“Designing successful forest renewal practices for our changing climate: The Mother Tree Project” - Project update

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We sincerely thank all of the people who have worked with us since October of 2015 to get the Mother Tree Project off the ground. We would like to share with everyone what we have accomplished so far as a group.

Fig 1. Mother trees at the Venables site.

Objectives

This is a long-term silviculture systems experiment, studying management of Douglas-fir forests, primarily in interior British Columbia (BC). We are investigating above- and below-ground responses to silviculture systems that retain varying proportions of big old “Mother Trees” and smaller trees, across a broad climatic gradient. We are regenerating the cut areas with a range of local and migrated tree provenances. Our eperimental design is based on a “space-for-time” theory, where the range of current responses across regional climates is used as a proxy for predicting responses with climate change over time. The treatment responses we are studying include stand productivity, dynamics and structure, carbon storage, biodiversity, mycorrhizal networks, wildlife habitat and use, and fire risk. We are working with First Nations at one of the sites to include their perspectives regarding management of Douglas-fir forests.

The project is unique to BC because of its large scale and replication across a broad climate gradient. Our overall goal is to provide scientific data to help direct management of Douglas-fir forests under a changing climate.

Site selection and experimental design

In 2016-2018, eight research locations were selected in the BC interior and one was chosen on the coast (Fig. 2). The interior locations span the climatic range of Interior Douglas-fir in BC, from south of Cranbrook to Ft St James. The coastal location has a much wetter climate, and here coastal Douglas-fir occurs.

Three replicate sites were selected at seven of the locations, and one replicate at two locations (total 23 sites) (Table 1). Each of the 23 sites encompasses 20-25 ha divided into five treatment units (4-5 ha each). The treatments (silviculture systems) cover a gradient of forest retention, from removal of all trees (clearcutting), to single tree retention, retention of 30% of the area in uncut patches, retention of 60% of the area in thinned patches, to an uncut control.

