The Provincial Monitoring Program –

Change Monitoring Inventory (CMI) data in the Cariboo Region

Ministry staff determining status of Change Monitoring Inventory plots after the 2017 wildfires.

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Forest Analysis and Inventory Branch

BRITISH COLUMBIA

Ministry of Forests, Lands, Natural Resource Operations and Rural Development

Summary

The Provincial Monitoring Program provides critical information on the current status of forest characteristics and how they change over time. This program fulfills the Provincial requirement to monitor landscape change and provides flexible data that can address a variety of topics. The Provincial Monitoring Program consists of three sampling initiatives, employing three different (but largely compatible) sample types, including the Provincial Change Monitoring Inventory (CMI), Provincial Young Stand Monitoring (YSM) and National Forest Inventory (NFI). All samples are systematically located on a grid. These fixed-radius plots are measured at regular time intervals using well-known sampling methods. Data are collected by certified contractors with quality assurance checks conducted by Ministry staff on a randomly selected 10% of the plots in each contract. Detailed sampling protocols and a design framework for these plot types exist elsewhere[1] so will not be duplicated here. All data are available to anyone upon request, with work being done on creating an interactive mapping tool with data download functionality.

This report provides an overview of the Provincial Monitoring Program, describes how it fits with other Provincial Inventory programs, summarizes program status and implementation, briefly describes sampling procedures, and finally demonstrates the data available from CMI plots in the Cariboo Region.

[1] https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/stewardship/forest-analysis-inventory/ground-sample-inventories/provincial-monitoring/provincial_cmi_and_ysm_sampling_framework_20180616.pdf

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Background

Forest Inventory Section Mission[2]

> "*To produce reliable forest inventories and stand growth models so that natural resource management in British Columbia is informed by credible information on forest condition*"

The Inventory Section is vital to attain MFLNRORD's commitment towards sustainable forest management, supporting management decisions that will, in turn, support strong rural economies that depend on forest resource jobs. The Inventory Section of the Forest Analysis and Inventory Branch (FAIB) has multiple integrated programs that each contributes unique data at multiple spatial scales to fulfill the Inventory Section's mission. The Provincial Monitoring Program collects data enabling change monitoring, which until recently, was not possible. These data also support other Inventory Programs by providing information used to validate spatial inventory data and by providing an independent dataset to allow for model verification. These data can also be used to address emerging issues such as mountain pine beetle[3], climate change, carbon accounting[4] and wildfire.

Before the Provincial Monitoring Program, change in forest characteristics was estimated by photo interpreted forest inventories from one time to another; however, this is not a one-to-one comparison of change because polygon delineations shift over time. The preferred method for long-term monitoring of forest characteristics is to collect data from a simple, self-weighting sample employing fixed-area plots with tagged trees[5]. In BC, this is the Provincial Monitoring Program that includes three related plot types that have similar objectives and sample design – National Forest Inventory (NFI), Change Monitoring Inventory (CMI), and Young Stand Monitoring (YSM) plots. All the plots included in the Provincial Monitoring Program are located on the 20 by 20 km National Forest Inventory (NFI) grid, or an intensification of the NFI grid, with the objective of monitoring change on the landscape over time.

The Ministry of Forests, Lands, Natural Resource Operations, and Rural Development has been working towards a Provincial Monitoring Program since the late 1990's. Sampling on the 20 by 20 km grid was started in mid-2000s to support the development of Canada's NFI efforts[3]. This national standard sampling grid is the basis of the Provincial Monitoring Program. However, there are only 268 NFI plots across the province representing a small sub-set (11%) of the 2,391

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[2] FAIB. 2013. Forest inventory strategic plan. MFLNRO-FAIB. Victoria. 8p.

[3] Penner and Omule. 2012. Mountain Pine Beetle Impact Analysis Using CMI Data. Forest Analysis and Inventory Branch. Ministry of Forests, Lands and Natural Resource Operations.

