition # 71 (tswg_news_bulletin_71.pdf). Further details are provided in articles, but the Forestry Adaptation Network (forestryadaptation.ca) and the Reforest Canada Collective (Canadian Tree Seed Services and Suppliers Tool) are organizations looking to expand information on assisted migration and other topics. In November, 2025 the latter hosted a two-hour webinar on Planning Ahead for Climate-Adapted Forests Planning Ahead for Climate-Adapted Forests - YouTube). Dr. Sally Aiken also recently was involved in a conversation on Trees, Genomics and Climate that touches on many of the important and complex aspects of Assisted Migration in a very accessible manner (https://www.conversationsthatmatter.ca/episodes/586-trees-geonomics-climate). All of the above are recommended if you want to learn more about Assisted Migration of forest trees. I'm sure there have been other initiatives around the country that we have missed and invite you to inform our readership about them.

Our next News Bulletin will be themed "**Seed Collection**" and we hope to have it available in early July to assist 2026 collections, so please provide content by early June. On this topic I'm interested in your oldest tree seed collections, whether they still reside in storage and if you have any long-term germination results.

The TSWG hosted a joint workshop with the Canadian Tree Nursery Association (CTNA) in August in association with the Ottawa CFGA conference. The theme was **Growing Resilience: The Power of Seeds and Seedlings** in keeping with the general conference theme. The presentation Abstracts and an overview of our discussion sessions are included in this edition. The Powerpoint pdf versions of the talks are also available on our new google drive site and we hope to use this to populate other tree seed information in the future.

I know I am not alone in hearing the need for seed science and technology information beyond trees. Most, but not all, of the interest has been championed by first nations throughout Canada. The National Tree Seed Centre has been a champion of this cause with the Indigenous Seed Collection Program (Indigenous Seed Collection Program - Natural Resources Canada). Recently in BC we have had a series of four Native Seed & Plant workshops. An overview of the purpose and objectives as well as links to the presentations from each of the workshops can be found here: https://intranet.gov.bc.ca/for/provincial-operations/firb/native-seed-and-plants

Since our last News Bulletin we've had two people pass away in BC that had a huge influence on our current seed supply system. Bruce Devitt passed away on November 8th 2025, just shy of his 93rd birthday. Bruce had a varied and illustrious career that is summarized in his obituary (William Devitt Obituary - Victoria, BC). Bruce was responsible for the Provincial seed and nursery program in the 1960's and 70's when the provincial Tree Seed Centre was in Duncan. Jenji Konishi was the second person who passed away and you can find his obituary in the News Bulletin. He was involved in championing seed orchard development and the building of our current provincial Tree Seed Centre in Surrey. He was responsible for hiring both Brian Barber and myself in the early 1990's.

I would also like to acknowledge the retirement of Dr. Patrick von Aderkas from the Centre of Forest Biology at the University of Victoria. I'm not sure who I will use as my gymnosperm reproductive biology sounding board, but looking for volunteers. Patrick has been a very vocal supportive of our working group and has contributed to many workshops and News Bulletins. Thank you. For those not familiar with Patrick's research you can see his profile page here: P. von Aderkas - University of Victoria.

On a more positive note we have completed the building of new freezer and cooler spaces in BC and been given our occupancy permit. The two coolers separating seedlots in process and seed in stratification has been a very welcome addition for operations. We were also able to obtain four new CONVIRON (Germination | Conviron) germinators and crossing our fingers for a couple more to complete our upgrade. Our oldest CONVIRON germinator was from the 1970's, so Canada knows how to make durable cabinets for germination testing.

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The Cancellation of Canada's 2 Billion Trees Program: A System-Wide Setback for Forest Restoration

Canada's decision to cancel the Two Billion Trees (2BT) program comes at a moment when the country can least afford to scale back its forest-restoration ambitions. As highlighted in recent reporting by *Corporate Knights*, CBC's *Daybreak North*, the loss of 2BT reverberates far beyond planting targets. It disrupts the entire "seed-to-site" system that supports Canada's climate resilience.
Executive Director of CTNA-ACPF Rob Keen said in a recent statement: "Canada cannot achieve climate resilience, wildfire recovery, or biodiversity goals without

strengthening the full forest-restoration supply chain. Seed, nurseries, and planting capacity must be treated as essential national infrastructure and not temporary programs that can be turned on and off." His message reflects a widely shared concern that the cancellation removes key structural support from a system already facing historic wildfire impacts and increasing pressures on seed availability.

The 2BT program was far from perfect, but it offered coherence and direction at a national scale. It helped stabilize demand, support long-term planning, and build the capacity required to restore forests affected by wildfire, pests, and climate-driven disturbances. Its abrupt removal leaves significant uncertainty across the restoration pipeline.

This is also a workforce story: thousands of green jobs, from seed collection to nursery production to tree planting, depend on a functioning restoration economy, particularly in rural and Indigenous communities.

If Canada intends to meet its climate-adaptation, biodiversity, and wildfire-recovery goals, reinvesting in the full seed-to-site continuum is not optional. It is foundational.

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TSWG/CTNA WORKSHOP

Growing Resilience: The Power of Seeds and Seedlings

Our biennial workshop was held this past August in conjunction with the Canadian Tree Nursery Association (CTNA). The common thread of reforestation embodies both groups, so it was a smooth linkage. The theme of the workshop **Growing Resilience : The Power of seeds and Seedlings** was in keeping with the main CFGA conference theme of Building Resilience through Forest Genetic Resource Management and Collaborative Action. The workshop started with a memorial to Melissa Spearing and the dedication of the workshop to her memory. I know she would be pleased with the continuation of the News Bulletin.

The majority of the workshop was focused on tree seed management across Canada and we had seven speakers provide perspectives on their unique seed management systems. During the lunch break our groups split for either a members only CTNA Annual General Meeting or participated in some TSWG brainstorming regarding our future direction. The afternoon included a bridging talk and a review of seed use efficiency. The rest of the afternoon was spent continuing some of the TSWG brainstorming as well as providing some input for the prioritization of seed and seedling information needs. The Abstracts of the talks are provided and the presentation pdf versions can be found at this link.

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Strengthening Canada's Nursery Capacity to Support Seed Transfer and Climate-Ready Reforestation

Canada's forest restoration system depends on the integration of seed, seedlings and planting - from collection and testing to propagation and, ultimately, out-planting. While discussions about seed transfer and assisted migration often focus on genetics, climate models, and policy frameworks, an equally critical part of the story is the specialty of Canada's nursery sector to grow the right trees, for the right place, at the right time.

Across the country, forest nurseries are facing unprecedented opportunities. Climate-driven disturbances, including the record 2023–2025 wildfire seasons, have dramatically increased demand for reforestation stock. CTNA–ACPF estimates that restoring just 15% of the area burned between 2023 and 2025 alone would require more than 7 billion additional seedlings, in addition to the ~600 million seedlings produced annually. A strong and resilient nursery system is therefore essential, not only for meeting current demand, but for supporting the future of assisted migration and regionally adapted seed transfer.

However, the sector does face some challenges as skilled labour shortages, and an aging workforce threaten the stability and potential growth of the pipeline that links seed movement to successful reforestation outcomes. The ability to implement climate-smart seed transfer guidelines depends directly on nurseries having the people, infrastructure, and technical expertise to propagate the required stock at scale.

To address this challenge, CTNA–ACPF has started to develop the Forest Nursery Training Program (FNTP). This will be Canada's first coordinated, sector-wide training pathway for large-scale forest seedling production. Developed with support from Natural Resources Canada's 2 Billion Trees Capacity Grant, and a Technical Task Team of various backgrounds including nursery and educational specialists from across Canada, the program focuses on three groups vital to long-term workforce resilience: Indigenous communities, post-secondary students, and current nursery employees seeking to advance their skills. The training model blends virtual coursework with structured co-op placements at host nurseries, ensuring graduates gain both theoretical knowledge and hands-on experience.

Strengthening training and succession planning within

nurseries has direct implications for seed transfer and assisted migration. Growing climate-adapted, regionally appropriate seedlings requires precision in seed handling, stratification, propagation, irrigation, pest management, and quality control. As seed zones evolve and assisted migration prescriptions become more complex, the technical demands on nursery staff will only increase. Skilled workers are therefore a foundational requirement for the genetic integrity and long-term success of Canada's forest restoration strategy.

As seed movement policies adapt to a changing climate, the nursery sector stands ready to play its part in ensuring that high-quality, climate-ready seedlings move efficiently from seed collectors and seed centres into the hands of planters and restoration practitioners.

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Seeing the Forest for the Seed

Canada's National Tree Seed Centre (NTSC) was originally established at the Petawawa Forest Experiment Station in Chalk River, Ontario. Initiated as Petawawa Project P-169 by Dr. Ben Wang on May 15, 1967, the creation of a seed bank was required to 1) coordinate an increasing number of national and international requests for Canadian tree seed for breeding, research and operational plantings and 2) provide information and develop standards for seed testing, storage, quality analysis, and seedlot germination behaviour. In addition, the seed bank maintained an inventory of seed from major Canadian tree species that largely focussed on pines and spruces important to the forest industry.

NTSC aims to modernize its operational activities while continuing to align with the core objectives for seed banking, support for seed research, and knowledge mobilization established at its inception. In part because of Canada's commitment to the Convention on Biological Diversity signed in 1992, the NTSC expanded its collections beyond commercial species of interest. Today NTSC has the mandate to collect and preserve a representative sample of seed from every native tree and shrub species across its range in Canada. We are supporting national efforts towards growing and maintaining healthy forests by prioritizing species and populations under cumulative threats from climate change, habitat loss, and invasive pests and pathogens.

In Canada there are 1027 different ecodistricts, which are ecological land classification units based on areas of similar geologic, vegetative, climatic, and hydraulic variables. Characterized by distinct biological assemblages of vegetation and wildlife, NTSC uses these regions to define the population boundaries for its collections. While individual tree and shrub collections are desired from every ecodistrict, collections from a targeted number of these regions will be selected to achieve the broadest sampling of genetic diversity across the Canadian landscape moving forward. Today the NTSC houses over 14000 seedlot collections from around 250 different native tree and shrub species in Canada

The launch of the Indigenous Seed Collection Program on the spring equinox of 2022 with support from the 2 Billion Trees Program has been a significant and positive addition to NTSC knowledge mobilization activities. Supporting Indigenous seed collection initiatives for species of medicinal, spiritual, ecological, and economic importance, the NTSC has provided field and laboratory training sessions on seed collection, handling, and storage to more than 250 Indigenous participants from across the country.

NTSC continues to provide advice, training, guidance, and research support to more than 200 different academic, governmental, private and community-based organizations across Canada and internationally. NTSC recognizes the tenuous nature of Canada's seed supply chain, particularly with respect to underrepresented non-commercial species. The viability and sustainability of future forests depend entirely on the availability of appropriately sourced and high-quality seed. Through its work and advocacy, NTSC aims to promote the idea that the forest should be seen for its seed not just its trees.

For more information about the National Tree Seed Centre please visit the website: National Tree Seed Centre - Natural Resources Canada

For more information about the Indigenous Seed Collection Program please visit the website: Indigenous Seed Collection Program - Natural Resources Canada

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Conifer Seed Management in the Maritimes

Effective conifer seed management is critical to sustaining forest productivity and ecological resilience in the Maritime Provinces. Land ownership patterns vary significantly—Nova Scotia (35% crown, 65% private), Prince Edward Island (12% crown, 88% private), and New Brunswick (50% crown/public, 30% private, 18% industrial freehold)—shaping reforestation strategies and seed demand. New Brunswick's provincial nursery plays a central role, producing millions of seedlings annually for Crown land in New Brunswick—primarily white spruce—sourced from extensive seed orchards. The Atlantic Forest Seed Centre, established in 1978, supports regional forestry by extracting, processing, testing, and storing seed for multiple clients through a comprehensive inventory system. Despite these organizational structures, challenges persist, declining germination rates in key species such as white spruce, red spruce, jack pine, and white pine raise concerns about long-term seed viability. Seed use legislation remains minimal, with the Maritime provinces largely unified under broad seed zones, though species-specific exceptions exist. Current priorities emphasize maintaining orchard seed inventories, improving germination performance, and ensuring sustainable seed supply for commercial forestry. This presentation highlights the strengths and vulnerabilities of

Maritime seed management systems underscoring the need for adaptive strategies to secure future forest productivity and resilience.

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Seed management in Quebec: a provincial matter

The Direction Générale de la production des semences et des plants forestiers of the Ministry of Natural Resources and Forestry is the sole organization responsible for managing the seedling production sector. It ensures sufficient inventory to fulfill seedling requirements according to clearly defined areas of use, through the establishment of seed orchards, cone harvesting, seed processing, and allocation. In addition, it monitors seedling production and quality management through nursery audits, and the distribution of forest seedlings for Quebec's public and private forests. Forest ownership in the Province of Quebec is 92% public.

Public forests are managed by the Ministry of Natural Resources and Forestry. Natural regeneration is prioritized on 80% of the land and seedlings planted on the other 20%. Around 130-140 million of seedlings are produced each year.

All seeds harvested for the reforestation program are processed at the province's unique tree seed center in Berthier, which is ISO9001 certified. The expertise was developed for 10 conifer species and 8 hardwood species where 4 are recalcitrant (bur and red oak, black walnut and bitternut hickory).

As part of a process of continuous improvement in seed harvest quality, an ambitious action plan has just been implemented to build a diverse and skilled network of seed collectors and maintain an annual harvest volume sufficient to sustain the expertise of Berthier TSC staff.

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Forest Genetic Resource management Efforts in Ontario

Ontario's century-long effort in forest genetic resource management has evolved through periods of progress, restructuring, and capacity challenges. Early initiatives—including research at the Petawawa Research Station and the Ontario Tree Seed Plant, established the basis for understanding genetic variation and maintaining a seed supply. Provincial tree improvement programs expanded through the mid-20th century, supported by seed zones and breeding orchards, but shifts brought by the Crown Forest Sustainability Act (1994) decentralized responsibilities and revealed uneven regional capacity, variable local expertise, and gaps in infrastructure. The transition from Forest Genetics Ontario to independent regional organizations (SWTIA, NeSMA, and the FGCA) further required adjustments in coordination, funding, and long-term maintenance of genetic assets. With support from the Forestry Futures Trust, these groups now work to supply adapted seed, conserve genetic diversity, and contribute to climate adaptation and species-at-risk efforts, while navigating aging orchards, emerging climate risks, and resource limitations. This ongoing work reflects both the progress made and the challenges that continue to shape Ontario's approach to sustaining resilient forest regeneration programs.

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Ontario Tree Seed Genetic Archive

The Ontario Tree Seed Genetic Archive (OTSGA) was created in 2021 to preserve representative seed samples of Ontario's native tree species and support Ontario's genetic and biodiversity conservation. The OTSGA aims to collect and store seed samples of native tree species across their natural ranges within the province. The operational strategy is to collect 100,000 viable seed per species in each eco-district the species is present in. These seeds are collected from four distinct collection sites across the eco-district to maximize the genetic diversity. The archived collections will provide appropriately sourced seed to support forest genetic and climate change adaption research, as well as species and population recovery programs. Currently the OTSGA has 205 collections representing 9 conifer, 8 broadleaf, and 10 shrub species.

During the 2023 and 2024 collection seasons, priority was given to black ash (*Fraxinus nigra*) due to the threat of Emerald Ash Borer, with collections being made from 46 mother trees across 4 eco-districts. The OTSGA has also been working with the National Tree Seed Centre and the Forest Gene Conservation Association comparing alternative stratification and propagation techniques for black ash. A trial 90-day stratification at 4°C led to significant embryo maturation, however, this treatment did not result in any germination.

Work is also being done on in-vitro propagation of excised black ash embryos. In this year's trials, black ash seeds were removed from their samaras, soaked in aerated water for five days, then surface-sterilized in a 1% sodium hypochlorite solution for 10 minutes, and finally rinsed three times with distilled water. Next, the seeds were dissected, and the embryos were carefully removed and placed on Murashige and Skoog basal medium containing sucrose and solidified with agar, with the pH adjusted to 5.7. The embryos were placed in a germination chamber running 30/20°C, for an 8-hour photoperiod (60 $\mu mol/m^2/s$) with 70% RH. After 10 days, embryos whose cotyledons had greened were transplanted to a peat-perlite medium and kept under the same conditions until the formation of the first true leaves, at which point they were moved to our greenhouse. This technique yielded a germination rate between 76-94% for 6 of the seed lots tested, with an 89% survival rate through first growing season. Three other seed lots had <45% germination, however this was likely due to contamination of the embryos or media during the process.

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Seed use in Alberta

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Seed use standards and practices in British Columbia

Over 220 million seedlings are planted annually in British Columbia (BC) by forest tenure holders and government agencies. This Herculean reforestation effort requires 1000s of kilograms of high-quality tree seed. The collection, storage, and use of this seed is governed by a comprehensive set of regulations, standards and practices. Forest professionals are responsible for preparing silviculture prescriptions and identifying the biogeoclimatically-suitable tree species (see texts on Climate change species selection in this bulletin from page 18 to 30) for each harvested area. Seed selection is subsequently guided by the *Chief Forester's Standards for Seed Use*, which require all tree seed used to establish a free growing stand to: be registered, tested and stored at the provincial tree seed centre; have an effective population size of ≥10; and, be deployed within its climate-based seed transfer limits.
Seed orchard seed must also be used, if available, to realize the province's investments in tree breeding. Approximately 65% of all seed used annually is produced in ~100 seed orchards, managed by the Ministry and companies, with an average genetic gain for volume of +20%. Data for all orchard and wild stand seedlots (e.g. source, inventory, transaction history, test results and more) is recorded in the Ministry's Seed Planning and Registry System (SPAR), which is also used to initiate nursery seedling requests.
The Forest Genetics Council of BC helps guide and coordinate related activities. Collectively, these seed use policies and practices serve to enhance the health, productivity and adaptation of BC's new forests.

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Bridging the Gap between Seed Science and Operations

The presentation started with credits to the seed scientists who have been the stepping stones to where we are today. The first people that come to mind are the late Ben Wang and Dr. George Edwards of the Canadian Forest service who both lead seed science and technology groups in Petawawa and Victoria respectively. The next is Dr. Derek Bewley who was a world renowned seed scientist who spent most of his career at the University of Guelph. He published 275 papers, supervised a large number of graduate and post-doctoral students and was co-author of several books with **Seeds: Physiology of Development and Germination** being the most recent and most accessible book. Among those he supervised, some went on to support tree seed science and Dr. Tannis Beardmore (CFS Maritimes) and Dr. Allison Kermode (Simon Fraser University) published widely on tree seed. Currently lesser know students were Dr. David Gifford who passed away too early in his career and Dr. Bruce Downie who initially worked on conifers with Ben Wang, but has been focused on agricultural species at the University of Kentucky. In BC, Dr. Carole Leadem was a seed physiologist who helped form the programs we have today and of course all of the above had support teams.

This trip down memory lane is to emphasize that there were very active seed science research programs, but there are very few scientists dealing with tree seed today. The above are either deceased, retired or ventured into other species where research funding is flowing. It isn't just the scientists either as we are seeing a rapid succession as baby boomers retire taking with them their experience, knowledge and wisdom of highly relevant cone and seed operations. With increased reforestation expectations, tree seed can become a bottleneck due to a lack of educational coverage, research funding and interest. The tree seed supply system is taken for granted and unsustainable in its current form. All of these factors contribute to what I see as a vicious cycle of "**no funding, no research, no trained people, no teaching, no progress**".