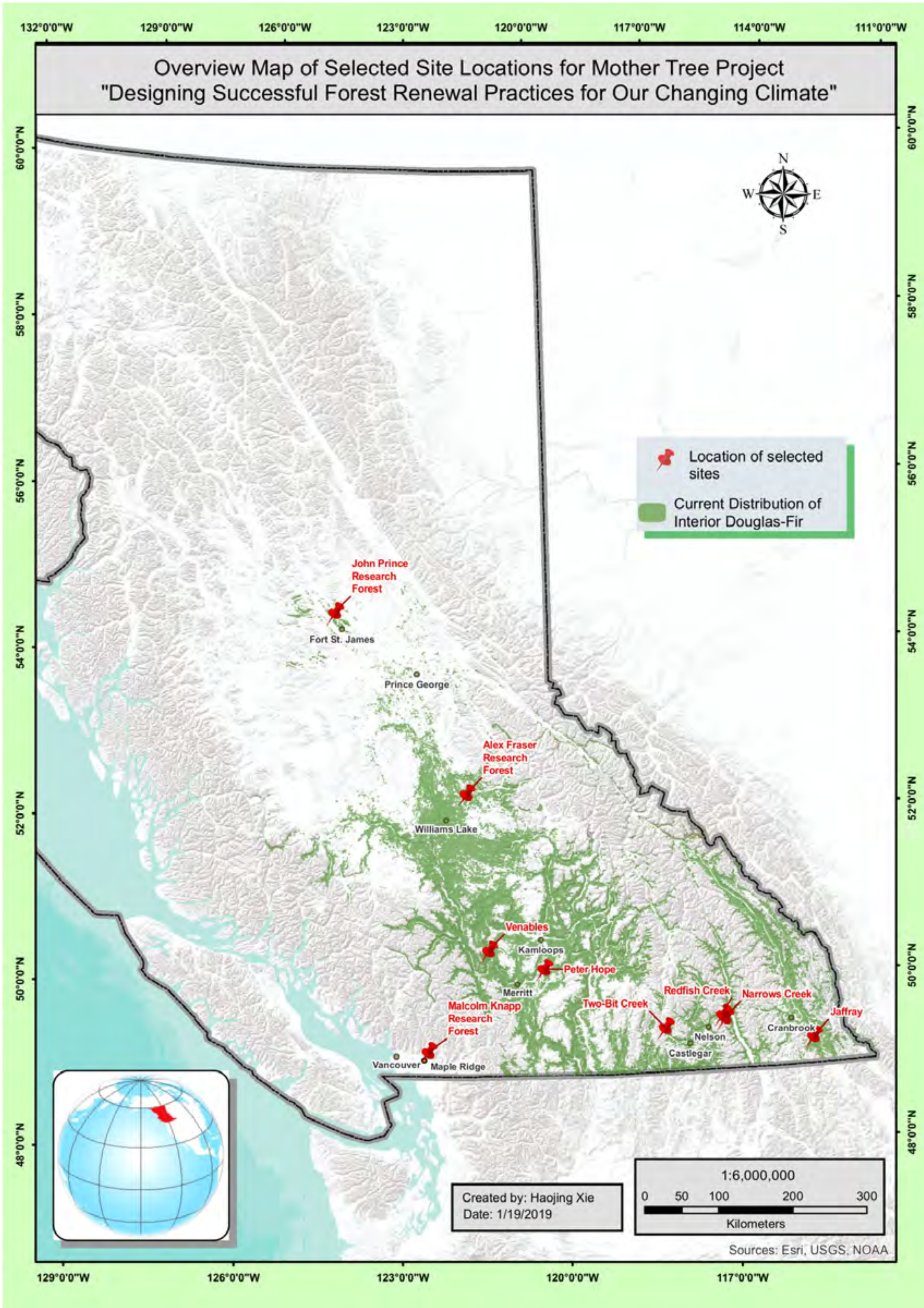

Fig. 2. Map of the study locations, showing the current distribution of Interior Douglas-fir in BC.

Site characteristics

Table 1 lists partners, treatments, geographic, ecological and climatic characteristics of the study locations. For an illustration of what the sites looked like before logging, see Figures 3-11, keeping in mind that Douglas-fir forests are naturally variable.

The interior sites are in the Interior Douglas-fir (IDF), Interior Cedar-Hemlock (ICH), and Sub-Boreal Spruce (SBS) biogeoclimatic zones and the coastal one is in the Coastal Western Hemlock (CWH) zone. The selected sites are circum-mesic and before logging were occupied by mature Douglas-fir with varying components of other species.

Fig. 3. Jaffray. Moderate-sized Douglas-fir with a minor western larch component, sparse understory regeneration and a pinegrass-dominated plant layer.

Fig 4. Venables. Multi-layered pure Douglas-fir dominated plant layer.

Fig. 5. Peterhope Lake. Multi-layered nearly pure Douglas-fir.

Fig. 6. Two-bit Creek. Moderately dense Douglas-fir with a typically well developed understory plant layer.

Fig. 7. Redfish Creek. Douglas-fir mixed with western redcedar and other species; cedar regeneration and patchy understory plants.

Fig. 8. Narrows Creek. Dense Douglas-fir, western redcedar, western hemlock, and western larch with sparse understory trees and plants.

Fig. 9. Alex Fraser (ICH replicate). Douglas-fir with minor spruce component, understory subalpine fir and a lush plant layer.

Fig. 10. John Prince. Douglas-fir with a minor spruce component and patchy understory subalpine fir and plants.

Fig 11. Malcolm Knapp. Douglas-fir western redcedar, and western hemlock with sparse understory trees and plants.

Harvesting

Logging has been completed at six of the nine locations and is planned for late 2019 at the other three. Leave trees and residual patches were marked out prior to harvest. Figures 12 to 15 illustrate the four silviculture systems at the John Prince site.

Fig. 12. Clearcut.

Fig. 13, Single tree retention.

Fig 14. 30% group retention.

Fig 15. 60% retention with thinning.

Planting

In spring 2018 we planted the inner 1-ha of each of the treatment units (except the controls) at Jaffray, John Prince and Redfish. The owners of the cutting permits are planting the balance of the treatment units. Planting was done by Brinkman & Associates Reforestation with a crew of six planters each carrying one or two seedlots (total 10 seedlots per location) which were planted in an intimate mixture at 2.5 m spacing. The planting took 3-4 days at each location. Species planted were Douglas-fir (local A and B class seedlots plus five migrated provenances per site), and western larch, ponderosa pine and lodgepole pine. The planters installed colour-coded tags to identify the provenance of each seedling. A sample of seedlings of each provenance was measured for height and diameter at planting. On the coast we planted a mixure of Douglas-fir, western white pine, western red cedar, spruce and amabilis fir in spring 2019. The five remaining sites will be planted in spring 2020. In summer 2019 we conducted a preliminary assessment of seedling survival by provenance at the three interior sites. In 2020-21 we will conduct a detailed assessment of survival, condition and growth of the planted seedlings at each of the nine sites. Density of natural regeneration that established after logging will also be evaluated.