[4] Forest Analysis and Inventory Branch. Why We Need to Monitor Change In Our Managed Forests. BC Ministry of Forest, Mines and Lands. Victoria, BC. January 5, 2011.

[5] Status of British Columbia's Provincial Forest Inventory. June 2015. Ministry of Forests, Lands and Natural Resource Operations.

total possible 20 km grid points. In 2013, FAIB began establishing Provincial Change Monitoring Inventory (CMI) plots on each 20 by 20 km grid point to strengthen information on forest characteristics and to provide 100% provincial coverage. To provide more information on the state and growth of young stands, sampling on an intensification of the 20 km grid is being conducted with Young Stand Monitoring (YSM) plots. Typically, YSM plots are on a 10 km by 5 km grid and include stands that are between 15 and 50 years of age as defined by the spatial VRI coverage.

The main strengths of the Provincial Monitoring Program include:

1. Standard un-biased plot location provides scientifically-sound data collection over the entire province.
2. Intensity of sampling can be scaled up or down as needed in relation to the 20 km grid.
3. Simple, repeatable and durable plot locations ensure long-term truly-permanent plots.
4. Truly-permanent plots allow for change monitoring over time regardless of what changes occur to that forest (logging, fire, insect damage, road construction, etc.).
5. Methods are standardized provincially, nationally and internationally.
6. Robust dataset enables flexible and timely ground-based information for a wide range of applications such as climate change, forest health, and regeneration dynamics.

It is important here to highlight that the Provincial Monitoring Program is different from Industry established plots that focused on monitoring change in post harvest regenerated stands within each operating area/tree farm licence (TFL). Industry established monitoring programs all vary in grid size so that a target sample size was achieved within an area of interest. In contrast, the Provincial Monitoring Program uses a standardized grid across the whole province in all stand types.

Integration and Data Uses

The Provincial Monitoring Program is integrated within the Forest Inventory Section by contributing to the Vegetation Resource Inventory (VRI), LiDAR Enhanced Forest Inventory, and Growth-and-Yield Modeling efforts. The data collected by the Provincial Monitoring Program is also used by a range of stakeholders to address current topics of interest.

Provincial Monitoring Plots are used by FAIB to verify photo and LiDAR estimations of forest attributes. Strategic-level information on forest cover is provided by Vegetation Resource Inventory (VRI) program through photo interpretation of stand-level forest attributes[6]. Historically, photo estimations of forest attributes were audited and adjusted using temporary

plots consisting of a 5-point cluster plot design with probability proportional to size with replacement (PPSWR) plot location. These VRI plots are efficient at capturing stand volume and species composition, and heterogeneity, but are designed to be temporary plots. Increasingly, fixed-radius monitoring plots located on the grid are also being used to audit photo estimations while also contributing to monitoring forest dynamics[7].

Where LiDAR data is available, spatial forest inventories are now being enhanced to increase accuracy and resolution primarily on canopy height and canopy closure with estimates of volume, basal area and density also possible. Monitoring plots have been used in the calibration and validation process of LiDAR based tree attribute estimation; however, additional subjectively-located plots are also being established in order to cover the range of all forest types in the area covered by LiDAR data.

Provincial Monitoring Program plots can be used as an independent data source to verify growth-and-yield models. Growth-and-yield models were built and validated using data collected from the Permanent Sample Plot (PSP) program. Plots in the PSP program are subjectively located in a wide range of ecosystem conditions to enable modeling of these conditions[8]. Monitoring plots could be used as an independent data source to validate growth-and-yield models that were developed using PSP data. For example, CMI and YSM data have been used to demonstrate the accuracy of Growth and Yield predictions for timber supply review (TSR)[9].

Program Status and Implementation

As of December 2019, there are 173 NFI plots (Figure 1), 660 CMI plots (Figure 1) and 764 YSM plots (Figure 2). There have been re-measurements of 144 NFI plots and 268 YSM plots.