We deal with highly diverse species and that needs to be appreciated, especially by seed scientists coming from the less diverse agricultural crop species on which most seed science education is based. My biggest pet peeve is someone thinking they can understand seed biology with limited, or even one population to describe a species. Many continuous improvement initiatives also focus on reducing diversity, but this diversity is critical for our long-lived crop species. With our highly variable product I am often skeptical of science producing 'answers' without any operational verification. I feel aligned with these continuous improvement principles: 1. Stop fixing and start improving 2. The best practices are the ones you already have 3. Changing behavior is more important than changing processes 4. If you aren't failing, you aren't trying.

The science being performed on tree seeds is going deeper to use the latest tools, to get funding, to publish, but these are removed from operations and extension has become something abandoned on the global scale when it is needed more than ever.

There are reduced resources dedicated to reproductive biology, collection management and cone & seed services in all Canadian provinces. Two specific bottlenecks are the lack of interest and investment in the infrastructure required for cone and seed processing to be able to meet growing demands and the second is interest, research and funding in the areas of reproductive biology/physiology and crop development. The second is especially perplexing in my jurisdiction where we have such a huge investment in seed orchards with 'improved' seed being mandated by regulations. This is in glowing contrast to the levels of funding allocated to selection with genomics tools, yet the efficient integration of these tools still requires cones to produce seed in the pipeline. Does no one believe climate change will impact the reproductive biology of our tree species? There simply needs to be a better balance in funding and agencies need to also invest in the less sexy and technologically shallower tools.

There are a few hints I'll provide in terms of weighing the importance of scientific publications:

1. Are the conclusions for a species based on a representative sample? All to often the "treatments" receive much more attention that the genetic entries – mind boggling!
2. Not all germination tests are created equal. Although the 4 replicates of 100 seeds is a standard used by many, you'll find 4 X 50 and 4 X 25 seed results or even unreplicated tests. This has an impact on the precision of measurement and needs to be considered accordingly.
3. Sometimes the "no treatment" is a poor CONTROL if used alone to evaluate a treatment. The best example is the use of some type of treatment to break dormancy, but the benefit is overstated if not compared to the standard and cheap practice of simply stratifying seed.

4. The practical aspects of seed "treatments" are often best based on operational seedlots, but an understanding of seed physiology is best investigated using only filled seeds that were formally obtained by x-ray analysis. The latter does add steps and generally not found in current research results.
5. The interpretation of interactions (i.e. seedlot* treatment) are often ignored when drawing conclusions or performing mean separation tests on the main effects.
6. Can the treatment be bulked up to an operational scale? At times research designed to offer operational solutions are actually impractical or cost restrictive to scale to an operational scale. This needs to be considered up front and not something the practitioner themselves needs to solve.
7. I'm aligned with science providing stepping stones for decision-making – the science will change over time, accept it. Decisions still need to take place – doing nothing is a decision. It is often difficult to change decisions/policies made based on best available information (which may have been poor) versus starting from scratch.
8. A statistical significance of α =0.05 is the academic standard, but give me something that provides a big benefit at 85% confidence and I'll take that risk.

In closing there are four main take home messages I have to offer to help ensure the sustained availability of high quality and adapted tree seed.

1. Encourage, Support and Fund Technical Extension positions/efforts
2. Ensure Operations are involved in prioritizing and designing research. Make sure scientists understand the real problem and want to work on it.
3. Determining seed needs sounds simple – it isn't, especially at the National level. The past is not a good predictor of the future anymore. Demand is difficult to predict
4. Scientists, Policy-makers and practitioners all have to play a role in educating and being educated

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Nursery seed use efficiency

Based on a presentation to the Tree Seed Working Group & Canadian Tree Nursery Association joint workshop *Growing Resilience: The Power of Seeds and Seedlings*, August 11, 2025.

In recent years, the increased focus on tree planting in response to wildfires and carbon sequestration has increased the demand for seed. Some of this demand is being met via more intensive seed collection of wild stands, and the establishment of new seed orchards. Nurseries can also grow more seedlings with the seed available by increasing their seed use efficiency. While no nursery aims to needlessly waste valuable seed, their primary goal is maximizing seedling production per unit area, especially expensive greenhouse space. In situations where the nursery is supplied seed by the seedling purchaser at no cost, there is little financial incentive for saving seed. Growers are the most optimistic people you will ever meet, but they are usually loath to take on additional risk such as increasing the number of empty cavities in their crop by not using enough seed at sowing. However, understanding the risks by considering all factors, makes it possible to make an informed decision regarding seed use.

The amount of seed needed for a particular crop is influenced by germination capacity, purity, species, stock type, seedling specifications, the size of the order, nursery practices and grower proficiency. While the ultimate measure of seed use efficiency is "seeds per seedling", which is simply the total number of seeds a nursery requests or purchases divided by the total number of seedlings planned or contracted to be grown.

The first step in calculating how much seed to use is to gather as much info about the seed as you can. Use online resources, past experience and/or talk to the seed supplier. Find out when the germination capacity was last tested and under what conditions? Ask whether the seed has been analyzed for pathogens such as *Fusarium or*

Caloscypha which can reduce germination. Knowing the seed purity is invaluable as "dirty" seed increases the potential for more empty cavities thus increasing nursery risk. Accurate seed weight (i.e. seeds per gram data) is a crucial component when calculating your seed requirements, which if wrong will result in too little or too much seed on hand. And finally, find out as much information about the seedlot provenance as possible, to determine if you expect it to be challenging or easy to grow.

Seed is best conserved at the planning stage via an Excel spreadsheet before the seed is removed from storage and stratified. If a nursery waits till sowing to conserve seed, they've missed the boat. During sowing, one shouldn't be thinking about seed conservation, but rather, how to effectively distribute all the seeds on hand amongst the planned number of cavities. To do that, one needs to determine two main factors: seeds per cavity (SPC) or sowing factor, and the oversow (OS).

Seeds per cavity can be determined by using sowing tables developed from probability equations (Schwartz 1993), which suggest a SPC value based on the germination capacity. It is calculated to sow the number of seeds that minimizes the number of empty cavities, usually 1-2%. With decreasing germination, you can still maintain the desired number of empty cavities by increasing the SPC. This method utilizes fractional sowing, whereby the SPC value may not be a whole number. For example, 1.80 SPC means 80% of the cavities have two seeds and 20% have one seed. Your greatest opportunity to conserve seed is by reducing the SPC. For example, at 90% germination, reducing the SPC from 2.00 to 1.50 will result in only 2.2% more empty cavities, but requires 25% less seed. As most sowing equipment is not 100% accurate, it is usually cost effective for nurseries to compensate for this by having a person or two on the sowing line filling any empty cavities when sowing large seeded species. Also, while reducing the SPC increases the probability of empty cavities, some nurseries still obtain 100% cavity fill by sowing enough doubles for transplanting later during thinning.

The OS is the number of extra cavities sown above the requested amount of seedlings to account for empty cavities, disease, insect, abiotic damage, and seedlings not meeting the contract specifications. Thus, reduced seedling specifications such as lifting to an "extractable plug" increase seed use efficiency by increasing seedling recovery. Placing a large seedling order also increases seed use efficiency, as nurseries usually increase the OS for small orders due to the higher risk when something goes wrong to a small number of containers. Oversow is also adjusted for seedling stock type, as recovery is generally greater on stock grown in larger cavities; and growing location, as stock grown outdoors is subject to more risk. Oversows are nursery specific, based on experience and the grower's proficiency and risk tolerance. Decreasing the OS does not result in as much seed conservation as reducing the SPC, especially if the seedling owner does not plant the overruns (i.e., seedlings grown in excess of the requested amount). While decreasing the OS also increases nursery profitability, it also increases the risk of not growing enough plantable seedlings to fill the order. Putting this all together, nurseries can use an Excel spreadsheet to adjust SPC and OS to determine seed requirements for each seedling order.

Seedling customers sometimes suggest single sowing, especially for scarce, high value seed with high germination. Nurseries are reluctant to single sow, as they would have to substantially increase the OS to grow the contracted amount of seedlings, and in typical nursery contracts, nurseries are not compensated for sowing additional containers. However, seedlings grown outdoors where the cost of an empty cavity is less compared to that in a greenhouse, are potential candidates for single sowing. When sowing seed of extremely variable or unknown germination, it can be sown with a high OS and paid for by the container so that the nursery is compensated for poor cavity fill.

When a nursery reduces the amount of seed they sow for a specific order, they want to ensure they maximize the seed they have. There are many practices a grower can use to reduce the seed to seedling ratio by increasing the percentage of plantable seedlings recovered per container. This begins with proper seed handing practices, such as shipping to the nursery via express courier in an insulated container with ice packs to keep the seed cool during transit (Kolotelo et al, 2001). During sowing, constant monitoring of the SPC and adjusting is crucial. In the greenhouse, uniform germination is the key to increasing seed use efficiency, as it sets the stage for crop uniformity and potential high recovery. Germination is affected by many factors such as stratification, seed disinfection and growing environment, which are all under the grower's control.

At most nurseries, there is likely the potential for increasing seed use efficiency. Seed conservation is most effective when practiced upfront on spreadsheets prior to seed stratification. Nursery seed use efficiency can be tracked by calculating a nursery's seed per seedling ratio, which may then be used as a parameter in seedling contracts to encourage seed conservation.

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Workshop Breakout Sessions

This is a summary of our TSWG brainstorming session and discussions on the prioritization of seed and seedling information needs. One of the big messages was the desire for more regular communication options beyond our workshops and News Bulletins. Suggestions were offered (slacker/ WhatsApp / Modle / Stack overlap) and the group was reminded the TSWG had a TREESEED ListServer Discussion Group for questions in the early 2000's. This was abandoned due to the time to maintain and respond to questions and the increased e-mails this service created. In addition to other communication venues like webinars, there was a desire for the News Bulletins to be searchable (i.e. bring up all articles with stratification in the title). Search engines do not search through pdf documents the way our computers do. No solutions pending, but if anyone can assist with this, consider it a call to action.

As part of the workshops dedication to Melissa we decided to start with her past survey questions which are reproduced below. We didn't get through all five and added an additional one: **What is your highest webinar topic of interest?** Information gathered will help with our upcoming survey to enable a much greater number of people to weigh in, so this is simply a non-exhaustive listing of thoughts that came up in Ottawa.

1. **What is your highest tree seed / nursery research priority.**

   - Crop production models
   - Chain of custody – seed loss through processing system
   - Seed costing
   - Storage of recalcitrant species for genetic conservation and production
   - Epigenetics – state of knowledge
   - Climate change – phenology, variability and asynchrony of reproduction

2. **What tree seed / seedling information is critical to have in courses dealing with trees/forestry**

   - ▪Big picture forestry – each provinces uniqueness
   - Use of tree seed – seed orchard vs. wild
   - Collection course – mentoring /practice; hands-on work
   - Training mid-level and senior managers
   - Portable field-friendly Guidebook
   - Certified collector /processor information

3. **What is your highest webinar topic of interest**

   - Crop forecasting and frequency(i.e. Krebs Yukon bumper crop)
   - Collection techniques / logistics / labour issues
   - Seed upgrading
   - Stratification modification / seed vigour
   - Seed orchard management
     - use of GA & purchase / girdling
     - Topping methods
     - orchard pest id and management
   - Assisted migration
   - Transplanting germinants
   - Tips and Tricks – practical demos/equipment

Melissa's remaining survey questions are presented below. There is certainly some overlap in content. It is difficult to capture all the contents of a couple of brainstorming sessions concisely and it only reflect opinions of the relatively small number of people present compared to our distribution list which is close to 600 people. Consider this an invitation to start thinking about your highest tree seed information needs. Forward any of your thought to one of our four team members. We listen and that is why assisted Migration was the theme of this News Bulletin as it came up several times during our discussions.

4. **What is your biggest concern with tree seeds / seedlings?**
5. **What is your biggest tree seed / seedling extension/information need?**
6. **What is your most critical infrastructure need to secure your required tree seed / seedling supply?**

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ASSISTED MIGRATION

Climate Based Seed Transfer: history, rationale, development, and misperceptions

Climate change and the need to maximize seed deployability are driving interest in revisiting how tree seed is sourced. When combined with new provenance data, genecology analysis methods, GIS, and climate tools, significant opportunities emerge in the area of seed transfer systems. This article describes the history of seedlot transfer systems, the rationale for a new era of seed transfer systems, the components and operation of a climate-based seed transfer (CBST) system, and some of the common misperceptions regarding CBST.

History of seed transfer systems

Natural regeneration following timber harvesting was common practice in western North America during most of the first half of the 20th century. The seedbed laying dormant in the soil, or seed from the adjacent forest, was relied upon to provide seed to regenerate cutblocks. However, plantation forestry was more common in Europe and eastern North America where human population densities were far greater. Through a long history of species field trials foresters learned the specific climate, pest, soil edaphic (nutrient and moisture), and shade tolerances of each species. Further, provenance trials taught foresters that the best seedlots for a site are those that are climatically closest to the site, from which arose the adage “local is best”.

As human populations grew in western North America, so did artificial regeneration. For many important timber species, seed zones were established in the 1960s and 70s to respect the ‘local is best’ paradigm and ensure that seedlings for reforestation and restoration would be adapted to the areas where they were planted. Seed zone boundaries were often drawn along major geographic barriers, vegetation boundaries, or elevation bands to group regions based on presumed climate uniformity. In this ‘fixed zone’ system, referred to as ‘geographic-based seed transfer’ (GBST), seed from geographic zone ‘X’ could be deployed only to zone ‘X’.

Erring on the side of caution, most early fixed zone seed transfer systems consisted of many very small zones restricting seed transferability and leading to a demand for larger zones (Ying and Yanchuk 2006). At the same time in the 1990s, the nexus of desktop computing, geographic information systems, and fine-scale climate models, facilitated the emergence of ‘focal point seed zone’ systems (Parker 1992), allowing seed for a given plantation location to be procured from all *point locations* within a threshold geographic, climate, or genetic distance from the plantation (Fig. 1). Early examples of a focal point seed transfer system are the climate matching tool “Seedwhere” (McKenney et al 1999) and the Seedlot Selection Tool first released in 2010 (St. Clair et al 2022).

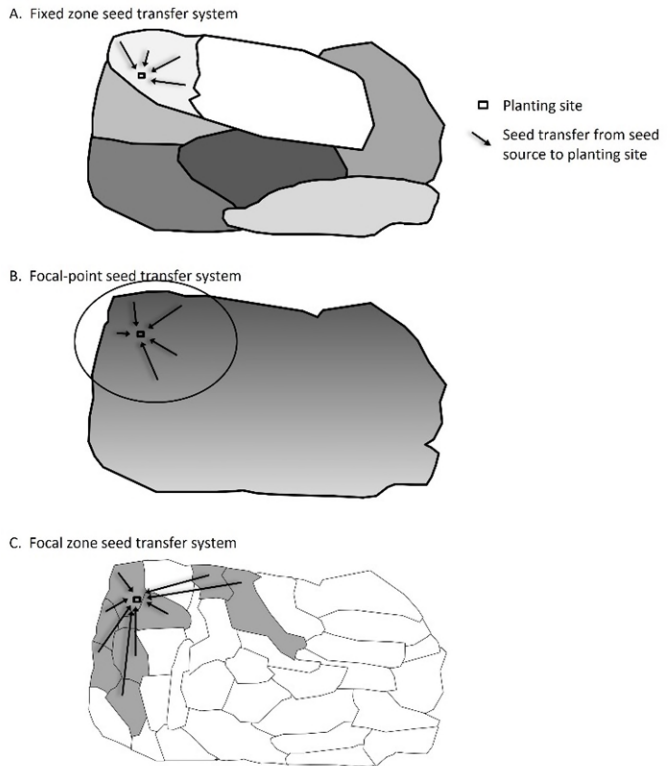

Fig. 1. Examples of (a) fixed zone, (b) focal point, and (c) focal zone seed transfer systems.

Rationale for a new system of seed transfer

In the same year as focal point seed transfer systems were proposed, came a seminal article recommending that tree seed be moved uphill and northward to address concerns regarding changing climates (Ledig and Kitzmiller 1992). However, the recommendation gained little traction until publication of reports illustrating predicted massive shifts in ecosystem climates in British Columbia (Hamann and Wang 2006) and in tree species climate niches (McKenney et al 2007) in Canada. Shortly thereafter, there followed a landslide of articles on the topic of assisted migration. In the forestry context, assisted migration usually refers to the establishment of plantations with seed sources from climates slightly warmer than the plantation climate to help ensure plantations remain healthy and well-adapted throughout their lifespan (Pedlar et al 2012).

While focal point seed transfer systems resolved the issue of overly restrictive seed deployability (Ukrainetz et al 2011), they resulted in an infinite number of seed zones. Consequently, seed deployment and procurement areas for each seed source or plantation location required reference to a unique map that could be generated only using a focal zone seed transfer system; there was no single map of seed zones. Also, despite being published in 1990, more robust methods to quantify safe (or 'critical') seed transfer distances, SSTDs (Raymond and Lindgren 1990), had not been incorporated into either fixed or focal zone seed transfer systems. Wishing to address these issues, facilitate the implementation of assisted migration, and further capitalize on GIS, downscaled climate data, and new analytical techniques, 'focal *zone* seed transfer' was proposed (O'Neill et al. 2017).

Components and operation of a climate-based seed transfer (CBST) system

To ensure wide seed deployability, focal zone seed transfer systems allow seed transfer between a finite, manageable number of seed zones. Seed for a plantation seed zone (a seed zone to be reforested) can be procured from any seed zone whose climate is slightly warmer than the plantation seed zone. Or, from the perspective of a seed owner, seed from a given seed zone can be deployed to any plantation seed zone whose climate is slightly colder than the seed zone from which the seed originated. The new seed transfer systems recently implemented in BC and Ontario use focal zone seed transfer and are called 'climate' based seed transfer (CBST) systems because a climate threshold distance between zones determines inter-zonal transferability. The steps below describe the development of a CBST system, based largely on methods described in O'Neill et al. (2017).

1. Identify a seed zone map

Any system of vegetation, ecology, or climate classification mapping can be used, however, the more uniform the climate within units, the greater the accuracy of estimates of seed transfer impacts. As a rule-of-thumb, the standard deviation of mean annual temperature within most land units (seed zones) should not exceed 1.0 °C. If any units violate the rule, they should be split or an alternative mapping system used. In BC, the 207 biogeoclimatic ecosystem classification (BEC) variants form the seed zones used in CBST, while in Ontario, CBST operates on ecodistricts.

2. Identify a genetic suitability threshold

Identify the amount of plantation adaptation – in terms of height (relative to the height of the optimum population) - that you are willing to forgo to provide operational flexibility to users. In BC the system constrains inter-zonal transfers so that the longest transfer will result in expected heights no less than 97.5% of the height of the optimum (local) population. This value – the lowest expected height – is expressed as a proportion of the height of a local seed source (transfer distance = 0) (i.e., 0.975) and is referred to as the *genetic suitability threshold*. Multiply percent height forfeiture associated with genetic suitability threshold by 2.5 to obtain percent volume forfeiture. (E.g., a height forfeiture of 2.5% equates to approximately 6% volume forfeiture.)