Data collection and research studies

So far most of the research on the Mother Tree sites has been conducted by university scientists and students, Some of the main research studies are described below.

National Forest Inventory plots

Field data was collected in 2017-2019 using the National Forest Inventory (NFI) ground sampling guidelines (CFIC and CFS 2008) to calculate a carbon budget for the forest ecosystems before and after logging, as well as to document stand characteristics, productivity and biodiversity.

The 0.04 ha (r=11.28 m) NFI plots are located at the centre of each 4-5 ha treatment unit. A total of 113 plots were established and measured pre-harvest. Post-logging measurements are complete at six of the nine locations with the remainder scheduled for 2020. Future re-measurements are planned for two and five years post-logging, then every 10-20 years thereafter throughout the stand rotation.

Each live and dead tree $\geq$ 9 cm DBH (diameter 1.3 m above ground level) occurring within the 0.04 ha plot was tagged at the base and stem mapped. Species, DBH, height, height to live crown, crown class, damage and wildlife attributes were recorded for each tree. The age of dominant Douglas-fir and other major species were counted on increment cores for determination of site index. Trees and shrubs > 1.3 m tall and <9.0 cm DBH were measured within a circular 50 m^2 plot (r = 3.99 m), nested within the 0.04 ha plot.

All pieces of coarse woody debris (CWD) (>7.5 cm diameter) were measured along two perpendicular 30-m line transects intersecting each other at the NFI plot center. Species, decay class, diameter, and tilt angle were recorded for each piece. The number of pieces of small woody debris (1-7.5 cm diameter) was counted on a 10-m section of each CWD line transect.

Forest floor depth and substrate type were recorded every 2 m along each 30-m CWD transect.

Figure 16. Sampling forest floor along the CWD transect.

Fig. 17. Microplot sampling. The plants, fine woody debris, forest floor, and two layers of mineral soil have been collected.

One circular 1 m^2 (r=0.56 m) microplot was established at each end of the 30 m transects (total four microplots per NFI plot). Within each microplot, a 20 x 20 cm sample of forest floor extending from the ground surface to the mineral soil interface was collected. Samples were oven dried and weighed in the lab and analyzed for percent carbon and nitrogen content. All bryoids, herbs, trees/shrubs <u><</u>1.3 m in height, and fine woody debris (<1 cm diameter) were collected from the microplots, oven-dried and weighed.

Mineral soil was collected from the microplots in approximately 10-cm diameter holes at depths of 0-15 cm, 15-35 cm and 35-55 cm. The volume of each sample was measured in the field by lining the excavated holes with plastic and using a graduated cylinder to measure the volume of water that filled the hole. The mineral soil samples were oven-dried, weighed, and percent carbon and nitrogen was determined.

Vegetation was assessed using two plot sizes (r=5.64 m and r=10.0 m), nested within the 0.04 ha plots. Species and percent cover of all herb, bryoid and seedling germinants occurring within the smaller plot were recorded. Percent cover of each tree and shrub species by height class (>10 m; 2-10 m; and < 2 m) were estimated within the larger plot.

Elevation, slope, aspect, slope position, and other physiographic features were recorded at each NFI plot. A soil pit (≥ 60cm depth where possible) was dug just outside of each NFI plot boundary. Mineral soil horizons were classified and evaluated for soil texture and coarse fragment content, and the mineral soil and forest floor were classified to Order. Biogeoclimatic variant was determined from field maps ((https://www.for.gov.bc.ca/hre/becweb/resources/maps/FieldMaps.html and soil moisture regime, nutrient status and site series were estimated based on vegetation, soils, and site features.

Carbon stored in each pool (Mg ha^{-1}) (above- and below-ground live and dead trees, woody debris, stumps, forest floor, mineral soil, and understory plants) was calculated using methods developed by the Canadian Forest Service. Tree and plant biodiversity were calculated using richness (number of species) and Shannon's diversity index. Productivity was estimated using site index (height at a reference age of 50 years) by inputting age at DBH and height for individual trees into SiteTools ver. 4.1b [BCMOF 2017].