Total number of intersections on the 20 km grid over the entire province is 2391 (this is the maximum possible number CMI plots). Approximately 33% of these points (797 plots) are, and will continue to be, 'photo plots' as they fall on non-treed land (inland water, ice, rock, grasslands, or snow), private land, First Nations Lands, or parks. Therefore, 66% of the points (1594 plots) are, and will be, measured on the ground. With a 10-year re-measurement cycle, an average of 160 CMI ground plots will be measured per year on the 20km grid. This is a

[7] https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/stewardship/forest-analysis-inventory/ground-sample-inventories/100mhtsa_kamloopstsa_yms_vrivpip.pdf

[8] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-inventory/ground-sample-inventories/permanent-sample-plot

[9] Penner and Omule. 2012. Change Monitoring Analysis Using CMI Data. Forest Analysis and Inventory Branch. Ministry of Forests, Lands and Natural Resource Operations.

realistic number to re-measure annually and is comparable to the number of PSPs that are measured annually.

Fewer Provincial CMI plots might be required in the north of the province because of the limited access and activity. One possibility in the north is to use a 40km grid in certain TSAs, which would reduce the number of plots by approximately 75% (Table 1). The number of ground plots might be further lowered in the north due to a higher percentage of photo plots because of extensive areas covered by mountains, snow and ice.

Table 1. Number of grid points by TSA using a 20km grid and a 40km grid.

TSA	20km Grid Points	40km Grid Points
Cassiar TSA	327	82
Fort Nelson TSA	249	63
Nass TSA	45	12