3. Develop transfer functions and quantify safe seed transfer distances

Using provenance trial data, develop transfer functions relating population climate transfer distances to population height. (Adaptation traits other than height can be used. Adjust the genetic suitability threshold accordingly.) If you are pooling data from multiple provenance test sites, response variables will need to be standardized to account for site productivity differences (O'Neill et al. 2017). Identify the 3-6 climate variables that generate the strongest functions. Once each relationship is fitted, divide all population heights by the expected height of a local population (transfer distance = 0) and re-fit the relationship so that height = 1.0 at transfer distance = 0. Use the transfer functions to identify the SSTD associated with the genetic suitability threshold for each climate variable (Ukrainetz et al. 2011).

4. A provenance test 'work-around'

As the number of planted tree species vastly exceeds the number of species with wide-ranging, long-term provenance tests, SSTDs are often 'borrowed' from species with reliable provenance data, from local practitioners, or inferred from the maximum climatic range present within existing fixed, geographic seed zones. This can be accomplished by overlaying a fine grid onto a GBST seed zone map and calculating the 95th percentile of climate transfer distances between a random selection of points within each seed zone. In British Columbia, multiple climate variables are combined with equal weight into a single transfer distance index and SSTDs are defined for the index. Use of the index results in seed rarely being transferred further than the distances provided in Table 1. Distances in Table 1 are approximate and will vary by species and number of climate variables used in a CBST. Use of fewer (or more) than 6 variables may require use of SSTDs larger (or smaller) than those provided here. Climate variables with SSTDs given in % imply that seed must not be transferred to seed zones that have a mean greater or less than the seed source seed zone mean value for that climate variable. For example, seed from a seed zone with MAP of 1000 mm, must not be transferred to seed zones with MAP > 1400 mm or MAP < 600 mm.

Climate variable	Climate variable abbreviation	Units	Safe seed transfer distance (+/-)
Mean annual temperature	MAT	°C	3.0
Mean coldest month temperature	MCMT	°C	4.0
Temperature difference	TD	°C	3.0
Mean annual precipitation	MAP	Mm	40%
Mean summer precipitation	MSP	Mm	35%
Growing degree-days > 5 °C	DD5	°C	35%

Table 1. Recommended safe seed transfer distances (SSTDs) for six climate variables.

Note that switching from a geographic-based seed transfer system (GBST) to a CBST system does not alter SSTDs. Consequently, the establishment of new provenance tests is not necessary when converting to CBST if existing SSTDs in GBST result in acceptable plantation growth and health.

5. Calculate migration distance

Migration distance is the climate distance seed procurement areas must be moved to ensure that plantations are established with seedlots whose historic climate – the climate to which they are best adapted (i.e., the climate prior to rapid recent Anthropogenic climate change) - will match the plantation climate shortly after establishment – the match date climate (Ukrainetz et al.

2011) (Fig. 2). Restoring populations back into their historic climate is expected to mitigate climate change impacts most effectively (Sattler et al 2024). The climate migration distance is calculated for each of the 6 climate variables by subtracting the match date climate (in BC - 15 years, or ¼ rotation after plantation establishment) from the historic (1931-1960) climate for the province (or for each seed zone, if climate change differences among seed zones is large).

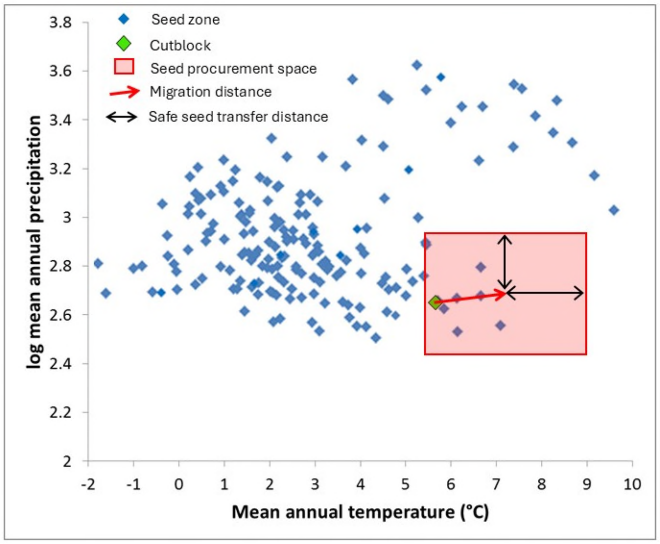

Fig. 2. Schematic illustration of the operation of climate based seed transfer system that uses focal zones. Seed for a plantation seed zone (a seed zone to be reforested) can be procured from any seed zone whose climate is withing the safe seed climate transfer distance of the plantation seed zone climate. When assisted migration is used, the seed procurement space shifts to a climate slightly warmer than the plantation seed zone. Shifting of the procurement space is achieved by adding the migration distance to the cutblock (plantation) climate. Multiple climate variables can be used to define the procurement space. Alternatively, all climate variables can be combined into a single index and safe seed climate transfer distances can be defined for the index.

6. Identify suitable inter-zone transfers

To identify acceptable transfers between seed zones while accounting for climate change, the climate migration distance is added to each 1961-1990 plantation seed zone climate variable to calculate the 'migrated' climate of each plantation seed zone. Then, for each migrated plantation seed zone, seed zones within the SSTD of all climate variables (within +/- the SSTD of MAT, *and* within +/- the SSTD of MCMT, *and* within…, etc.) are identified as the acceptable seed procurement seed zones.

Misperceptions regarding CBST

Critics of CBST contend that the risks associated with using assisted migration are too high. However, knowing that populations migrate extremely slowly in nature, and knowing that the mean annual temperature (MAT) has increased 2.0 °C since the mid-1950s (considerably more in much of boreal Canada), use of GBST or CBST without assisted migration (i.e., establishment with local seed sources) would result in establishment of plantations adapted to a climate 2.0 °C colder than the plantation climate at establishment and approximately 4.0 °C colder than the plantation climate at harvest. Whereas use of CBST with assisted migration as implemented in BC results in plantation establishment with seed sources adapted to an MAT 0.5 °C warmer than the plantation climate at establishment and approximately 1.5 °C colder than the plantation climate at harvest. These findings suggest that the risk of maladaptation should be lower with assisted migration than without.

Concern is also expressed that CBST with assisted migration will result in seedlings being established in 'different' soils where growth and survival may be compromised. However, use of assisted migration does not imply that species' edaphic (soil nutrient and moisture) requirements can be abandoned (Mackenzie and Mahony 2021). Further, while assisted migration outside of the species' range may be discussed frequently in the literature, the wide natural distribution of most tree and many shrub species, combined with the relatively short geographic and climate distances actually proposed for assisted migration (Ukrainetz et al. 2011) suggest that most assisted migration in will likely take the form of assisted migration within the species' range (assisted gene flow), not assisted range expansion.

Some stakeholders have expressed reluctance to adopt assisted migration because of a lack of provenance trials. As mentioned in the previous section, fixed seed zones have been developed in most parts of Canada and abroad without extensive provenance trials, so clearly, seed transfer systems do not require provenance trials. Developers of fixed zone seed transfer systems for species lacking provenance trials either borrowed SSTDs from other species, or used expert, local, or anecdotal knowledge to 'guesstimate' SSTDs and fixed geographic seed zone sizes needed to ensure SSTDs were not violated. Conservative SSTDs can therefore be borrowed from well-developed provenance trials or inferred from climate ranges observed in fixed seed zones of GBST systems.

Assisted migration implemented without a CBST tool in place can pose risks. Seed sources transferred beyond their safe-transfer distances can fail due to maladaptation. Alternatively, species introduced intentionally (e.g., cane toads in Australia, and emerald ash borer and kudzu in the United States) or unintentionally (e.g., spotted knapweed, zebra mussels, blister rust, and Dutch elm disease in North America) (https://www.invasivespeciescentre.ca/) can become invasive, wreaking havoc on the recipient ecosystem by disrupting or displacing local species, particularly when an introduced species reproduces readily and escapes controls imposed by other organisms in its native habitat. The risk of a species failing or becoming invasive is negligible in assisted migration in forestry when a CBST system is in place to constrain the procurement of seed sources to within common SSTDs and migration distances. Likewise, the risk of acquiring a hitchhiking pest that becomes invasive is also minimal because climate migration distances used in CBST are associated with short geographic transfer distances, usually in the order of 200 to 300 m upward elevation transfer or 200 to 400 km poleward transfer, and do not require transcontinental or intercontinental transfers which are commonly associated with species invasions (Mueller and Hellmann 2008).

Summary

CBST with assisted migration, delivered in a focal zone seed transfer system should be inexpensive, low risk, easily implemented, and transparent. Focal zone seed transfer preserves the use of a fixed number of seed zones, while providing near-maximum seed deployabiltiy. Analyses of seed transfer systems suggest that volume growth rate at rotation of lodgepole pine and interior spruce should be approximately 15% and 6% greater in CBST with assisted migration than in GBST. Likewise, seed deployability should be 230% and 710% greater in CBST with assisted migration than in GBST for lodgepole pine and interior spruce (Luo et al. 2025).

This article focuses on CBST – low-hanging fruit in climate change adaptation, which can eclipse other adaptation strategies with significant potential: planting wider range of reforestation species (Mason et al. 2012) or multiple seedlots of a species to buffer climate certainty and help ensure maintenance of forest cover (Looney et al. 2023); partial harvesting to protect seedlings from intense solar radiation (Robinson et al 2022); testing and selecting for growth stability across a wide range of environments; and screening for pest resistance and drought tolerance. The collective experience of the tree seed community will be needed to help implement CBST more widely and advance additional climate change adaptation measures.

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Climate Change Informed Species Selection for Reforestation in British Columbia

Climate Change Informed Species Selection (CCISS – pronounced 'kiss') is a Biogeoclimatic Ecosystem Classification-based analysis framework that predicts climate change impacts on tree species environmental suitability at a site-specific level. The CCISS tool is a web-based application (**https://bcgov-ffec.ca/cciss/**) that makes this analysis accessible to practitioners to help guide climate change adaptation in reforestation decisions.

Understanding tree species environmental suitability is one of the foundational pieces of information that practitioners require for the creation of silvicultural prescriptions that will lead to successful reforestation over a rotation period. Climate change will affect this goal by progressively altering environmental conditions and therefore the suitability of tree species established on a site over time.

To address this challenge, the CCISS tool projects changes to species environmental suitability at a site series level for any user selected location in the province and estimates the future suitability of a tree species to this changing climate. To account for future climate uncertainty, the tool looks at a wide range of global climate change models and emissions scenarios to capture the range of plausible climate futures for any location in BC in 20-year periods out to 2100.

To assist users, the tool compares the current species selection guidance in the Chief Forester's Reference Guide (CFRG) with the future forecast from the CCISS analysis. Reports from the tool highlight where species are stable/improving or declining/unsuitable and where new species have become suitable and could be considered as candidates for assisted migration.

The CCISS tool has been designed to assist professional decisions in the following contexts:

1. Selecting tree species for individual reforestation prescriptions
2. Designing stocking standards for reforestation policy
3. Setting landscape-level stocking standards to manage risk

4. Identifying best locations for off-site species reforestation trials and/or assisted range expansion
5. Identifying regions and site conditions where forests and tree species are at highest risk to climate change stresses
6. Learning about the distribution and ecological tolerances of BC's tree species

CCISS is intended as an input to tree species selection decisions, not as a definitive answer. Any tree species selection decision needs to account for other information, synthesized through professional judgement, including non-BEC factors (e.g. forest health, extreme weather, silvicultural systems), potential sources of error, and other lines of evidence.

The impacts of climate change on tree species environmental suitability is highly site-specific and varies across each species' range (Fig. 1). Silviculturists can act now by reducing the deployment of tree species into high-risk areas of their historical range, instead choosing a mix of resilient species. For species projected to have large expansions in their suitable range, the decision to practice assisted migration requires careful consideration by Indigenous Nations, ecologists, policymakers, and communities.

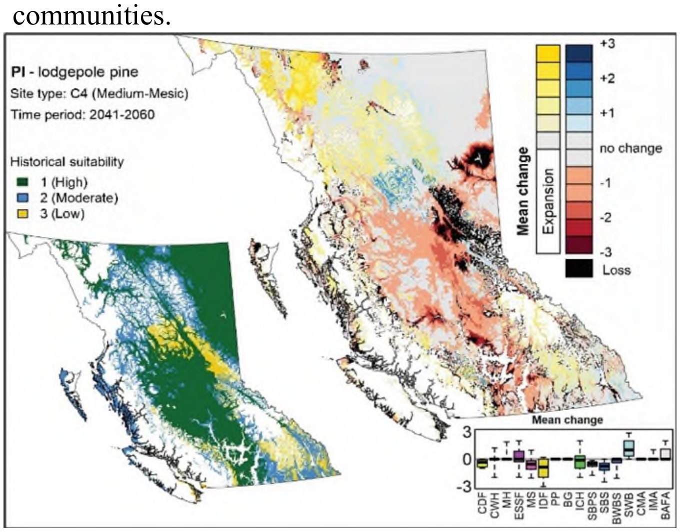

Figure 1. CCISS projections for changes in environmental suitability of lodgepole pine (Pl) on mesic (i.e. zonal) soils (C4) indicate areas of declining suitability (red), increasing suitability (blue), and expansion of the range into newly suitable areas (yellow) under 2041-2060 climate scenarios. Historical suitability (1961-1990 climate) is shown on the left with areas of historically high (E1), moderate (E2) and low (E3) envirionmental suitability. Boxplots of mean changes in suitability plotted by BEC zone on bottom right.

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Tree species trials established decades ago can inform the potential for assisted tree migration in central British Columbia

In British Columbia, as in many parts of Canada, silviculturists have long experimented informally with planting tree species outside their natural ranges, often with small *ad-hoc* trials planted within conventionally managed forests. Many of these trials were originally established for demonstration or local interest purposes; today these trials may provide important scientific information that can guide the development of assisted migration strategies. While species distribution models suggest that suitable climates for many tree species in British Columbia are migrating northwards, field data are required to test model predictions and to better understand the potential for species to be planted outside their range. In many regions of the province, however, there are relatively few field experiments designed to explore these questions, and recently established trials will require decades to produce actionable results. In the interim, informal species trials may provide the best information to better understand the range of climatic and environmental conditions suitable for reforestation species. In 2020, BC Ministry of Forests researchers initiated a project to explore this potential.

We collected data from 25 informal trials in central BC where Douglas-fir, western larch, and/or ponderosa pine were planted between 20 and 70 years ago north of their current geographic ranges, often by several hundred kilometres (Figure 1). Using ecological and long-term tree growth data collected from each site, we found the following:

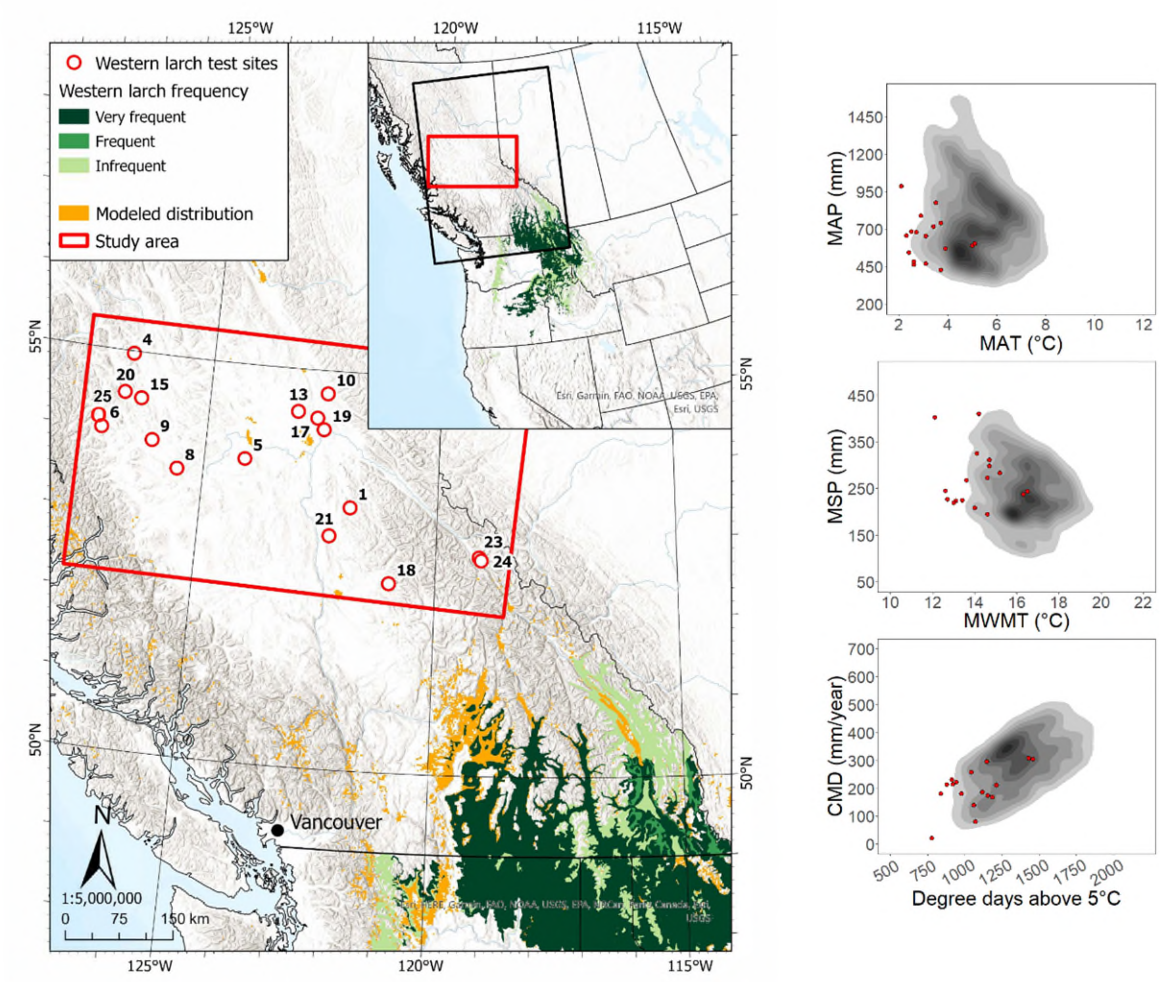

Figure 1: Western larch test site locations and current geographic and climatic ranges. Left panel: test site locations, the species' current geographic range (CGR) in British Columbia and northwest United States. Species CGR data are from MacKenzie and Mahony (2021); modelled distribution shows the estimated species suitable climatic habitat in 1997-2006 (Gray and Hamann, 2013). Right panels: the 1981–2010 climate normals of the test sites (red dots), along with a kernel density distribution of the species' climate normals from its distribution in western North America (grey contours). MAP, mean annual precipitation; MAT, mean annual temperature; MSP, mean summer precipitation; MWMT, mean warmest month temperature; CMD, climatic moisture deficit. Figure reproduced from Griesbauer et al. (2025).

1) All three species appear to be well-adapted to the climate of central BC where they are capable of good growth, form and vigour. In fact, they all showed faster height growth in central BC (outside of their natural geographic range) than populations located further south within their natural geographic ranges.