Results from the NFI plot data will be available in late 2019 in two journal articles and a technical report. The first article will document trends in pre-logging productivity, carbon storage and biodiversity across the climate gradient. The second article will describe harvesting effects on the magnitude and distribution of carbon within ecosystems across the climate gradient,

Fire risk

We are conducting Fire Risk assessments for each of the treatment units following harvesting to evaluate how it varies across the climate gradient and with silviculture system. Fire Risk data will be summarized in late Fall of 2019.

First Nations

At the Venables site situated near Spences Bridge we are engaging with Cooks Ferry Indian Band to include their perspectives on Interior Douglas-fir management, particularly in regard to Mother Trees. We are planning a workshop with them for Fall 2019 and will be prepare a report on this part of the project in late Fall of 2019.

Website

We are excited to have a website for the Mother Tree Project in the works. It will be available to the public in late Fall 2019.

Documentary film

We are making a documentary film describing the project which will be posted on the website once we have approval from our funding source, the Forest Enhancement Society of BC.

Workshop

We are planning to have a field workshop at one of the centrally located sites in Fall of 2019.

Graduate student projects

The Mice to Moose Wildlife Project is **Alexia Constantinou**'s MSc focus at UBC. She is using a combination of wildlife cameras and live small mammal trapping to evaluate the effect of logging treatments on terrestrial mammal diversity and ranges.

Fig.18. Alexia checking a wildlife camera in the winter.

Wildlife cameras have been installed in each treatment unit at three of the Mother Tree sites: Jaffray, Alex Fraser Research Forest, and John Prince Research Forest. So far, the cameras have captured a wide range of species at all different life stages, and particularly exciting are photos of cubs and fawns in the spring. Alexia is also working on engaging with the local First Nations. She will be preparing a report of preliminary findings in the Fall of 2019, with full results available when she completes her degree.

Fig. 19 Image captured by a wildlife camera at Jaffray.

Joseph Cooper (M.Sc. candidate, University of Alberta) is investigating how ectomycorrhizal species turnover behaves across the latitudinal range of Interior Douglas-fir. His four sites cover a north-south expanse of over 1,500 km, with our John Prince site being the most northerly one. His objectives are to determine below-ground ectomycorrhizal diversity across the latitudinal gradient, and assess how ectomycorrhizal community turnover alters with latitude, tree age, and climate.

Jessica's Fosteved's (University of Reading, England) M.Sc. project, completed in 2017, was titled "Mycorrhizal community influence on understory seedling regeneration in the interior Douglas-fir forests of British Columbia". She investigated the ectomycorrhizal fungal community associated with established Douglas-fir seedlings (approximately 5 years old) at the Redfish and Twobit Creek sites. Wildfires in 2017 prevented Jessica from working at other sites. Naturally regenerated seedlings were completely harvested from each replicate site at Redfish and Twobit. The fungal colonization of each root tip was identified to the genus level. Seedling biomass and site ecological data were recorded. Fungal communities exhibited diverse function, with a few morphotypes unique to each site and many common species also present. Short range exploration types dominated the plots at the drier site, whereas medium range exploration types were correlated with wetter conditions Seedlings produced more biomass at locations with higher fungal biodiversity and more conspecific adult trees.

Camille Defrenne (University of British Columbia) completed a Ph.D. project in 2019 that was motivated by the need to improve our functional understanding of fine roots and their associated mycorrhizal symbionts in natural ecosystems. Fine roots and ectomycorrhizal root tips were collected across a climate gradient (five regions) in three naturally regenerated, mature, closed-canopy forest stands per region. The five regions were selected to obtain a large biogeographic gradient of precipitation and temperature. A combination of morphological and molecular analyses of Douglas-fir fine roots and ectomycorrhizal fungi was used to address two research gaps: (i) identify within-species fine-root and mycorrhizal fungal trait-environments linkages and (ii) link fine-root and mycorrhizal fungal functional traits. Camille found substantial within population root trait variation which may enable root acclimation at the stand level. However, she also identified moderate but consistent trait-environment linkages across populations of Douglas-fir, and provided evidence for independent variations in fine-root morphological and chemical traits. The results highlight the existence of multiple axes of within species fine-root adjustments that were consistent with a potential increase in fine roots acquisitive capacity in harsher environments. In addition, she found temperature, precipitation and soil C:N ratio affected ectomycorrhizal communities and functional traits but had no effect on fungal richness and diversity. This project advances our knowledge of plant-mediated below-ground processes and should foster incorporation of below-ground ecology into terrestrial biosphere models which is key to predict plant persistence and resilience in the face of environmental change