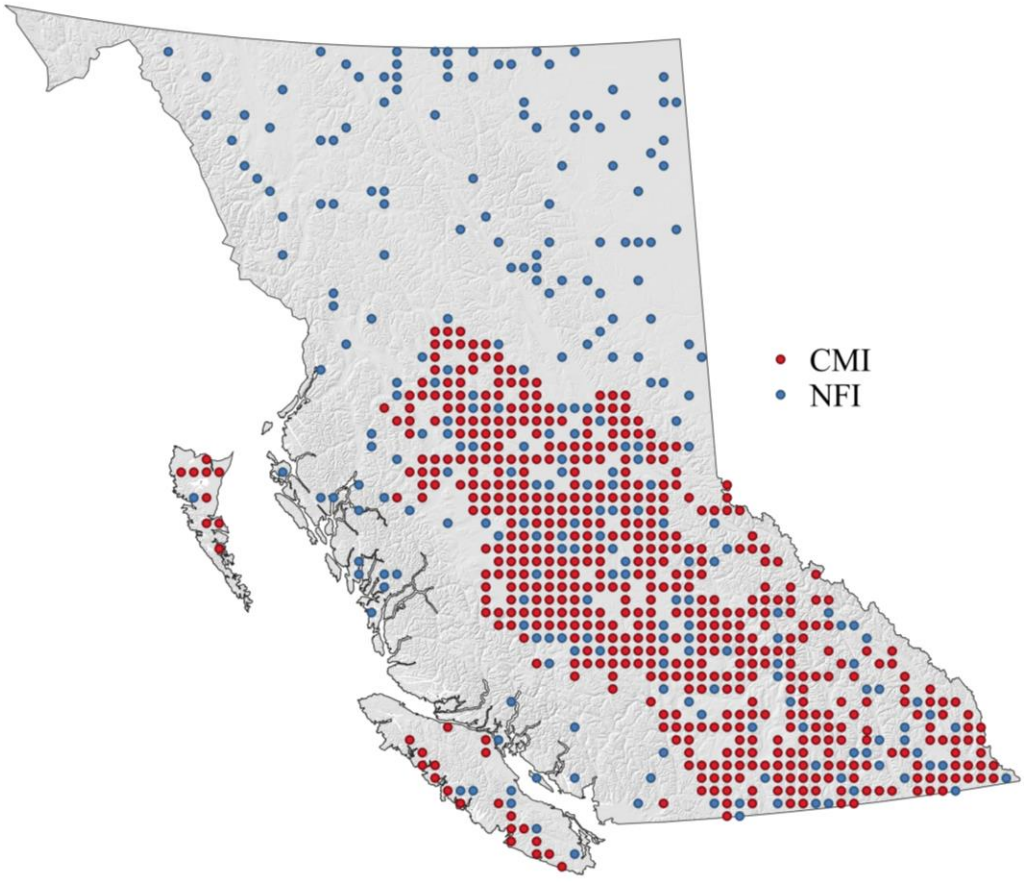

Figure 1. National Forest Inventory (NFI) Provincial Change Monitoring Inventory (CMI) plots established on the 20 km grid points as of 23 October 2018.

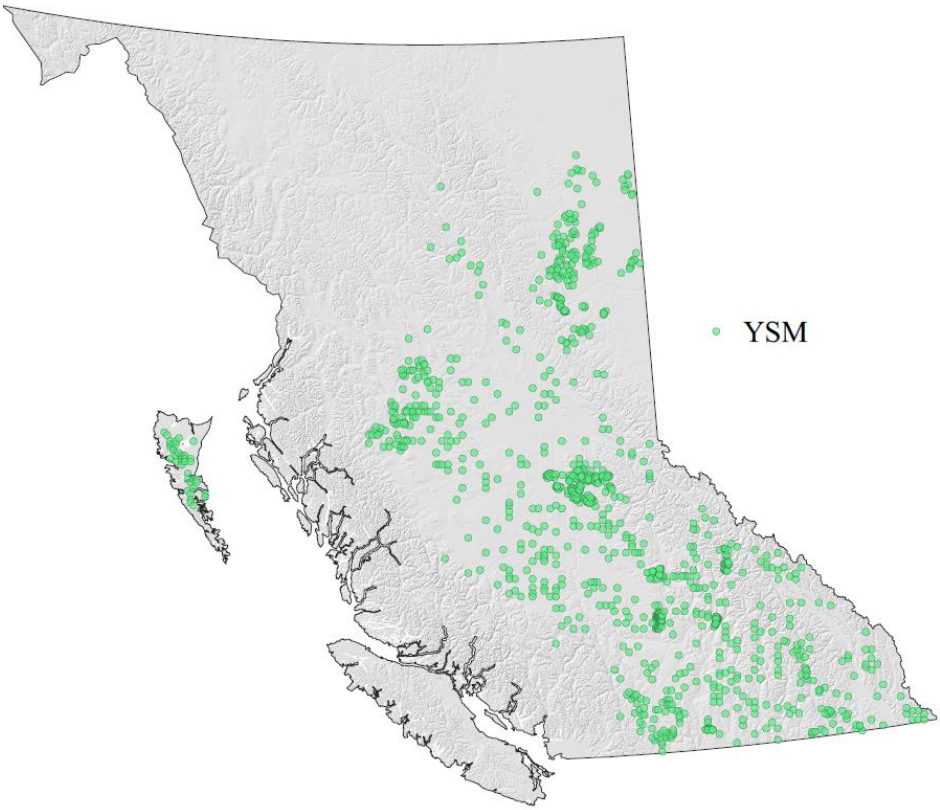

Figure 2. Provincial Young Stand Monitoring (YSM) plots established on an intensification of the 20 km grid as of 23 October 2018.