Based on these findings, we suggest that these species show good potential to be used in assisted migration reforestation strategies. Given the older ages of the trials (between 20 and 70 years), these species have likely been feasible silviculture options for many decades in central BC (Figure 2). Further, our results suggest that optimal growth for these species may occur in climates colder than their current natural distribution and support the hypothesis that suitable climates for these species are moving northwards.

Figure 2: Dougas-fir planted 70 years ago in central BC, west and north of its current geographic range.

2) Climates of most of the Douglas-fir test sites and about half of the western larch test sites were within the climate range where these species occur naturally, suggesting that part of the reason for the strong growth of these species outside their natural geographic range is that the climate to which they are adapted already occurs in central BC.

3) Douglas-fir and western larch were also more productive than lodgepole pine, a species that occurs naturally in the study area and is widely used for reforestation in central BC (Figure 3). Thus, we found evidence that Douglas-fir and western larch can compete with local tree species and maintain dominant/co-dominant crown class. While ponderosa pine grew more slowly than lodgepole pine in the study region, it was capable of good growth and maintaining a co-dominant canopy position when planted in pure stands in the study area (Figure 4).

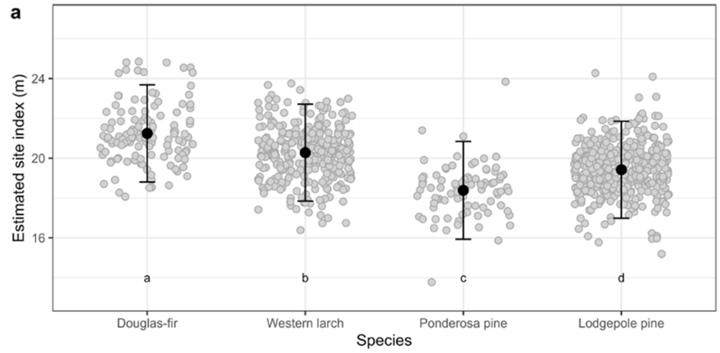

Figure 3: Estimated site index (i.e., total tree height at age 50) of Douglas-fir, western larch and ponderosa pine planted in central BC, outside their current geographic range. Height growth of these three species were compared to lodgepole pine, a species that occurs naturally in central BC and is used widely for reforestation. Doulgas-fir and western larch height growth exceeded that of lodgepole pine, whereas ponderosa pine had slower height growth.

Figure 4: Ponderosa pine planted in 1992 in central BC, several hundred kilometres north of its current natural distribution in southern BC.

4) The productivity of these three species varied strongly with site conditions. Specifically, growth of all trees increased with the amount of available soil moisture. Thus, while these trees appear suitable for assisted range expansion across a wide climatic range in central BC, their productivity can be expected to vary with site conditions, which should be considered by forest managers.

Results from our study suggest that these conifers have substantial potential to be used for reforestation in large areas of British Columbia in areas colder and north of their current geographic range. In fact, their potential for range expansion may be larger than suggested by species distribution models developed only using tree species' natural ranges. Perhaps most importantly, our study demonstrates that small, informal tree species trials established decades ago can provide valuable information to inform assisted migration practices. Where available, additional data such as survival and seed source should be analyzed to provide further insights. Given the prevalence of similar trials across Canada, similar approaches in other regions may yield additional valuable information to inform climate-adapted silviculture and complement findings from on-going assisted migration research trials.

More information can be found here: Griesbauer, H., O'Neill, G. and MacKenzie, W., 2025. High productivity of tree species planted outside their current geographic range indicates large regions of unrealized niche space. *Frontiers in Plant Science*, *16*, p.1650428. (https://www.frontiersin.org/journals/plant-science/articles/10.3389/fpls.2025.1650428/full)

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Guinnessometrics in Action: A Collaborative Trial Network for Climate-Adaptive Reforestation in British Columbia

As climate change begins to exert environmental pressures on forest ecosystems across British Columbia, the use of adaptive reforestation strategies is becoming essential to ensure plantations remain resilient under future conditions. Species distribution and climate models suggest that many tree species may be suitable beyond their current geographic ranges, with suitability expected to expand under projected climates. Historical trials have also, in some cases, demonstrated that non-local species can perform well outside their natural range (Griesbauer et al. 2025). Assisted range expansion into newly suitable areas therefore represents a promising adaptation strategy. However, robust field evidence is needed to clarify the conditions under which non-local species can be successfully established, providing the operational basis for broader deployment.

Traditional reforestation trials, though scientifically rigorous, are expensive, limited in number, and often confined to a narrow ranges of climate and site conditions. Their intensive and costly designs make them less suited to establishing the breadth of trials required to evaluate the feasibility of establishing climate-adaptation species across diverse environments. Addressing this challenge will require a larger network of trials that span a wide range of climatic, site, and ecological conditions.

Methods

Managing the practicalities and costs of establishing a sufficiently large and environmentally diverse network of trials was a primary consideration in designing a framework to investigate assisted range expansion. Drawing on the statistical pragmatism of William Gosset ("Student") and the principles of 'Guinnessometrics' (Ziliak 2019), we developed an approach that leverages the scale and efficiencies of operational reforestation programs to establish a large number of trials across a broad range of geographic and climatic conditions in a statistically meaningful way.

Trial establishment protocols and tools were designed to minimize disruption to operational planting programs and encourage uptake by volunteer collaborators. Each trial consists of a 5 × 5 grid of seedlings sourced from a single seedlot and stock type. With 25 trees per trial, at least eight trial replicates can be established from a single box of seedlings. Trials are planted within operational blocks under consistent site conditions and offset from roads and boundaries to reduce edge effects. Because these non-local trials are embedded among local species, only minimal marking was required by planters when establishing the trials.

To support data collection, we developed the GoM Trials iOS app, which records GPS location, photos, planter information, and stock type directly in the field. Data syncs automatically to a cloud-based database when WiFi is available and is published to a public R Shiny dashboard (https://thebeczone.ca/shiny/bybecmap/).

Species selection was guided by the Climate Change Informed Species Selection (CCISS) tool (MacKenzie and Mahony 2021), focusing on those species projected to expand their geographic ranges into central B.C.: Douglas-fir (Fd, *Pseudotsuga menziesii*), western larch (Lw, *Larix occidentalis*), western redcedar (Cw, *Thuja plicata*), ponderosa pine (Py, *Pinus ponderosa*), and western white pine (Pw, *Pinus monticola*). Smaller numbers of trembling aspen (At, *Populus tremuloides*), grand fir (Bg, *Abies grandis*), and western hemlock (Hw, *Tsuga heterophylla*) were also established.

We presented a GoM trial proposal to forestry practitioners at the winter 2023 session of the Northern Silviculture Committee in Prince George to elicit interest in the project. Twenty forest professionals from government and industry expressed interest in planting non-local species GoM trials during their spring operations. Based on collaborator requests, ~30,000 seedlings were purchased from production overruns of BC Timber Sales, Seedling Services and distributed free of charge. Overruns, resulting from routine over-sowing to ensure adequate supply, provided a cost-effective and scalable source of trial materials avoiding the need to pre-plan, manage seed purchase and sowing requests. Seedlots from the available overrun stocks were selected to best match the climatic similarity between source regions and planting sites.

Early qualitative assessments (<5 years) were conducted on some stands using a standardized scoring system. Individual trees were rated from “Excellent” (vigour score 4, performing better than local species) to “Dead” (score 0), with intermediate categories capturing health issues, maladaptation, and competitive stress. Trial performance was rated from the mean of tree scores.

More formal quantitative surveys are planned at year 5, including measurements of height, DBH/caliper, form, and vegetation competition indices. Where site series were not recorded at planting, they will be determined during measurement to enable assessment of edaphic influences. Pairwise comparisons between non-local trials and fixed-area plots of adjacent operational plantings will provide direct evidence of relative performance under current conditions.

Trial performance will be analyzed using Bayesian multilevel models to account for the correlated, non-random nature of the data. Survival (proportional), growth (continuous), and performance (ordinal) will be modeled against predictors such as species, seedlot climate distance, stock type, planting year, edaphic conditions, and climate parameters. These analyses will help identify climates and sites most likely to be suitable—or unsuitable—for reforestation with non-local species.

Results

Over three planting seasons, project collaborators established approximately 2,400 GoM trials (800 trials or 20,000 seedlings / year) across central BC (Figure 1). Median distance of trials from natural stands were 615km for Western larch,330 km for Ponderosa pine, and 305 km for western white pine. Douglas-fir and western redcedar trials had many trials planted closer to natural stands (medians of 30.1 km and 53.6 km, respectively) but other trials as distant as 200km were established.

We investigated survival and qualitative performance of 240 trials established in the hard drought conditions of 2023 and 2024 using the standardized scoring system. Trial performance as calculated as the mean of tree performance suggest that the majority of trials have 'Fair' or better performance for all species with ¼ to ½ of trials performing as good or better than the local species (Figure 2).

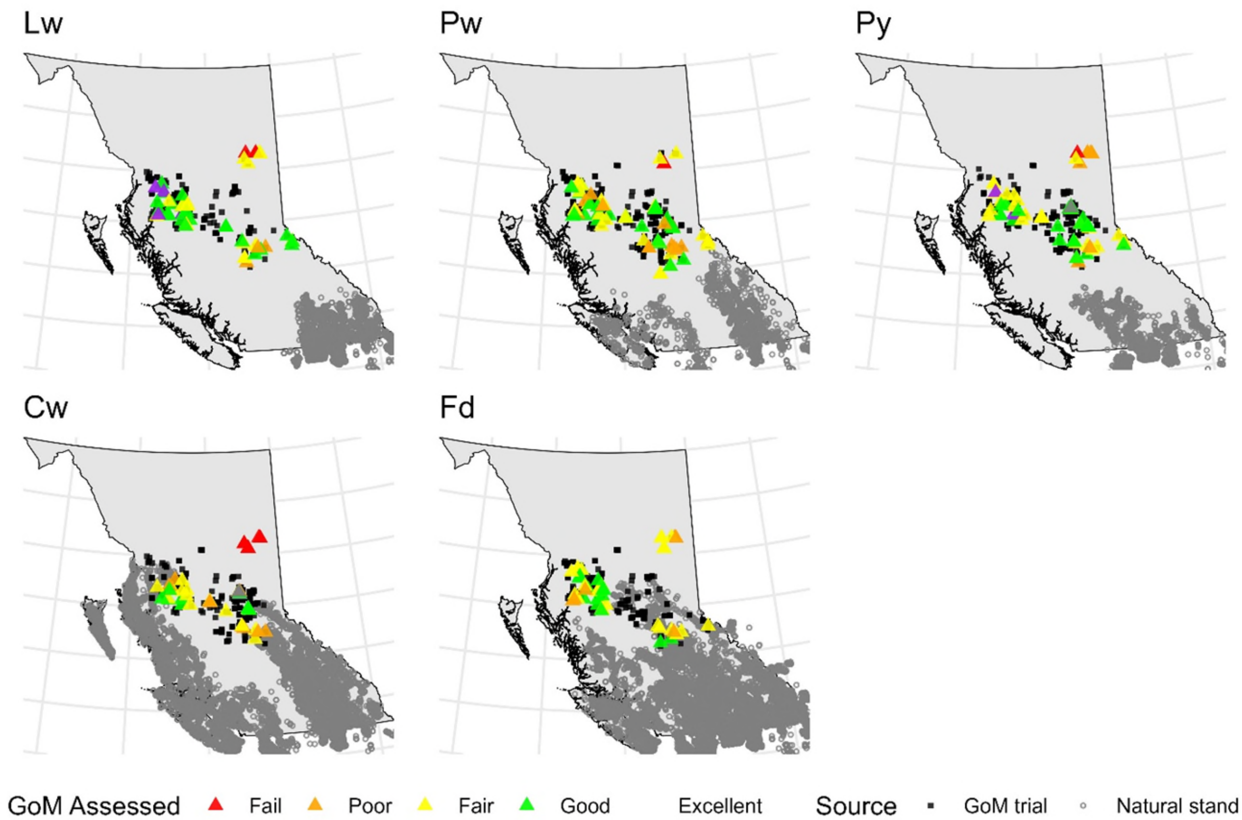

Figure 1. Locations of established GoM trials (2023-2025) with colour-themed assessed performance where surveyed. Lw=western larch, Pw=western white pine, Py=Ponderosa pine, Cw=western redcedar, Fd = Douglas-fir

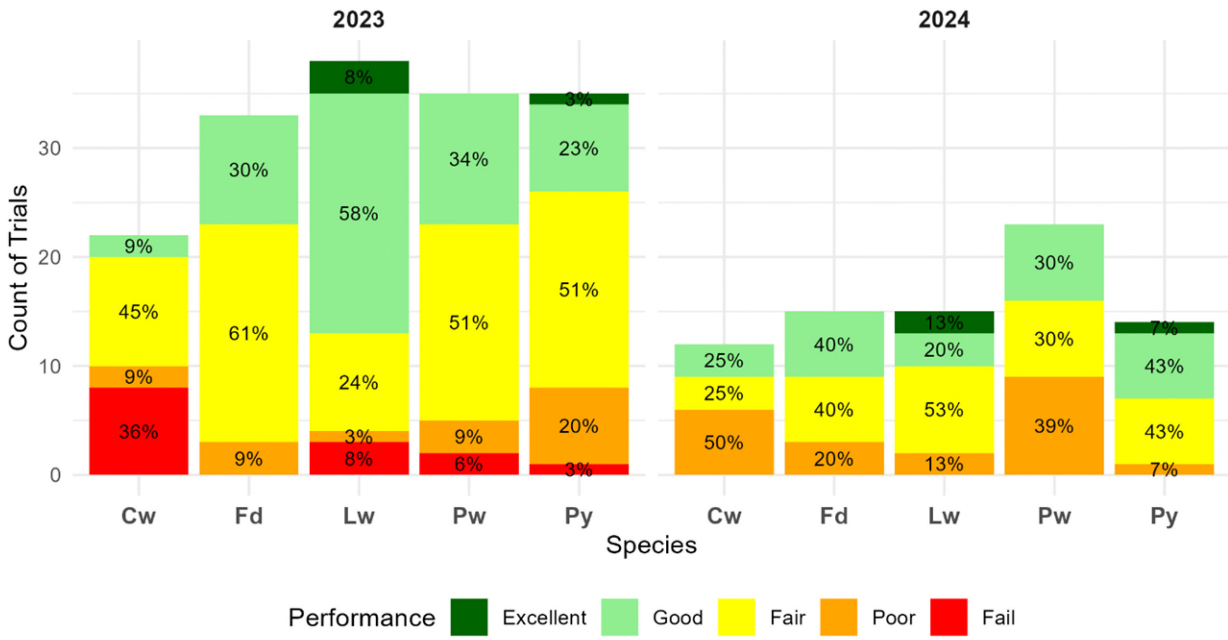

Figure 2. Distribution of qualitative performance of 242 trials established in 2023 and 2024. Lw=western larch, Pw=western white pine, Py=Ponderosa pine, Cw=western redcedar, Fd = Douglas-fir

Discussion

To prepare plantations for future climates, forest practitioners can use models to anticipate trajectories of suitability change. However, before widespread adoption of new non-local species into operational practice, establishing and assessing field trials are essential to build practical experience and test the limits of establishment feasibility.

The Guinnessometric (GoM) network provides operational, and research advantages compared with traditional reforestation trials. Because GoM trials are embedded within routine planting contexts, they require minimal additional effort and allow foresters to explore regeneration strategies at relatively low cost and risk. A large and geographically distributed set of trials using a consistent protocol has resulted from the involvement of numerous collaborators. This large body of equivalent trials will support a strong statistical analysis of environmental, spatial, and temporal factors influencing species survival, growth, and adaptation. Furthermore, these trials may provide valuable insights for other research and management inquiring over the long-term.

The successful establishment of a large number of trials over only three planting seasons, where few existed previously, provide important body of test sites to determine the current feasibility of planting climate-adapted tree species outside their current range. The initial results from some preliminary surveys indicate that a sizeable portion of trials for all species are well-established but that some areas, like the southern boreal forest around Fort St. John appear to remain largely unsuitable. A more comprehensive survey of sites will provide more definitive insights to guide decisions on more widespread implementation of range-expansion.

While some limitations are imposed by the GoM approach —such as reduced control over establishment conditions and small plot sizes—the network offers meaningful value to both forestry practice and research. With more than 800 trials planted annually with minimal effort by any one practitioner, the GoM network demonstrates how operational foresters can contribute to structured experimentation and share insights across regions for both the research community and reforestation professionals.

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Modelled biogeoclimatic units of the western United States as future bioclimate analogues for climate change modelling in British Columbia

The Biogeoclimatic Ecosystem Classification (BEC; MacKenzie and Meidinger, 2018; Pojar et al., 1987) is the foundational framework used in British Columbia (B.C.) to guide climate- and site-specific reforestation decisions, particularly the selection of appropriate tree species. With climate change, current guidance must be adjusted to account for a range of plausible future climates to ensure plantations remain resilient through to maturity.

MacKenzie and Mahony (2021) leveraged the BEC framework to develop an ecological approach to inform adjustments to tree species selection guidance with the Climate Change Informed Species Selection (CCISS) tool. They modelled the redistribution of biogeoclimatic subzone/variant (BGC units) climate envelopes under projected future climates using machine learning (Wang et al., 2012) and then linked equivalent site conditions and their associated tree species suitability ratings between the current BGC unit and 30 future modelled future BGCs, spanning 20-year normal periods to the year 2100. The Climate-Based Seed Transfer system (CBST; O'Neill et al., 2017) also employs BEC subzone/variants as climate units to guide the selection of climate-adapted seed sources for reforestation.

Using BGC units as the central component of climate-change adaptation guidance has the advantage of directly integrating scientific advances into well-established decision-making systems for forest and land management in British Columbia. However, both these approaches require the existence of equivalent BGC units in regions that have analogue climates for future climate conditions in B.C. The Natural Subregions of the ecological land classification system of Alberta serve as comparable climatic units to BEC and provide analogue sources for future climates in the boreal forests of northeastern B.C. (Natural Regions Committee, 2006). By contrast, no BEC equivalent units exist for regions south of B.C., which are the most likely sources of climate analogues in southern coastal and interior B.C. To address this gap, we developed a modelled BGC product for western North America, enabling the identification of suitable climate analogues beyond provincial boundaries

Methods

We initially acquired and compiled 45,620 Forest Ecosystem Plots plots from USDA Forest Regions 1 and 6. From this set, 18,974 plots that represented mature forests on broadly circum-zonal (average) site conditions were attributed to a BGC zone by tree species composition and then to prospective BGC subzone/variants based on overstorey and understorey composition following BEC classification principles. A subzone is a regional climate where the potential natural vegetation on zonal sites is the same plant association (Meidinger and Pojar, 1991; Pojar et al., 1987). To fill in distribution gaps, additional plots were obtained from the Forest Inventory and Analysis program and assigned to prospective BGC units. Additional training points were then added to grassland regions by adding points from US GAP/LANDFIRE program maps In total, 36,689 training points were used. Creation of BGC units and descriptions of their ecology and tree species distribution was assisted by review of available plant associations and forest habitat types described for National Forests and other public lands (e.g. Cooper et al., 1991; Franklin and Dyrness, 1988; Lillybridge et al., 1995).