Monika Gorzalek completed her Ph.D. project at the University of British Columbia in 2017. Her overall objective was to determine whether Douglas-fir would preferentially transfer carbon and/or nitrogen through mycorrhizal networks to kin over strangers in response to herbivory treatment. Using seedlings with and without access to a mycorrhizal network (restricted or permitted via mesh of two pore sizes), stable isotope probing was used to track carbon and nitrogen in the system. One seedling of a pair was designated as the 'donor' and defoliated immediately prior to photosynthesizing with 99%-13C-CO2 as well as pulse-labelling with 99%-15N ammonium nitrate. Both a greenhouse and field experiment were performed to corroborate results. Transfer was determined by measuring 13C and 13N in tissues (needle, stem, root) of kin and stranger seedlings. Carbon was transferred through the mycorrhizal network with significantly more carbon transferred to kin than strangers. Herbivory (in the form of western spruce budworm defoliation and manual defoliation) induced transfer of carbon to kin over strangers. Douglas-fir families differed in their tendency to transfer carbon and nitrogen to kin. Molecules potentially involved in defense signaling were identified using liquid chromatography coupled with mass spectroscopy. Ectomycorrhizal fungi that can form mycorrhizal networks were found on all seedlings. She concluded that preferential carbon transfer through mycorrhizal networks occurs between kin in Douglas-fir and is amplified by herbivory stress. Herbivory is not necessary for transfer, as some transfer also occurred in the no-herbivory treatment.

Amanda Asay will complete her Ph.D. degree at the University of British Columbia in the fall of 2019. Her research was conducted to further understanding of positive interactions between plants, which in addition to competition, can help shape a plant community and ecosystem. Her project focused on potential influences on the processes of kin recognition and selection including seedling density, soil (mycorrhizal) inoculum potential and species-specific community composition. When seedlings were grown in pots with limited resources, she found that increasing the density and reducing the mycorrhizal potential both created environments where kin seedlings behaved in a more similar manner to strangers. When grown in the field, seedlings required a greater density for a kin/stranger differential response to be detected. Keeping density consistent but changing community composition resulted in cooperative behaviours in kin seedlings when they were grown solely with other kin. When heterospecific or stranger conspecific neighbours were present, more competitive behaviour and lower overall growth resulted. The results could have important forest management implications, particularly surrounding the concepts of legacy trees and natural regeneration of the locally adapted seed they produce, maintaining access to mycorrhizal associations and networks and the potential for family substructuring. Kin relationship considerations may be particularly important in harsh climates or at the leading edge of the range of Douglas-fir, which is expected to move northward and upward as the climate shifts.

What is coming up

Our website, which will be up and running in late Fall 2019, will be the place to find information about the Mother Tree Project. Two journal articles, several reports and our documentary film will be accessible through links on the website. Information about other developing, ongoing and completed work will also be available

Research signs have been erected at the Peterhope site and we plan to install signs at other sites this year.

We are in the process of applying for an EP no. to ensure that the Mother Tree sites are reserved for long-term research.

In September 2019 we were fortunate to receive a Forest Carbon Initiative grant to measure carbon stocks two years post-logging, including in deep mineral soil layers (up to 1 m). The grant will also allow us to conduct a detailed assessment of planted and natural regeneration at each site.

References

[BCMOF & BCMOE] British Columbia Ministry of Forests and Range and British Columbia Ministry of Environment. 2010. Field manual for describing terrestrial ecosystems. 2nd Ed. Forest Science Program, Victoria, B.C. Land

Manage. Handb. No. 25. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/LMH25-2.htm

[BCMOF] British Columbia Ministry of Forests. 2017. SiteTools vers, 4.0 beta. Forest Inventory and Analysis Branch, Victoria, B.C.