Plots that were classified to BGC units were then attributed with annual and seasonal climate predictors from the climate surface 'climr' (Daust et al., 2024). These data the used to train a Random Forests classification model (Breiman, 2001) of BGC subzone/variant climate envelopes.

We built a 400 m hex polygon grid for each state in the western USA and each polygon was attributed with climr climate predictors. The BGC Random Forests model was then used to predict BGC membership for each polygon in each state grid. To create a final BGC map raw state maps were merged into a single map, hexes were merged to create larger contiguous polygons based on BGC membership. To simplify the map merged polygons less that 6 hexes in size were combined with the adjacent polygon that shared the longest common boundary.

We then assigned BGC membership from this map to all 208,110 ecosystem and FIA plots based on spatial intersection with the predicted BGC map and reviewed map distribution relative to data and iterated the model and map prediction. After the map final map was selected, plots assigned to each mapped BGC were reviewed and summarized to identify common plant associations or habitat types and more broadly what tree species were found in each BGC. From this information, tree species suitability ratings were assigned across edaphic conditions for use in the CCISS tool.

The predicted BGC map for the western USA was then merged with the most recent BGC map of British Columbia and the map of Natural SubRegions of Alberta to create a seamless BGC map for western North America (Figure 1).

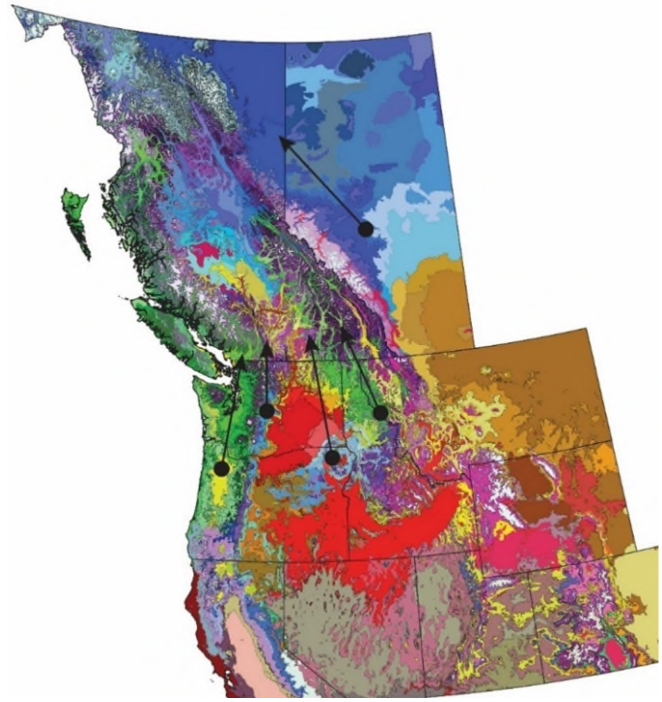

Figure 1. Biogeoclimatic map of western North America. Arrows show the generalized sources of transboundary biogeoclimatic analogues for future climates in British Columbia

Results

Thirty BGC zones were identified for the conterminous western USA—eleven of which also occur in British Columbia (Meidinger and Pojar, 1991) and two of which occur in Alberta (Natural Regions Committee, 2006). The 17 new biogeoclimatic zones of the USA were proposed based on a review of vegetation description reports and data. Most zones have multiple subzones and approximately 163 new biogeoclimatic subzone/variants were mapped.

Six of the 17 new BGC zones are forested occurring mostly south of the Washington-Oregon border, including the Coastal Mixed Evergreen (CMX) with 4 subzones, Coastal Redwood Forest (CRF) with 2 subzones, Coastal White Fir (CWF) with 4 subzones, Mountain Hemlock – Red Fir (MHRF) with 3 subzones, Interior Grand Fir (IGF) with 5 subzones, and Interior White Fir (IWF) with 4 subzones. The new zones encompass tree and understorey assemblages significantly different from current B.C. vegetation which may provide insight into potential dramatic ecological shifts under warmer future climates (**Table 1**).

Table 1. Tree species of Forested Coastal Biogeoclimatic Zones. Grey highlighted species do not naturally occur within B.C.

Scientific Name	CDF*	CMX	CWF	CRF	CWH	MH	MHRF	Common Name
Pseudotsuga menziesii	**C****	**C**	**C**	**C/S**	**C/S**		s	Douglas-fir
Arbutus menziesii	*c*	***C***		*c*				*Arbutus*
Thuja plicata	c			c	**C**			Western redcedar
Abies grandis	c			c				Grand fir
Calocedrus decurrens	c	c	**C**					**Incense-cedar**
Notholithocarpus densiflorus		**C/S**		**C**				**Tanoak**
Quercus chrysolepis		**C**						**Canyon live oak**
Abies concolor		c	**C**				c	**White fir**
Chrysolepis chrysophylla		c	c		c		c	**Giant chinkapin**
Chamaecyparis lawsoniana		c						**Port Orford-cedar**
Sequoia sempervirens				**C**				**Coast redwood**
Tsuga heterophylla				**C**	**C**	c		Western hemlock
Abies amabilis					**C**	**C**		Amabilis fir
Chamaecyparis nootkatensis					c	c		Yellowcedar
Abies procera					c			**Noble fir**
Picea sitchensis					c			Sitka spruce
Tsuga mertensiana						**C**	**C**	Mountain hemlock
Abies lasiocarpa						c		Subalpine fir
Abies magnifica							**C**	**California red fir**
Pinus contorta							s	Lodgepole pine
Acer macrophyllum	**S**	**S**		s	**S**			Bigleaf maple
Quercus garryana	**S**							Garry oak
Pinus ponderosa	s	s	s					Ponderosa pine
Fraxinus latifolia	s							Oregon ash
Alnus rubra	s			s	**S**			Red alder
Cornus nuttallii	s	s			s			Western flowering dogwood
Quercus kelloggii	s	s						**California black oak**
Umbellularia californica		s		s				**California laurel**
Pinus lambertiana		s	s					**Sugar pine**
Pinus monticola			s		s	s	s	Western white pine

* Zone names: CDF: Coastal Douglas-fir; CMX: Coastal Mixed Conifer; CWF: Coastal White Fir; CRF: Coastal Redwood Forest; CWH: Coastal Western Hemlock; MH: Mountain Hemlock; MHRF: Mountain Hemlock – Red Fir.

** **C** – major climax species; c – minor climax species; **S** – major seral species; s – minor seral species

Many forested BGCs described for British Columbia also have subzones defined for the western United States. These include the Coastal Douglas-fir (CDF) with 3 subzones, Coastal Western Hemlock (CWH) with 15 subzones, Mountain Hemlock (MH) with 5 subzones, Engelmann Spruce – Subalpine Fir (ESSF) with 15 subzones, Interior Cedar – Hemlock (ICH) with 8 subzones, Interior Douglas-fir (IDF) with 16 subzones, Montane Spruce (MS) with 11 subzones, and Ponderosa Pine (PP) with 8 subzones. These recognizable forest types represent less radical analogues to B.C.'s current ecosystems.

A USA BGC zone map created in this way has BGC types and boundaries that match closely with equivalent zones at the international border suggesting that the analysis is producing a sufficiently accurate map for the purposes of providing BEC-equivalent analogues for climate futures of British Columbia.

The predicted future redistribution of BGC units from the CCISS analysis frequently identifies USA BEC units as the best analogues of future climates in British Columbia. Figure 3 shows the generalized source and destination of USA and Alberta BEC units into British Columbia

Discussion

The extension of the biogeoclimatic ecosystem classification (BEC) system into the western USA extends BEC-based forest management tools beyond provincial boundaries. By aligning ecological units across jurisdictions, this work ensures that guidance from CCISS, CBST and other climate adaptation tools based on BEC are adequately informed with realistic shifting climate envelopes, particularly for the southern regions of British Columbia. The close correspondence of mapped BGC zones at the Canada–U.S. border demonstrates that the modelling approach is sufficiently robust to capture ecological continuity across political boundaries, thereby enhancing confidence in its application to climate adaptation planning.

And by linking modelled BGC units to described plant associations and tree species suitability ratings across edaphic conditions, this work enables practitioners to anticipate both opportunities and constraints in future reforestation strategies at a site level. This information also opens other potential avenues for research and application including transboundary conservation planning and dynamic vegetation model predictions of species turnover under climate change.

Collaboration with land managers across jurisdictions will be essential to ensure that mapped BGC units are interpreted consistently and applied effectively in reforestation and seed transfer programs. Iterative refinement of mapping and subzone definitions using additional plot data and vegetation descriptions will improve ecological resolution going forward.

This product provides important information for anticipating and managing the impacts of climate change on ecosystems in British Columbia. The identification of new BGC zones and their alignment with existing Canadian units ensures that climate adaptation tools are relevant for southern areas into more distant time periods. While methodological limitations warrant ongoing refinement, the resulting map and descriptions represents a practical and ecologically meaningful step toward climate-resilient forest management across borders. Publication of a formal product is expected in 2026.

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Conservation of Native Trees Under Climate Change

Forest genetic resources are significantly threatened by human activities, including changes in land use, forest fragmentation, the introduction of invasive species, and atmospheric pollution. Climate change is particularly altering the environmental conditions to which tree populations have adapted, negatively impacting the sustainability and resilience of forests.

In British Columbia (BC), native trees are conserved through both *in situ* and *ex situ* conservation efforts, achieving a conservation rate of 93.3% under current climate conditions (Wang et al., 2020). *In situ* conservation involves maintaining tree populations in their natural habitats, such as parks and nature reserves (89.0%), while *ex situ* conservation includes collecting seeds and storing them at the BC Tree Seed Centre (4.3%).

For *in situ* conservation to be effective, it is crucial to preserve the genetic diversity and evolutionary potential of tree species. This preservation enables trees to continue adapting to changing environments while providing essential ecological services. Additionally, protected areas for tree species must align with their fundamental niches under future climate conditions.

The fundamental niche is the multidimensional climate space where a species can survive and reproduce, whereas the realized niche describes the specific climate conditions a tree species occupies in its natural habitat, limited by factors such as interspecific competition and migration constraints. For conservation efforts, it is important to understand that, since the trees are already established, the factors limiting the realized niche are less of a concern. Therefore, comprehending the fundamental niches is vital for conserving tree species. Unfortunately, current climate niche models primarily predict only realized climate niches.

In our recent study, we investigated lodgepole pine and Douglas-fir, which have been introduced into many countries beyond their natural habitats, making them ideal candidates for examining their fundamental niches. We built climate niches for these two species using broader ranges of species than native ones and examined the sensitivity (correct prediction rate for species presence) and specificity (correct prediction rate for species absence) crossing points to determine fundamental niches. We successfully identified the threshold for estimating these fundamental niches (Zhao et al., 2023).

Using the concept of the fundamental niche threshold, we analyzed 43 native tree species in British Columbia, including 24 conifers and 19 broadleaf species. To assess potential changes in the distribution of these tree species across western North America, we employed Random Forest models alongside extensive occurrence data under various climate scenarios. Our analysis revealed distinct "winners" and "losers" among the species, with broadleaf trees generally demonstrating more positive responses than conifers (in prep.). Specifically, 79% of broadleaf species are projected to expand their suitable habitats, while only 54% of conifers are expected to show similar positive trends. Notable winners include *Betula occidentalis* and *Thuja plicata*, while *Pinus albicaulis* and *Arbutus menziesii* are likely to face significant habitat contractions.

After identifying the fundamental niches of 43 tree species, we estimated the protected areas where these species exist within those niches. We identified a total of 210 protection units, calculated by multiplying the number of species by the number of biogeoclimatic zones in which they occur. We modeled with a mid-range scenario (SSP245) across three periods: 2011-2040, 2041-2070, and 2071-2100. Additionally, we examined a business-as-usual scenario (SSP585) for the period from 2070 to 2100. Our findings indicate that the impact of climate change is moderate, with protected units showing percentages of 4%, 4.5%, and 5.7% contraction for the respective periods under SSP245. For the SSP585 scenario, this impact is estimated to be 8.7%.

Some of our tree species, particularly conifers, are facing significant challenges, including *Juniperus scopulorum*, *Larix laricina*, *Picea mariana*, and *Tsuga mertensiana.* These challenges underscore the urgent need for awareness and action to protect these tree species.

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Landscape genomics of Douglas-fir (*Pseudotsuga menziesii*): adaptive potential for future climatic conditions

The long, challenging, yet profoundly rewarding journey of my PhD at the University of British Columbia finally came to an end last month when I had the honor and privilege of being hooded and crossing the stage. Sharing this moment with my wife, daughter, and supervisor (Sally Aitken) was particularly special as they were my source of inspiration, motivation, perseverance, and determination from the beginning.

If you are interested in climate adaptation in conifers and the genetic architecture of climate-adaptive traits, check out my thesis available here: https://open.library.ubc.ca/soa/cIRcle/collections/ubctheses/24/items/1.0449299 with the Abstract reproduced below. Stay tuned for the next few papers coming out soon!

There is an urgent need to better understand how populations of trees will respond to changes in climate and the intensification of extreme weather events. Characterizing the amount of genetic variation and genetic architecture of climate-adaptive traits is important for developing management approaches that mitigate the effects of climate change on forests. In this dissertation, I combined three large-scale common garden experiments (~6,000 seedlings) with population genomic approaches to investigate phenotypic and genomic variation across the natural ranges of the two main varieties of Douglas-fir (*Pseudotsuga menziesii* var. *menziesii* and var. *glauca*), as well as within breeding zones in British Columbia.

Seedlings from 74 natural and 14 selected breeding populations were assessed for drought tolerance, cold hardiness, growth, phenology, and plastic responses to drought. I also used a case-control genome-wide association approach to identify single nucleotide polymorphisms (SNPs) associated with drought tolerance and cold hardiness within populations, and tested for repeated evolution between varieties, pleiotropy between traits, and allelic clines along environmental gradients. Finally, I tested the effects of selection for growth in tree breeding programs on climate adaptive phenotypes, and on the frequency of SNPs associated with cold hardiness and drought tolerance, by comparing selected seedlots with their wild counterparts. Signals of local adaptation to drought were weak within var. *glauca* and nearly absent within var. *menziesii*. Genetic variation for drought tolerance in seedlings is maintained primarily within rather than among populations. The complex polygenic architectures and genomic redundancy controlling climate adaptation make it challenging to use genomic information in management of Douglas-fir. Selection for faster growth reduced cold hardiness in var. *menziesii*, but had weaker effects in var. *glauca*. Drought tolerance was not affected by selection for faster growth. There is potential to increase drought tolerance through selection within breeding populations. These results collectively can inform adjustments to assisted gene flow in Douglas-fir.

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Assisted migration film overview

If you've been to the BC Tree Seed Centre or the Kalamalka Research Station recently, you may have noticed a small film crew lurking around the halls. This is part of an upcoming documentary film about human-nature relationships in British Columbia, where assisted migration is a central focus. The project, with a working title of Moving Trees, is looking to explore the implications of a future in which the province's landscape looks and feels very different to today; a future which humans might play a large role in shaping through strategies like assisted migration.

My starting point is the debate around assisted migration. Proponents argue that it is a necessary intervention to maintain healthy ecosystems in an era of climate change. Critics on the other hand will argue that it crosses a line between humanity and the natural world, that it is not our place to be shaping Nature in this way (Aubin et al. 2011). In this critical view, the value of the Nature derives from its separateness to humanity. Untouched, pristine and wild places take on the highest value as exemplars of an uncontaminated world which once existed but has slowly been eroded as people have come to dominate the planet. Seen in this way, interventions like assisted migration paradoxically both save and destroy Nature at the same time: they save the ecosystems Nature consists of but destroy the natural essence that makes Nature what it is.
This paradox presents a seemingly impossible choice. Yet perhaps the way out of this paradox is to look at the cultural context which makes it possible, for this context contains a critical assumption: the existence of Nature itself. Deconstructing this assumption is not to deny the existence of the non-human world, nor to deny its importance. Rather, it is to question the categories of *Nature* and *the natural* standing in opposition to *culture* and *the human.*

As many environmental historians have noted, capital "N" Nature is a profoundly cultural invention. Capital "N" Nature is much more than the places and ecosystems it consists of. It is the complex web of cultural meanings which we project onto those places and ecosystems. These meanings do not exist in isolation, they have particular histories from which they emerged, and the baggage these histories carry with them shape dominant ways of thinking about Nature today. Oftentimes, these histories harken back to a conflux of colonial fantasies about virgin lands waiting to be explored and conquered, theological narratives about a fall from grace, and the romantic sublime. In the words of historian William Cronon: "As we gaze into the mirror it holds up for us, we too easily imagine that what we behold is Nature when in fact we see the reflection of our own unexamined longings and desires" (Cronon 1996).

Most readers of this bulletin would be well aware that in reality, a whole lot of human effort goes into managing the places we consider Nature. Yet I think many of us also feel that there is something special in the idea of a Nature that is somehow primordial and untouched. After all, isn't this what drives the very foundations of Nature conservation, and what draws so many visitors to this part of the world every year? Conservationist writers from John Muir to Bill McKibben have extensively referenced this idea of Nature in advocating for removing human traces from the landscape. I too have cherished this idea, and although much of my research has been focused on tearing it apart, I am probably still carrying some small part of Nature's allure with me each time I go out into the woods. But even in those places considered most preserved, most pristine, such as provincial and national parks, there are elaborate management strategies in place, if only to maintain the illusion of human absence.

The paradox then is not that human intervention to maintain Nature destroys its essence. Rather, what is paradoxical is a Nature which exists independent of human activity and culture, both ideologically and materially. Nature as an idea could not exist without some human culture inventing it, and Nature as an object could not exist without some culture actively working to keep it from being influenced by our actions. Even if we look past this, it's also worth asking: can we really shape a sustainable relationship with the non-human world while denying our involvement in it? To quote Cronon once again: "To the extent that we celebrate wilderness as the measure with which we judge civilization, we reproduce the dualism that sets humanity and nature at opposite poles. We thereby leave ourselves little hope of discovering what an ethical, sustainable, honourable human place in nature might actually look like".

At this point you may be asking how assisted migration fits into all of this. The answer is that assisted migration, and climate change adaptation in general, will require new ways of conceptualizing and acting upon our relationships to the non-human world. No longer can we pretend, even if we would like to, that Nature must exist in isolation from us, since we will be playing an outsized role in shaping it. As we think about this future, we are also provided with an opportunity to reflect on the past which brought us here and the present which we are currently negotiating. The corollary is that if imagining nature as something that can only exist apart from humanity is no longer valid, if it ever was, then what comes next? What new paradigm will replace the one we have been holding onto until now? If the preservation of Nature in some imagined original form is no longer an acceptable goal, then what new intentions should this future paradigm serve?

It is this particular historical moment we are in, where we are needing to deal with the consequences of anthropogenic climate change, all the while trying to renegotiate our material and ideological relationships to the non-human world, that I am interested in documenting and exploring. I feel very lucky so far to have been able to collaborate with those on the front lines of preparing British Columbia's forests for climate change, including the teams at the BC Tree Seed Centre, Kalamalka and Cowichan Lake Research Stations as well as the Landing Nursery and Hawkeye Holdings. I'm excited to continue covering these efforts over the next year, and to speak with a wide range of stakeholders in BC's forests, all with the goal of answering: how did we get here, and where should we go?

If looking for answers to these questions sounds interesting to you, then please feel free to reach out. A project like this is fundamentally always a collaborative one, and whether that's just a casual conversation on the topic or a potential appearance in the film, I'd be happy to hear your input.

Some readings

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Seed Transfer in Ontario

Canada's changing climate is increasing the risk that tree populations may become maladapted to the climate at their current growing locations. In response, Ontario updated its Tree Seed Transfer Policy in 2020 to reflect the evolving natural, operational, scientific, and policy environments, including a changing climate (https://www.ontario.ca/page/ontario-tree-seed-transfer-policy).

This policy renewal was made possible through strong collaboration among federal and provincial science, operations, and policy teams. Key components of the update included:

- a custom climate similarity analysis,
- identification of critical seed transfer distances,
- extensive engagement with practitioners to assess readiness and receptivity, and
- the development of an online interactive tool to allow users to explore seed transfer options under climate change.

Further information about the policy update and the major steps in the process can be found in this article, *Enhancing forest resilience: advances in Ontario's wild tree seed transfer policy*, https://pubs.cif-ifc.org/doi/10.5558/tfc2022-002.

Key features of the updated policy

The policy is designed to help forest managers balance climate adaptation, operational flexibility and long-term regeneration success. It identifies where wild seed can be collected, used and transferred, supported by a 'focal zone' approach that:

- combines the strengths of local seed use and climate similarity,
- uses ecodistricts for practical application and
- balances science with operational flexibility.

The process uses *Seedwhere* to match the projected climate of a planting site with the climate to which a seed source is adapted.

The online interactive Tableau tool allows users to explore seed collection and deployment options. It supports the transition from legacy seed zones to the current ecodistrict units. Users may also explore different climate change scenarios at different points in time. https://public.tableau.com/profile/larlo#!/vizhome/SeedSourceOntario/Intro

Forest managers have begun using the Tree Seed Transfer Policy to support climate informed seed sourcing in their forest management plans. Initial results show that the climate transfer seed sources perform as well as the local ones and, in some cases, better than local sources. Tree species that have been transferred include red and white spruce, and red and white pine.

Our aim in sharing this update is to promote national awareness of seed transfer efforts in Ontario, share findings from the 2022 Forestry Chronicle publication to support other jurisdictions and emphasize the importance of cultural and operational shifts in seed sourcing and management under a climate change.

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Planning Ahead for Climate-Adapted Forests

We are noticing a growing interest among forest practitioners and researchers in both operational and research-based assisted migration. While it is inspiring to see this enthusiasm and the increase in funding opportunities supporting such work, there are also important nuances that are often overlooked in project funding, planning, and execution. At the same time, although some continue to debate acceptable levels of risk, researchers increasingly emphasize that taking no action may be far riskier than taking well-planned steps forward. Drawing on our own experience, we hope to share lessons learned, key planning considerations, and how we came to understand them.

The Forest Gene Conservation Association (FGCA) in Ontario has been fortunate to contribute to numerous projects involving the procurement of source-documented, high-quality seed for assisted migration trials, seed production areas, and other initiatives. Each project has tested, challenged, and strengthened our understanding that improving efficiencies in seed procurement is just as important as moving the material itself. Ensuring forests have diverse options in an uncertain climatic future aligns with our mission to maintain genetic diversity as the foundation of resilient forest landscapes.

In Ontario, many of the regions most critical for seed sourcing under a changing climate are also among the most heavily developed in Canada. Expectations that these areas can reliably produce large quantities of genetically diverse seed at minimal cost are unrealistic and can lead to project failures.

For projects requiring material from the United States (U.S.), significant preparatory work is essential. This includes identifying suitable populations, establishing trusted contacts, and ensuring that proper handling practices are followed throughout the chain of custody.

FGCA's early involvement in assisted population migration was inspired by work led by Natural Resources Canada in Pickering. That site included both population-level assisted migration and assisted range expansion for several species. FGCA adopted a similar design, with added replication. Between 2011 and 2016, this assisted migration trial was established on six sites across southern Ontario, with some variation in species based on local conditions. Although the original intention was to procure seed and grow all material at a single nursery, the project's funding timelines did not allow for adequate planning, and stock from multiple nurseries was used.

These six trials continue to provide lessons and insights. They also offer valuable opportunities for local practitioners to observe how different provenances perform, adding ongoing value to the work. From this experience, FGCA committed to supporting organizations in moving material responsibly and ensuring that high-quality, source-identified seed is used.

A strong example of rigorous, adaptive seed procurement is found in the Adaptive Silviculture for Climate Change (ASCC) project delivered by Natural Resources Canada (NRCan) at the Petawawa Research Forest (PRF). Although the project included many treatments, FGCA was contracted to procure seed aligned with climate projections, maintain seed viability, and ensure excellent provenance records.

Purpose and Scope of the Project

FGCA was engaged to source high-quality, source-identified seed for the first Canadian ASCC site at Petawawa. This required securing seed aligned with multiple climate-change periods for species including red oak, white oak, white pine, red pine, and pitch pine, including material from the U.S.

The work included locating and assessing seed sources and collectors, ensuring genetic and geographic suitability, delivering seed with appropriate documentation and quality testing, managing international shipping and phytosanitary requirements, and troubleshooting during poor seed years.

After reviewing hundreds of contacts across the northeastern U.S., only 38 were able to support the project or successfully provide seed. FGCA's strong Ontario-based network proved invaluable for securing local provenances.

Results

Red oak sourced from Wisconsin and Iowa arrived in excellent condition with high viability. White oak was high quality at collection but lost viability during short-term storage and shipping, despite extensive efforts to salvage acorns. A second collection season was needed to compensate for these losses. Conifers were more straightforward, using both stored and fresh seed. Pitch pine posed challenges due to limited populations and poor seed production, requiring a small fresh collection supplemented with banked seed from the National Tree Seed Centre.

A recurring theme in the ASCC project was the difficulty of sourcing large volumes of genetically appropriate, recalcitrant seed under the following conditions:

- The primary collection year (2022) was extremely poor for seed production in both Ontario and the U.S.
- Cooled transport, phytosanitary requirements, paperwork, and brokerage services added cost and slowed timelines.
- Oak acorns deteriorate rapidly during storage and transport.
- Few collectors had experience with detailed source documentation and specialized seed handling.
- Many potential sourcing areas lacked natural, genetically suitable stands.

Despite these challenges, FGCA fulfilled all deliverables through intensive coordination, including multiple cross-border permit applications, forecasting seed availability across jurisdictions, last-minute adjustments, and maintaining excellent communication with NRCan. Extra handling, sorting, and processing were necessary to optimize usable seed.

Recommendations

Projects involving assisted migration should account for longer timelines and plan for at least two seed collection seasons to buffer against poor seed years. Where timelines cannot be extended, substitute species may need to be considered. Stock types should be selected carefully to maintain consistency and support compressed timelines. Phytosanitary regulations and cold-storage requirements introduce significant cost and risk and must be included in project budgets. Delays are inevitable, but clear and ongoing communication before, during, and after the collection season greatly improves success.

Despite the challenges, FGCA met all procurement targets, making strategic substitutions when needed and delivering all seed and acorns with complete documentation and quality assessments. Throughout the process, we supported the Petawawa Research Forest and NRCan with transparent communication, quick pivots, and effective problem-solving. By securing seed from both Canadian and U.S. sources representing all required climate periods, FGCA positioned the Petawawa Research Forest to confidently propagate seedlings for upcoming ASCC research plots and operational plantings.

Regardless if you are interested in moving seed or stock, proper documentation is key not only to make sound decisions about where to move material but also to continue to monitor trees established. Many organizations across the country have made climate appropriate movements of seed or stock and information sharing on this topic saves time, money and significant headaches.

For more information about our work or to get in touch, please visit fgca.net

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Forestry Adaptation Network: Join us!

Canada's forests are facing unprecedented challenges from climate change—shifting seed zones, increased wildfire risk, and evolving pest pressures. For professionals working in forest genetics and tree seed science, staying ahead of these changes is critical.

To support the development and implementation of climate-adapted policy and practices, the Canadian Forest Service hosts a bimonthly virtual meeting that connects experts and facilitates knowledge sharing. For example, the October 2025 session focused on climate-adapted seed sourcing and assisted migration, followed by a December meeting on economic aspects of adaptation. All sessions include presentations and discussions on a particular topic under the broader goals of strengthening the resilience of our forests, advancing management approaches, and supporting the communities that depend on a competitive and future-ready forest sector.

Our bimonthly meetings are merging with the Forestry Adaptation Network (FAN) online hub, which is upgrading to a new online platform that will officially launch in 2026. In collaboration with the Canadian Council of Forest Ministers' Climate Change Working Group, this initiative aims to bring together a broader community of practitioners and experts. The goal is to share trusted resources, showcase practical tools, and create a collaborative space where we can support each other in driving climate adaptation in forestry.

To get information about future bimonthly meetings and an early look at the new FAN virtual space, contact Réjean Lebrun to get on the email distribution list and consider signing up at forestryadaptation.ca to get an early look at the new online platform. Please feel free to share this invite with anyone else who may be interested.

Réjean Lebrun

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Using Dendrology to Better Understand Outcomes at an Oak Assisted Migration Trial in Southern Ontario

Assisted migration offers the potential to maintain forest health and productivity under climate change by using seed sources that are suited to the projected climate at planting sites. This typically involves northward or upslope movements of seed sources that may be within (assisted gene flow) or beyond (assisted range expansion) existing range limits. In Canada, the use of assisted gene flow is an increasingly common tool for incorporating climate change adaptation into future forests, with climate-based seed transfer policies and decision support systems already in place for several provinces.

Assisted migration trials are a good way to assess potential outcomes for translocated species and seed sources at locations of interest. As part of a collaboration between the Canadian Forest Service (CFS) and the Forest Gene Conservation Association (FGCA), we assessed 13-year growth and mortality of white oak (*Quercus alba*) at an assisted migration field trial near Woodstock, Ontario (Pedlar et al. 2024). The trial involved 3 seed sources, including local (Ontario seed zone 37), Pennsylvania (southern origin), and Tennessee (southernmost origin). Results showed no significant differences between seed sources with respect to height growth, but the southernmost seed source from Tennessee had significantly lower survival than the local seed source (Fig. 1). These findings suggest that white oak seed sources can be moved significant distances (about 400 km northward) without incurring high growth or mortality losses, though long-distance movements (upwards of 1000 km northward in this case) may carry risks of increased mortality – at least in the short term. While common garden results remain site specific, the climate distance from the origin of the seed sources and the common garden can be used to assess where in the landscape provenances may succeed.

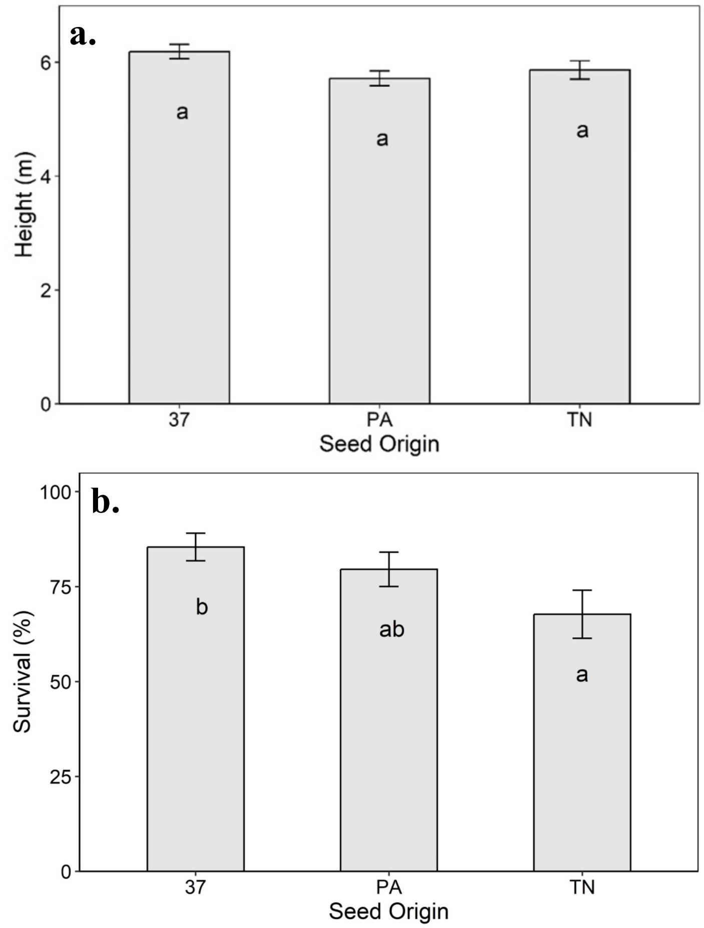

Figure 1. Height (a) and survival (b) of three white oak seed sources at an assisted migration trial near Woodstock, Ontario. Seed sources include: local (Ontario seed zone 37), Pennsylvania (PA), and Tennessee (TN). Sources sharing the same letter are not significantly different.

To get a deeper understanding of these results, we obtained stem cookies from a sample of trees at the site during a thinning operation in fall 2024. Cookies were dried, sanded using different paper grits (120 to 400), and scanned at a 1200 dpi resolution. Growth rings were measured on the images using the software packages Coorecorder and Cdendro 9.8.4. Early results from this exercise suggest that the provenances were growing similarly until experiencing an extreme climate event in 2021, which caused growth of all provenances to decline by more than 50% (Fig. 2).

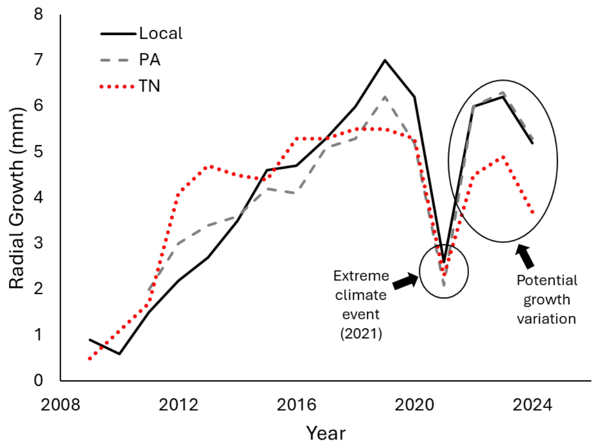

Figure 2. Radial growth of three white oak provenances at an assisted migration trial near Woodstock, Ontario. Ontario. Seed sources include: local (Ontario seed zone 37), Pennsylvania (PA), and Tennessee (TN).

The exact nature of the extreme event remains to be determined but is likely related to a late freeze that occurred in May of that year. In several years following this extreme event, growth of the Tennessee seed source has lagged behind the local and Pennsylvanian sources, suggesting potentially lasting tissue damage from the event – a result that wasn't apparent from traditional height and mortality measurements. We hope to complete and publish the results from this study in spring 2026. Ongoing monitoring at this site will aim to shed light on the duration of this impact and assess other climate-related events that may occur over time.

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Planting for the Future: How SCRCA Is Using Assisted Migration to Build Climate-Resilient Forests

Science is telling us that the climate is changing, and that southern Ontario will face more severe drought conditions as annual temperatures continue to rise. For forest practitioners, this raises an urgent question: **how do we ensure the forests we plant today will survive in the climates of tomorrow?**

One emerging solution is assisted migration. The planting of species, or sourcing seeds, that are naturally drought-tolerant and originate from climates expected to resemble southern Ontario's future conditions. While this concept is straightforward in theory, putting it into practice can be more complex. However, by partnering with organizations focused on the current and future health of Ontario's forests, the St. Clair Region Conservation Authority (SCRCA) has begun implementing these practices directly on the landscape.

The Assisted Migration Oak Trial

In 2016, SCRCA partnered with the Forest Gene Conservation Association (FGCA) to establish an assisted migration oak plantation, one of six FGCA-led trials across southern Ontario.

The goal was to scientifically evaluate the growth of red oak (*Quercus rubra*) and swamp white oak (*Quercus bicolor*) sourced from three different ecoregions: southern Ontario, Pennsylvania, and Tennessee.

However, due to differences in nursery practices south of the border, one of the three sources supplied black oak instead of swamp white oak. Additionally, the limited number of repetitions in the trial design meant the results could not be considered statistically significant.

However, the work was far from wasted. The SCRCA now has a seed collection site with excellent genetic potential—one that, with proper management, will provide source-identified seed for generations of forest practitioners across Ontario.

Growing the Next Generation

Although the SCRCA trial was the last of the six oak trials established, earlier trials elsewhere in the province are already producing seed. In 2025, bur oak seedlings grown from seed collected at one of those other FGCA trials were planted on SCRCA property.

The SCRCA is now collaborating with the University of Guelph to collect DNA samples from these seedlings. This research will examine the genetic makeup of the offspring and gain insight into cross-pollination between trees from different ecoregions. This research will help guide how these progenies can be used in future restoration work.

Identifying Climate-Resilient Species

Not all trees are the same; therefore, they do not respond equally to climate change and associated stressors. Recent analyses have identified species likely to remain resilient as conditions shift. Moving seed north from the United States is complicated by phytoremediation requirements, meaning hardwood seed would not meet regulations due to the presence of seed pests. This has shifted efforts to source evergreen seed instead which is easier to meet these regulations.

As a result, white pine, with its extensive natural range and adaptability, has emerged as a strong climate-resilient candidate. Using SeedWhere, Forest Canada identified white pine seed sources from North Carolina, an area whose current climate closely resembles what is projected for future southern Ontario.

In 2024, SCRCA established a 2-hectare white pine plantation using seedlings grown from both southern Ontario and North Carolina seed. Supported by funding from Hydro One, the site was fenced to protect the young trees from browse. It will serve both as a future seed collection site and as a qualitative observation area to monitor how North Carolina-sourced white pine performs under current and evolving climate conditions.

In 2025, SCRCA expanded this work by using North Carolina white pine in its afforestation program. Efforts will be made to protect these seedlings so their growth and adaptability can be observed over time.

Looking Ahead: Building Forests That Last

The SCRCA remains committed to adopting new best management practices that support the long-term health of southern Ontario's forests. As other climate-resilient species are sourced from southern regions, they will be incorporated into restoration sites with the intention of future seed collection.

Tree seed is critical to the future of Ontario's forests. When that seed is sourced and planted with climate resilience in mind, the forests that grow from it will be better equipped to withstand the challenges ahead.

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Planting for the Future: Assisted Migration and Adaptive Silviculture at the Petawawa Research Forest

Foresters in Canada and elsewhere are increasingly confronted with the question of which tree species to plant, but also from where (Pedlar 2024). As climate shifts faster than most tree species can migrate or adapt, managers require tools and experimental evidence to guide seed movement, regeneration, and long-term forest health and productivity. The Adaptive Silviculture for Climate Change (ASCC) initiative responds to this challenge through a network of field experiments across North America that test climate-adaptation strategies under operational conditions.

The ASCC network applies the adaptive-management framework articulated by Millar et al. (2007) and operationalized by Nagel et al. (2017). At each site, local stakeholders and scientists co-design experimental treatments representing three adaptation strategies along a climate-response gradient: Resistance, Resilience, and Transition. These strategies express trade-offs between short-term health and productivity and long-term adaptive capacity (Fig. 1).

Figure 1: The three adaptation strategies: resistance, resilience, and transition, forming the basis of the ASCC framework and guiding silvicultural treatments designed to help forests respond to climate change. Adapted from Millar et al. (2007) and Nagel et al. (2017).