CFIC and CFS] Canadian Forest Inventory Committee and Canadian Forest Service. 2008. Canada's National Forest Inventory: Ground Sampling Guidelines. Version 5.0. Ottawa. http://www.worldcat.org/title/canadas-national-forest-inventory-ground-sampling-guidelines/oclc/606580128

Wang, T., Hamann, A., Spittlehouse, D. and C. Carroll. 2016. Locally downscaled and spatially customizable climate data for historical and future periods for North America. PLoS ONE 11(6): e0156720. https://doi.org/10.1371/journal.pone.0156720

Project participants

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Alex Fraser Research Forest
Malcolm Knapp Research Forest
John Prince Research Forest
Harrop-Procter Community Forest
BC Timber Sales, Cascades District
BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development
Canadian Forest Service
Canadian Forest Products Ltd
Aspen Planers Ltd
International Forest Products Ltd
Kalesnikoff Lumber Co. Ltd
Brinkman and Associates Reforestation Ltd
PRT Nurseries
Roserim Nursery
Graduate and undergraduate students

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Photo credits

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Table 1. Partners, treatment and measurement history, geographic, site, and climatic characteristics of the nine study locations, arranged in order of highest to lowest aridity.

Location name	Venables	Two-bit Creek	Peterhope Lake	Jaffray	Redfish Creek	Alex Fraser	John Prince	Narrows Creek	Malcolm Knapp
Partner	Aspen Planers/ Cooks Ferry Band	Interfor	BC Timber Sales Cascades	Canfor	Kalesnikoff Lumber	Alex Fraser Research Forest	John Prince Research Forest	Harrop-Procter Community Forest	Malcolm Knapp Research Forest
Logging date	TBD	Winter 2019/20	Fall 2019	June 2017	June 2017	Nov 2018	Jan-Mar 2018	Oct 2018	Jan 2018
Planting date	2020	2020	2020	May 2018	June 2018	2020	June 2018	2020	April 2019
Year of pre-logging NFI plots	2018	2017	2018	2017	2017	2018	2017	2018	2017
Year of post-logging NFI plots	2020	2020	2020	2018	2018	2019	2018	2019	2018
No. of replicates	3	1	3	3	3	3	3	1	3
No. of plots	14	5	14	15	15	15	15	5	15
Geographic variables									
Nearby town	Cache Creek	Castlegar	Merritt	Cranbrook	Nelson	Williams Lk	Ft St James	Nelson	Maple Ridge
Forest Region[a]	TO	KB	TO	KB	KB	C	O	KB	SC
Latitude (°N)	50.54	49.52	50.32	49.21	49.63	52.45	54.65	49.58	49.32
Longitude (°W)	121.37	118.10	120.32	115.37	117.03	121.75	124.43	116.98	122.54
Site variables									
Average elevation (m)	1280	620	1100	1075	850	950	880	1080	540
Dominant aspect	SE, W	W	variable	S	SE	SE	S	W	S, W
Average slope gradient (%)	20	15	15	5	30	10	15	30	20
Slope position	mid	mid	mid	mid	mid	mid	mid	mid	mid
Dominant soil order[b]	L	P	L,B	L	P	L	L	P	P
Soil texture[c]	SCL	SL, L	SiL, L	SiL, SiCL	SL	CL, L	(gr) CL	SL, SiL	SL, SiL
Biogeoclimatic variant	IDFdk1	ICHdw1	IDFxh2, IDFdk1	IDFdm2	ICHdw1	IDFdk3 ICHmk3 SBSdw1	SBSdw3	ICHdw1	CWHvm1
Site series	01/04	101/104	01/04	01	101/104	01	01	101/104	01/03
Climate data[d]									
MAT (°C)	3.5	7.7	4.1	5.3	6.8	4.4	2.3	5.1	8.0
MWMT (°C)	15.0	18.9	15.1	17.0	17.6	15.4	13.9	16.0	16.1
MAP (mm)	403	653	398	618	868	532	593	1059	2701
MSP (mm)	166	227	186	249	268	256	240	313	655
SHM	87.6	83.0	80.7	68.2	66.1	61.1	57.7	51.4	24.5
AHM	36.5	27.2	36.0	24.7	19.4	27.3	20.8	14.3	6.6

a KB = Kootenay-Boundary; TO = Thompson-Okanagan; C = Cariboo; O = Omineca; SC = South Coast
b L = Luvisol; P = Podzol; B = Brunisol
c SiL = silt loam; SiCL = silt clay loam; SL = sandy loam; SCL = sandy clay loam, CL = clay loam, L = loam
d Climate data are 1981-2010 averages derived from ClimateNA v5.50 based on latitude, longitude and elevation (Wang et al. 2016). MAT = Mean annual temperature; MWMT = Mean warmest month temperature; MAP = Mean annual precipitation; MSP = May–September precipitation; SHM = Summer heat: moisture index = (MWMT)/(MSP/1000); AHM = Annual heat: moisture index = MAT+10)/(MAP/1000)