In 2020, the Petawawa Research Forest (PRF), in Ontario's Great Lakes-St. Lawrence region, became the first ASCC site established in Canada. The site is managed by the Canadian Forest Service with the objective to evaluate how silvicultural treatments and seed source choices can help pine-dominated forests remain healthy, productive, and resilient under future climate conditions (Thiffault et al. 2024). More broadly, the ASCC network is comprised of over 200 management and research collaborators who share lessons learned to advance climate-informed forest management. By integrating findings from across this international network, the PRF site will contribute to identifying which actions can enhance forest ecosystems ability to cope with change while continuing to meet management goals and societal expectations (Nagel et al. 2025).

The Experimental Design at Petawawa

The PRF ASCC installation occupies 212 ha, divided into four replicated blocks of mixed pine and hardwood forest. Each block contains five treatments: Control, Business-as-usual, Resistance, Resilience, and Transition, representing a gradient of silvicultural intensity and genetic displacement distance (Table 1).

Table 1. Summary of Adaptive Silviculture for Climate Change (ASCC) treatments and associated assisted migration strategies at the Petawawa Research Forest.

Treatment	Adaptation Strategy	Description	Assisted Migration Approach
Control	Inaction	No harvest or planting; natural succession	None (reference)
Business-as-usual (BAU)	Baseline	Traditional regeneration from regular shelterwood harvest and underplanting using local seed sources of white pine	Local provenances only
Resistance	Maintain structure	Regular shelterwood harvest maintaining dominant pine canopy; underplanting with local and future climate-adapted genotypes of white pine	Within range
Resilience	Increase diversity	Irregular shelterwood with expanding gaps promoting mixed-species and irregular structure; planting local + future climate-adapted sources of multiple species	Within range and range expansion
Transition	Anticipate future	Regeneration emphasizing future climate-adapted provenances and species expected to thrive under warmer, drier summers	Within range, range expansion and long-distance migration

The Assisted Migration Component

Assisted migration, the deliberate movement of tree populations or species to better-matched climates, has emerged as a key adaptive strategy in forest management (Pedlar et al. 2012; Williams and Dumroese 2013; Xu and Prescott 2024; Lebel Desrosiers et al. 2025). Within the ASCC framework, assisted migration provides a practical means to implement adaptation treatments through seed source selection. Through two contracts, the Forest Gene Conservation Association (FGCA) conducted a

SeedWhere analysis (McKenney et al. 1999; Spearing 2020) and then coordinated the procurement of high-quality seed for the project in 2022–2023, covering both local and future climate-adapted provenances for eastern white pine (*Pinus strobus*), red pine (*P. resinosa*), pitch pine (*P. rigida*), red oak (*Quercus rubra*), and white oak (*Q. alba*), including sources from southern Ontario, Iowa, Virginia, and Wisconsin. Pitch pine (*P. rigida)* was donated by the National Tree Seed Centre.

Implementation and Early Monitoring

Seeds were purchased and transferred to Ferguson Forest Tree Nursery in Kempville, Ontario, where they were germinated and grown into seedlings. Planting began in the fall 2023, following mechanical and chemical site preparation of all experimental units. Each treatment (except the Control) integrates planted seedlings and natural regeneration, allowing evaluation of genetic and structural responses under differing microclimatic and competitive conditions. Early monitoring focuses on seedling survival, height growth, and phenology (Fig. 2), while long-term objectives include assessments of carbon accumulation, species composition, and regeneration dynamics. Wildlife responses to the treatments, as well as fuel loads and impacts on fire risks are also monitored.

Figure 2. A white pine (on the left) and a white oak (on the right) seedlings planted in experimental units of the ASCC installation at the Petawawa Research Forest (photos by N. Thiffault, fall 2025).

Implications for Canada's Tree Seed Community

The PRF installation of ASCC illustrates how silvicultural experiments and seed-supply science and practices must converge to achieve operational climate adaptation. The collaboration between CFS researchers, academics, the FGCA, the National Tree Seed Centre, and local nurseries demonstrates a viable model for integrating climate-based seed transfer into both experimental and operational contexts.

The Petawawa ASCC project directly addresses challenges regarding the operationalization of tree-assisted migration in Canada, including limited provenance data, seed supply constraints, and knowledge transfer barriers (Wotherspoon et al. 2025). While much of the planting focused on within range or range expansion, the inclusion of pitch pine, a species with a more southerly range, marks a tangible step toward testing long-range assisted species migration, the most forward-looking and uncertain form of assisted migration (Moreira et al. 2024).

Conclusion

The Adaptive Silviculture for Climate Change installation at the Petawawa Research Forest demonstrates how seed movement, silviculture, and climate adaptation research can be integrated into a single, long-term experiment. By combining the conceptual approach of the ASCC framework with the practical realities of seed sourcing and field implementation, the project provides a blueprint for science-based, climate-informed reforestation in Canada. Combined with other initiatives in Canada, such as the ASCC installation at the John Prince Research Forest (adaptivesilviculture.org/john-prince-research-forest/), the Desired REgeneration through Assisted Migration project (DREAM; Royo et al. 2023), and the DIVERSE project (diverseproject.uqo.ca), ASCC PRF underscores the importance of embedding assisted migration within a broader silvicultural context, ensuring that seed movement strategies are tested, refined, and operationalized through real-world forest management practices.

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Seed sourcing, a bottleneck for the experimentation and operationalization of forestry assisted migration?

The implementation of forestry assisted migration faces multiple uncertainties, notably surrounding seed sourcing and seedling production, but also regarding silvicultural strategies and inclusion within forest management. The DREAM framework (Desired REgeneration through Assisted Migration) was developed to reduce these uncertainties and propose a structured experimental approach for testing forestry assisted migration scenarios (Royo et al. 2023). It relies on the integration of climate and forest dynamics modelling, plant physiology and silviculture. The DREAM approach is growing into an international network of experimental sites, with four sites located in Québec (Canada) and five in Wisconsin (USA). At the Direction de la recherche forestière (Ministère des Ressources naturelles et des Forêts, Government of Québec), we manage two of the Québec sites, one of which was planted in 2018 (Lac-des-Amanites) and the second in 2024 (Lac-à-Charles). Diversity in tree species is increasingly recognized as a key to the resilience and adaptation of managed forests (Messier et al. 2013). Therefore, each site presents a diverse mix of conifer and broadleaved species, selected for their different functional traits and their ecological and socio-economic values (Figure 1).

Figure 1. Planting stock of the Lac-des-Amanites site comprised three seed sources for each of the five conifers (white spruce, red spruce, northern white cedar, white pine and red pine) and four broadleaved species (sugar maple, northern red oak, black cherry, shagbark hickory). We selected species for their ecological and socio-economic values, but also their trait diversity to promote functional diversity and resilience (Photo: Patricia Raymond).

Planted seedlings used in both experimental sites were produced using seed from three geographical sources per species, corresponding to the future climate conditions projected for the planting site. Our experimental sites will allow for comparing seedling performance in clearcut and partial cut understories, and under different competing vegetation management scenarios. In all sites, fences were also used to evaluate the impact of cervid browsing.

Establishing these two experimental sites came with multiple hurdles, particularly when procuring quality tree seeds matched to the future climate. Here, we will highlight the main challenges faced in this crucial step.

1. Finding seeds that matched climate analogues

Under the DREAM framework, the selection of planting stock relies on a climate analogue approach. With this technique, seeds are sourced in a region where current climate conditions match future conditions of a target destination site. The source region (aka climate analogue) is determined with climate analogue modelling, which determines the similarity of climates from different locations and times. This method is also used in the Seedlot Selection Tool (St.Clair et al. 2022) and others (see Wotherspoon et al. 2025). For both the Lac-des-Amanites and Lac-à-Charles sites, three meteorological variables were used in the climate analogue modelling: 1) mean annual daily temperature, 2) daily minimum temperature in May and 3) mean annual precipitations. We compared maps of dissimilarity index created with the combination of two future climate projections (RCP 4.5 and 8.5 from the Coupled Model Intercomparison Project Phase 5) for two periods (mid-century [2041-2070] and end-of-century [2071-2100]).

Despite the difficulties of climate analogue modelling, acquiring adequate quantities of quality seed that matched the climate analogue regions was even harder. Most of the selected species were not part of the provincial nursery's regular production catalogue, and thus were not subject to large-scale collection or conservation programs. Moreover, seed orchards were not available for these species either. This combination of reasons made high quality seedlots hard to obtain. We were able to access small seedlots from the National Tree Seed Centre (Fredericton, Natural Resources Canada). However, this facility has a limited geographical mandate (i.e., collect and store seeds from across Canada), and only provides small quantities of seeds for scientific research (Figure 2).

Figure 2. The National Tree Seed Centre could provide a few provenances of high-quality seeds, but in small quantity for our experiment (Photo: Patricia Raymond).

We thus had to organize seed collection for some species and climate analogues ourselves, which was a first for our team. Seed collection is a highly specialized domain, and we relied heavily on the Quebec tree seed crop collecting guide (Ministère des Ressources naturelles 1995) and our collaborators at the Centre de semences forestières de Berthier (Government of Quebec) for scientific and technical support. However, locating and accessing seed-producing mature trees remained a significant limitation to our ability to collect seeds. This was especially true for less common species such as pitch pine (*Pinus rigida* Miller) and black maple (*Acer nigrum* Michx), which were initially considered but later abandoned due to lack of seed availability. Individual trees from non-dominant species were not easy to locate as they were not necessarily identified in conventional spatial data or were located on inaccessible private lands.

Capacity was also an issue for our team. For four broadleaved species, private contractors who were willing and able to comply with the standards required by the Centre de semences forestières de Berthier were hired. We also involved other researchers, staff of the Direction de la recherche forestière, and even family members with varying levels of success. We purchased seeds through several commercial seed companies, but information essential for testing the climate analogue approach was difficult to assess. For example, the geographic provenance, origin, and precise number of the seed trees collected was uncertain. Quality from purchased seeds was also variable (Figure 3).

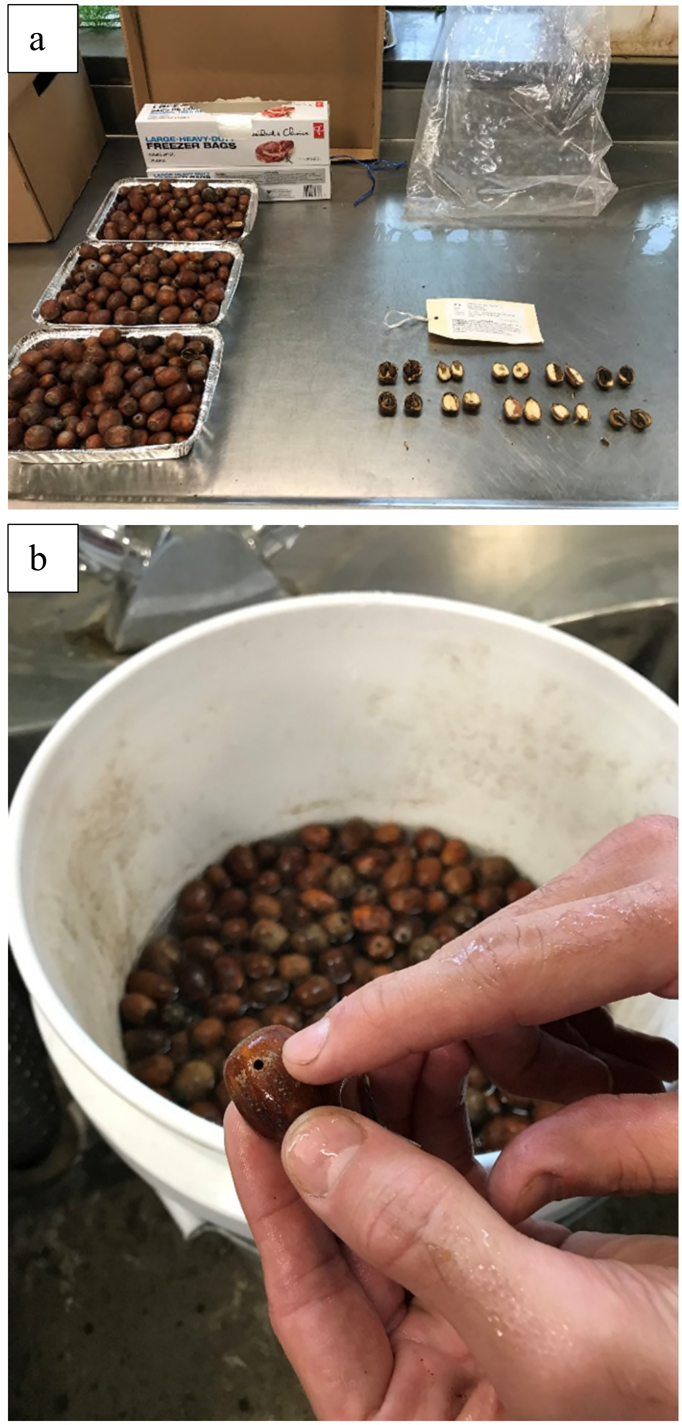

Figure 3: Poor quality northern red oak seedlot bought online from a U.S. tree seed retailer (a). Cutting (a), floating (b) and germination (c) tests have proved useful to assess seedlot quality (Photos: Patricia Raymond).

Coordinating this effort required a lot of work, even if the desired seedling production was modest (only 500 seedlings/species/climate analogue) compared to the usual nursery production size.

The coordination of seed collection was further complicated by timing and schedule issues. The timing was especially hard to fit within our regular activities, and poor timing had serious consequences. For example, collecting seed too early led to poor viability of red oak (*Quercus rubra* L.) acorns while late collection of white oak (*Quercus alba* L.) was limited because we arrived after squirrels consumed most of the crop. Additionally, some recalcitrant seeds cannot be preserved for more than one year without germinating (e.g., oak acorns and hickory nuts). We thus had to collect the seeds at the right moment, taking into account the nursery production timeline and the experiment establishment calendar. In addition, irregular mast years of these species added further complications as crop production did not necessarily comply with our needs.

2. Seeds with frontiers

While all the above listed issues arose in the context of a forestry assisted migration experiment, they are not necessarily caused by the climate analogue approach. Any plantation experiment that aims at producing seedlings for less common species will likely face similar issues. However, the need to transport seeds across national or international borders is closely associated with the use of climate analogues. This is particularly the case in southern Canada, for which most analogs will likely be located in the USA. Seed transportation is complicated by phytosanitary risks and is regulated by the Canadian Food Inspection Agency (CFIA), under the Seeds Act and Seeds Regulations. Moreover, seed collection and conservation are generally less well organized in the United States than in Canada. Equivalents to provincial or federal facilities such as the Centre de semences forestières de Berthier or the National Tree Seed Centre do not exist in the USA. Even for the Wisconsin DREAM experiment, collecting seeds within the United States but across state boundaries required important efforts in terms of networking and coordination (Royo et al. 2023).

These logistic and regulation aspects could severely limit long-distance translocation for forestry assisted migration other than for strictly scientific purposes. This suggests that if the Canadian jurisdictions are looking for a large-scale implementation of this approach, they should probably install seed orchards to facilitate seed sourcing according to their needs. The performance of the seedlings planted in the DREAM experiments may help decide if these orchards are necessary, and if so, which provenances they should contain. Analyses of survival and growth, five years after planting at the Lac-des-Amanites site, suggest that seedling translocations over distances of less than 500 km is reasonable considering the climate change projections (Dumais et al. 2025; Raymond et al. 2025). Thus, for Québec mixedwood and boreal forests, it is likely that relying on seeds from the southern part of the province would be sufficient. Implementing forestry assisted migration in the temperate forests of the southern part of the province, however, will require sourcing seeds from populations in the other provinces, or from south of the border.

3. Hazards once seed were acquired

Assessing seed quality prior to beginning the seedling production was critical. For instance, germination tests allowed us to detect poor germination rates of our first white pine (*Pinus strobus* L.) seedlot acquired from the USA. As a result, we were forced to search for new seeds all over again. Additionally, some species or provenances took longer to germinate than others. This was the case for the end-of-century analogues of black cherry (*Prunus serotina* [Erhr.]) and northern white cedar (*Thuja occidentalis* L.). American basswood (*Tilia americana* L.) was one species with almost no germination at all. There is still a lot to learn about the seed phenology of many species, making it critical for experts from academia, seed centres, and tree nurseries to work together and share their knowledge.

Conclusion

The climate analogue approach is promising for the future of forestry assisted migration. Our analyses of growth, survival and physiology, five years after plantation at the Lac-des-Amanites, suggested that southern provenances performed as well or sometimes better than local seed sources (Dumais et al. 2025; Raymond et al. 2025). The approach would also allow for a quicker implementation of forestry assisted migration, while awaiting the availability of new seed orchards based on transfer models and provenance trials. However, sourcing the significant quantities of high-quality seed required for forestry operations will be a big challenge. As demonstrated here, collaboration with tree seed and nursery experts was critical to the production of quality planting stock (Figure 4).

Figure 4: Procuring high-quality seeds is a key step to produce high-quality seedlings for a successful establishment of a forestry assisted migration plantation. Here, a 3-year-old mixed-species plantation at the Lac-des-Amanites, Réserve faunique de Portneuf, Québec, QC (Photo: Patricia Raymond).

To minimize the risk posed by climate change, we should invest in the resilience of the seedling production line, notably by increasing the number of seed orchards and provenances and by increasing our seed collection and storage capacity (Wotherspoon et al. 2025). These efforts should be realized for multiple species, diversifying from the typical nursery production. Moreover, international efforts to solve seed harvest and conservation challenges will be required to move forward.

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A knowledge transfer activity bringing together several research initiatives on assisted migration of forest tree species

Since 2021, the government of Québec, in collaboration with the province's university network, organizes the ***Rendez-vous de la connaissance en aménagement forestier durable***, a series of virtual meetings in French to transfer scientific knowledge on sustainable forest management. On November 25, 2025, the webinar focused on **research initiatives on assisted migration of forest tree species**.

Climate change is profoundly altering forest dynamics. New and innovative silvicultural approaches are needed to adapt our forests to new conditions. This *Rendez-vous* highlighted several research initiatives in eastern Canada on the topic of assisted migration of forest tree species. This silvicultural adaptation strategy aims to plant seedlings of southern species or provenances in areas where future climate conditions are predicted to be favourable for them. How can these initiatives help forest managers adapt their forest management practices? What criteria guide the choice of species and sites? How can this strategy be integrated at the landscape level? These are some questions that were addressed during the event.

Recordings of the webinar, in French, are available online:
https://diffusion.mern.gouv.qc.ca/public/DRF/Rvd-adf/2025/initiatives-recherche-migration-assistee-especes-forestieres.html

Presentation 1 — Assisted migration in temperate mixedwood forests: Five-year results according to three themes

The first presentation was given by **Patricia Raymond, Emilie Champagne, and Daniel Dumais** from the Direction de la recherche forestière (DRF) of the Ministère des Ressources naturelles et des Forêts (MRNF). It focused on the DREAM (Desired REgeneration through Assisted Migration) network, which aims to develop silvicultural scenarios for assisted migration of forest tree species. In Québec, it includes four experimental studies, including one established in 2018 in the Portneuf wildlife reserve, approximately 100 km northeast of Québec City. This first trial includes nine hardwood and softwood species planted in a mixture under various silvicultural scenarios, including partial cutting and small patch clearcut (1.2 ha). For each species, 3 seed sources (provenances) were selected: analogues to the current climate and to those projected for 2050 and 2080 at the study site. Five years later, 84% of all seedlings had survived. Partial cutting proved useful, particularly in reducing damage caused by late frost, with only a limited effect on ecophysiological performance. Within patch clearcuts, the three hardwood species from the 2050 and 2080 analogues experienced lower water stress; this indicates that the local provenance is less tolerant to drought. Height and diameter growth were similar among provenances for relocations of less than 500 km. The seedlings were able to recover from abiotic and biotic disturbances. Little data is available on assisted forest migration and its implementation. This study proposes concrete solutions for adapting forests to global change.

Presentation 2 — The assisted migration system for forest species at the Simoncouche teaching and research forest

The second presentation was given by **Sergio Rossi**, full professor in the Department of Fundamental Sciences at the University of Québec at Chicoutimi (UQAC), in collaboration with Patricia Raymond (MRNF), Nita Dyola (UQAC), and Roberto Silvestro (UQAC).

A new experiment on assisted migration of forest tree species was installed at the Simoncouche Research and Teaching Forest. The site, located near the city of Saguenay (Québec) and at the edge of the yellow birch–fir bioclimatic domain, represents phase 2 of the DREAM project and is the northernmost sector of the plantation network. In the fall of 2024, 2,400 forest seedlings, representing 5 species (sugar maple, red maple, red pine, red spruce, and eastern hemlock) and 3 climatic analogues, were planted. The design comprises 4 blocks incorporating different silvicultural scenarios (clear-cutting and partial cutting), as well as subplots from which deer are excluded. The presentation focused on the challenges faced during experimental setup and on results obtained during the first year of observations.

Presentation 3 — Assisted migration in the white birch–fir bioclimatic domain: A multiscale approach

The third conference was given by **Mathieu Bouchard**, associate professor in the Department of Wood Sciences at Laval University (ULaval), in collaboration with Frédéric Poirier (ULaval), José-Gabriel Yee-Paré (ULaval), and Hugues Power (MRNF).

Integrating assisted migration into forest management strategies requires consideration at two distinct spatial scales. The speaker presented the initial results of a project aimed at testing the implementation of the assisted migration concept in the white birch–fir bioclimatic domain, taking these two scales into account. At the local level, the implementation of a DREAM experimental design in the Montmorency Forest, 75 km north of Québec City, will test the performance of seedlings from different sources subjected to several types of environmental stress. On the larger scale of Management Unit 037-72 (Québec City region), an allowable cutting calculation incorporating the effects of climate change and various management objectives (biodiversity conservation, social acceptability, factory supply) indicates that the situations in which such plantations should be prioritized can be identified more precisely. The integration of different spatial scales helps identify promising avenues of research and can contribute to the reasoned and organized implementation of assisted migration in this bioclimatic domain.

Presentation 4 — "Extreme" assisted migration in a controlled environment: Preliminary results for eight hardwood and conifer species

The fourth presentation was given by **Loïc D'Orangeville**, associate professor in the Department of Wood and Forest Sciences at Laval University, in collaboration with Mackenzie Good (University of New Brunswick [UNB]), Rob Vaughn (Natural Resources Canada), Christopher Wong (UNB), Anthony Taylor (UNB), and Wendy Monk (UNB).

Measuring populations' ability to acclimatize to future climates is essential for designing assisted migration strategies that target vulnerable species and appropriate transfer distances. This requires evaluating several populations along broad climatic gradients that allow us to predict their resilience to extreme conditions and to anticipate declines in performance. The TransX project is a new network of 11 provenance tests covering a wide climatic gradient. Over the past 2 years, the trees established in these tests were studied in an assisted migration greenhouse experiment. Forty different provenances of 8 species were exposed to a warming gradient of up to +15 °C combined with severe drought treatments. Initial results of these experiments were presented regarding survival, growth, biomass allocation, growth phenology, and photosynthetic activity. These results should make it possible to anticipate the response of trees established in outdoor experiments.

Presentation 5 — Pines, oaks, and curious bears: Assisted migration in the ASCC Project at the Petawawa Experimental Forest

The final presentation was by **Nelson Thiffault**, research scientist at Natural Resources Canada's Canadian Forest Service (CFS-NRCan), in collaboration with his CFS-NRCan colleagues Trevor Jones, Michael Hoepting, and Jeff Fera.

How can we prepare our forests for tomorrow's climate conditions? At the Petawawa Research Forest (Chalk River, Ontario), scientists are testing different silvicultural strategies as part of the Adaptive Silviculture for Climate Change (ASCC) project. The core of this experiment is based on assisted migration: planting seedlings from warmer, drier regions today to see if they will be better suited to the future climates predicted for this region of Ontario. A 212-hectare experiment was installed to compare 5 adaptation strategies that range from inaction to transitioning to new species such as pitch pine, and also include approaches based on resistance (maintaining the current composition), resilience (promoting diversity to bounce back after a disturbance), and transition (actively supporting change). More than 170,000 seedlings and acorns from various local and regional sources, and even some from more distant regions such as Virginia and Iowa, have been planted, and nearly 20,000 are being monitored individually. Observations include tree survival and growth as well as treatment effects on biodiversity, soil, fire risk, and wildlife. This large-scale experiment, conducted as part of a North American network, offers concrete insight into the opportunities and challenges of assisted migration for maintaining productive and sustainable forests in the face of climate change.

In closing, Ms. **Alison Munson**, associate professor at Laval University, summarized the half-day conference.

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MISCELLANEOUS

National Seed Services & Supplier Directory

Canada's ambition to plant 2 billion trees by 2031 was expected to accelerate the demand for high-quality, climate-ready seed and nursery stock. Yet as the forest and restoration sector scales up, the tree-seed supply chain was expected to face unprecedented pressure. From fragmented infrastructure to a lack of understanding of the significant planning required, declining investment in seed orchards in parts of Canada, the ability to source, process, and manage traditional and non-traditional seed remains one of the most significant bottlenecks in achieving national restoration goals.

One of the major challenges and yet opportunities is for experts across Canada to collaborate and share experiences and resources to successfully scale up. To help meet this need, the Forest Gene Conservation Association in partnership with Forests Canada, with the help of National Resources Canada and the National Tree Seed Centre developed a new resource, the Canadian Tree Seed Services and Suppliers Tool. The tool is designed to provide a centralized, publicly accessible directory of seed service providers across the country, enabling restoration practitioners, governments, nurseries, Indigenous communities, and project developers to efficiently locate the services they need.

For professionals working in forestry, nurseries, or seed collection and processing, this tool represents both an opportunity and a call to action.

The newly released *Building Capacity in the Canadian Tree Seed Supply Chain* report (January 2025) produced by the National Tree Seed Centre, Forests Canada and the Forest Gene Conservation Association for the 2 Billion Tree Program, paints a clear picture: Canada must rapidly strengthen its seed supply chain to meet the needs of the 2 Billion Trees (2BT) program and broader restoration initiatives.

The report highlights several pressing issues:

1. Limited and Fragmented Infrastructure: Across the country, there appears to be insufficient capacity for seed purchasing, processing, storage, testing, and data management. This fragmentation makes it difficult for practitioners to find reliable service providers and plan long-term seed needs.
2. Jurisdictional Variability: Access to seed services differs widely by province, territory, and sector. These inconsistencies create challenges in maintaining quality, ensuring species diversity, and securing locally adapted or climate-ready seed.
3. Program brings no opportunities for forest genetics programming: Investment in seed orchards, breeding programs, and related infrastructure has declined over the past decade when now is the time to invest in this space for long-term gains in effective genetic resource management. This directly impacts the availability of high-quality seed, including hardwoods and specialized species.
4. Lack of Coordination and Strategic Oversight: Many jurisdictions lack integrated systems for coordinating seed procurement, tracking provenance, and planning for future climate-adapted needs. Without these systems, restoration practitioners risk shortages, delays, and mismatches in genetic stock.

Together, these barriers reveal a critical need: a more visible, connected, and collaborative seed-service landscape.

The new Canadian Tree Seed Services & Suppliers Tool responds directly to the challenges identified in the national report. The tool provides a centralized directory of organizations and individuals offering seed collection, extraction, processing, storage, testing, nursery production, training and education services. The tool supports large-scale programs like many funded through 2 Billion Tree Program agreements, while also supporting more localized restoration initiatives. The platform is capable of being updated annually, enabling new service providers to join and ensuring the database remains accurate and comprehensive.

By improving visibility and accessibility, the tool helps restoration planners navigate Canada's diverse seed supply landscape and supports more coordinated, climate-ready restoration planning.

For seed collectors, nurseries, processors, storage facilities, and technical specialists, being listed in the national directory offers several key benefits including:

- Greater visibility- ensuring your services are accessible to a growing community of buyers, seed sellers, project leads, Indigenous communities, municipalities, not for profit organizations and private landowners seeking trusted seed expertise.
- Expanded market reach- for service and seed suppliers including small, specialized or region-specific operations which can gain national exposure and increase opportunities for cross-regional collaboration.
- Collaboration and knowledge exchange: stronger partnerships and coordination are essential. By joining the directory, providers plug into a broader network for training, capacity expansion and finding efficiencies in the seed supply chain.

Canada's restoration future, whether it is for 2 Billion Trees, forest restoration, remediation work or other, depends on strong partnerships between seed collectors, processors, nurseries, researchers, Indigenous knowledge holders, and program funders. Tools that improve visibility and coordination such as the Canadian Tree Seed Services & Suppliers Tool are essential to overcoming capacity gaps.

Add your business or services to the national directory

Providers can submit their information quickly through the official enrollment form:

https://forestscanada.jotform.com/251905702441047

Your involvement will help ensure that high-quality, climatically appropriate seed is available when and where it is needed supporting restoration and conservation programs nationally and internationally and the health of Canada's future forests.

Forest Gene Conservation Association

Forest Gene Conservation Association

2025 Forest Nursery Association of British Columbia Annual Conference

On September 23rd - 25th, 2025, the Forest Nursery Association of British Columbia (FNABC) held its 43rd Annual Conference at the Mary Winspear Centre in Sidney, BC. The conference theme was "Rooted in Resilience: Growing in Challenging Times". Over 90 attendees from BC and Alberta forest nurseries, suppliers, Canadian and US agency representatives, gathered in-person for the three day event. The meeting focused on a number of major themes and presentations: forest nursery and silviculture training programs; Indigenous leadership in forest management; workplace safety; maximizing seed germination, seed IPM; pesticide trials & regulations; growing media trends; seedling nutrition; LED lighting; RFIDS tags, high tunnel greenhouses; native plant production & gene conservation.

Two awards were presented at the conference banquet. The first is the Green Timbers Award by which the forest nursery community recognizes the history and major contributions of an individual or organization to reforestation in British Columbia. The 2025 recipient is France Soulieres for her advocacy, extension, and FNABC representation for the forest nursery sector in BC. The Chief Forester's Award is a competition award presented by the Chief Forester or designate to the nursery that succeeds in producing the best specification seedlings of a BC forest species and stocktype chosen by the AGM Organizing Committee. The 2025 winner for the second year in a row was Landing Nursery Ltd. located in Vernon, BC. Congratulation to all award winners for their past, present and future contributions to the forest nursery sector. The evening's entertainment was highlighted with a performance by David Gogo, Juno Award nominee and a DJ session by Mood Beach.

Pre-conference tours were held at the Saanich Forestry Centre and Arbutus Grove nurseries. The conference was rounded out with post-conference tours of the Canadian Forest Service (CFS) facilities in Victoria hosted by Dr Nico Feau and Applied Bionomics Ltd, an insect bio-control research and production company. Dr. Feau focused on his research on the early stages of the reforestation system, by ensuring that conifer seeds and seedlings are resilient to pathogens in the context of climate change. The Applied Bionomics tour provided valuable insights on the research and operational production facilities needed to be a world-renowned bio-control supplier.

The agenda is available from the FNABC website: Final Agenda

This conference would not have been possible without the generous support from our industry and agency sponsors, the Organizing Committee, and several volunteers. The FNABC would like to thank all for their dedication and contributions. Thank you to all the speakers for their submitted presentations.

The next FNABC Conference and AGM will be held in September, 2026 in Prince George, BC. Please consult the FNABC website for future updates in the Spring.

David Trotter

FNABC Secretary
Email: fnabc@fnabc.com
Website: https://www.fnabc.com/

Modifications to the BCC Drying Line at the BC Tree Seed Centre

The BCC drying line at the Tree Seed Centre (TSC) is used to dry seed to a safe moisture for freezer storage following wet dewing and liquid separation for pitch removal. The drying is accomplished by spreading a thin layer of wet seed on mesh bottomed trays that slowly pass through three forced air drying chambers on a conveyor line (Figure 1).

Figure 1: BCC drying line

The desired 34°C air temperature of the chambers is achieved by passing the hot air from an electric heating element through a condensing coil that is circulating a steady stream of 10°Cwater to achieve the desired setpoint temperature.

In its original design configuration, the BCC specifications require 0.6 lps / 570.6 gph of coolant (water) cycling through its internal coil to regulate the temperature of the air being fed into the drying line. Average daily run time during production is approximately 7 hours which is roughly 15.11 m^3 / 3994.2 gallons of water per day. As supplied when the facility was built in 1986 this water was sent out of the building after a single pass through the system with no way to capture or otherwise reuse the water. Current metered water rates are \$1.34 per cubic meter which is approximately \$2.89 per hour of use. The expectation is that water rates will increase over time.

With the TSC focusing its efforts on resource conservation, reducing water consumption has been one of the facilities priorities. We have recently installed (April 2025) a Thermalcare Accuchiller (Figure 2).

Figure 2: Accuchiller

The 10-tonne water recirculation chiller is used in conjunction with the BCC drying line to reduce water usage. The Accuchiller is a scroll compressor type refrigerated recirculation chiller that is able to capture, chill, and recirculate the water used to regulate the drying line without loss. The water has now been replaced with a 30% inhibited propylene glycol / Water mixture which aids in corrosion and freezing protection. The glycol / water mixture that the system uses is stored within its internal reservoir and associated piping so it can be reused the following day. The dimensions of the unit are 87cm x 188cm x 158cm

The Accuchiller has been wired into the BCC drying line heater controls in such a way that no additional control/input from the operator is required. When the BCC system is turned on the Accuchiller will automatically start and when the system is turned off and it has completed its ramp down cycle it will automatically shut off.

While the initial goal was to reduce our water consumption, we have also found that because the coolant is being chilled to a consistent temperature the BCC drying line is now also maintaining temperature better than it had previously. While general maintenance will always be required, due to the relatively low load on the system we expect it to continue operating trouble free.

Kyle Good

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Jenji Konishi Memorial

Note: the same memorial was published in the BC Forest Professional magazine

August 9, 1937 – October 12, 2025

Jenji, youngest of four siblings, was born to Chiyoko and Kumajiro on Mayne Island. During WWII, the Konishis, and other families of Japanese descent, were dispossessed of their properties and forcibly relocated to the Interior. In 1943, the Konishis settled on a farm in Tappen where Jenji developed his love of the outdoors.

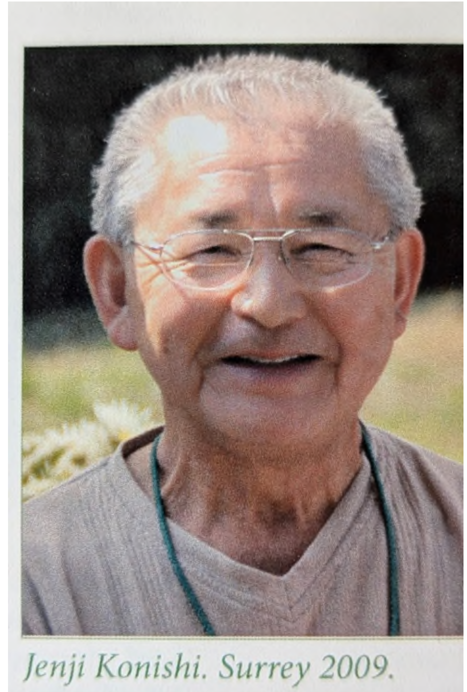
In 1961, Jenji graduated with a BScF from the University of British Columbia and was dispatched to inventory camps along the Skeena River by the BC Forest Service. In 1963, he moved to Prince George, where he married Doreen (Dori) and welcomed their children, Sandi and Jason. In 1969, they moved to Vancouver Island where Jenji served as the liaison forester for the Duncan seed extractory.

In the mid-1970s, the family moved to Brentwood Bay when Jenji assumed leadership roles in Victoria. He oversaw the establishment of several seed orchards and a new provincial tree seed centre in Surrey, completed in 1986. He was also the lead negotiator for the sale of the Ministry's seedling nurseries to PRT in 1988. He retired as Manager, Seed Services, in 1994. During his 33-year career, Jenji made significant contributions to BC's reforestation and tree improvement programs.

Family time was spent fishing, boating, camping, skating, and skiing. Road trips were not complete without Jenji abruptly pulling over and exclaiming *"check out the cone crop!"* Jenji made sushi and tempura with flair, built a smokehouse, and grew abundant produce. He also enjoyed competitive badminton and curling, and golfed well into his 80s.

Sadly, Dori passed away in 1991. Jenji was introduced to Joanne in retirement. They spent the next 30 years together building a new home, gardening, exploring, and entertaining family and friends.

Although Alzheimer's deprived him of his independence and memories, he maintained his humour and the twinkle in his eye. Joanne lovingly cared for Jenji in their home until his passing. Jenji's cedar carvings that adorn the homes of many colleagues and friends remind us of his wisdom, humility and kindness.



Jenji Konishi. Surrey 2009.

Jenji is survived by his wife, Joanne, daughter Sandi (Scott), son Jason (Donna), their respective grandchildren, many extended family, and lifelong friends.

Submitted by Sandi Arts and Brian Barber, RPF.

UPCOMING MEETINGS

Western Cone & Seed Summit May 6-8, 2026 Bend, Oregon

The **Western Cone & Seed Summit (WCSS)** is a 2.5 day event hosting practitioners spanning academia, private industry, tribal nations, non-profits, and public agencies to address the complex sourcing and supply chain of native tree seed, primarily conifers, for reforestation in Western North America**.** WCSS 2026 aims to build coalitions, share active solutions, and connect marketplaces for sustained cashflow that can weather the variability of seed production years across geographies.
Speaker and discussion themes include:

Active seed solutions- updates on successes and challenges to scaling seed supply operations.
Research, tech & genetics- assisted migration, new methods of propagation, orchard operations and more on where the science is heading.
Funding solutions- discussion around a diversified and resilient marketplace that can support skilled labor networks and small businesses involved in seed procurement. **Workforce and community engagement**- ideas and examples of training and compensation metrics for the necessary workforce including the integration of rural communities into roles across the reforestation pipeline.
For event updates and registration, please email felicia@radseedsolutions.com.

North American Forest Genetics Society

3rd Biennial Meeting June 15th-19th 2026, Quebec City, Canada2026

Connecting Research Across Scales and Disciplines to Uncover Species' Evolutionary Potential and Strengthen Forest Resilience.

NAFGS 2026 Conference

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