Sampling Procedures

The target population for CMI data collection is the entire province (land and inland waters). Grid points are sampled with either a photo plot or a ground plot (described above). The targeted sampling frequency for CMI is 10-12 years[10]. Sampling occurs within nested fixed-radius circular plots. The main plot is 11.28m in radius where trees greater than 9cm dbh are measured with a nested subplot of 5.64m in radius where trees greater than or equal to 4cm dbh are measured. Measured trees are tagged and details are collected on species, height, crown class, dbh, damage type, damage severity, wildlife use, and loss factors. Tree age is determined by coring site trees of all major species (>20% basal area) and counting growth rings under a microscope in the office. All tagged trees are stem mapped with cardinal directions and distances from plot centre (Figure 3). There is also a small tree plot of 2.5m radius where all trees smaller than 4 cm dbh are tallied by species, and stumps are tallied and given a decay class. Detailed establishment procedures and methodology for data collection is

[10] Omule, A. Y. 2013. A framework for implementing Young Stand Monitoring in British Columbia: a discussion paper. Contract report to MFLNRO-FAIB, November 2013. 47p.

provided in the Change Monitoring Inventory – British Columbia: Ground Sampling Procedures document[11]. Refer to the Ground Sample Inventories webpage for more resources.

Quality assurance

Data are collected by qualified independent contractors and Quality Assurance is carried out by Ministry employees who randomly select 10% of the plots in each contract to re-measure. Values collected by contractors and Ministry employees must be within defined thresholds of accuracy for each variable for the data to be included in the database. If the plot fails to pass the Quality Assurance procedure, then it must be re-done and another check from Ministry employees conducted.

Data access

The data collected by the BC Inventory Section on ground samples is freely available. To access the ground sampling data, please check the website.

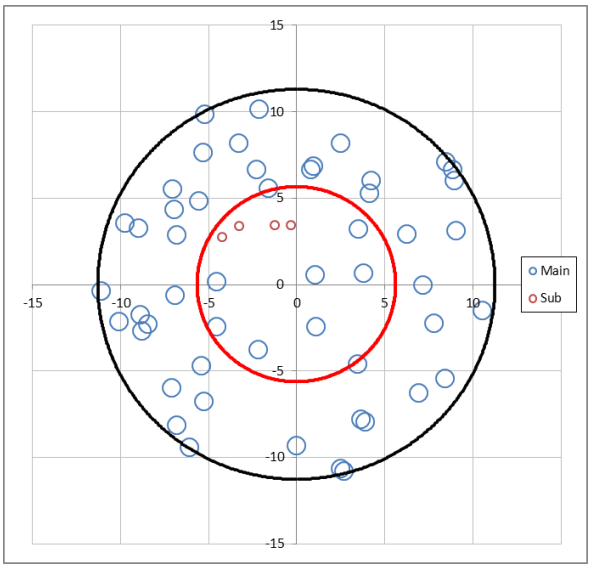

Figure 3. Image of stem mapped trees in the main plot and sub plot.

[11] https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/stewardship/forest-analysis-inventory/ground-sample-inventories/provincial-monitoring/standards/cmi_ground_sampling_procedures_2017.pdf

Change Monitoring Inventory (CMI) in the Cariboo Region Case Study

The goal of this case study is to display a range of variables available from CMI plots that might be useful to a variety of data users. The Cariboo Region was selected as a case study location because it was the first region to establish CMI plots on the 20 km grid. There are 208 plots in this region, of which, 81% (169 plots) are ground plots and 19% (39 plots) are 'photo plots' (described above).

Using both ground and photo plot data some general ecological observations can be summarized on a plot level over the entire region. The most common leading species in these plots was lodgepole pine (39%) followed by interior Douglas-fir (18%), and then non-treed plots (15%, Table 2). The plots cover a representative range of BEC zones in the region, with the majority of plots in the SBPS (24%) and then the IDF (21%, Table 3). Stand age ranged from 17 to 473 years old, with the majority of plots being less than 100 years old (Figure 5).

Plot level summaries over the entire region can also be conducted using ground and photo plot data related to timber characteristics. Top height ranged from 4 to 42m with the majority of plots having top heights of less than 20m (Figure 6). Top height is the height of the Top Height Tree (T) as taken from the sample data. This value is defined as the height of the T-tree, of which there should be only one. Basal area ranged from 1 to 102 m^2/ha with the majority of plots in the 1-10 m2/ha category (Figure 7). Spatially, plots with the largest basal area (BA) are generally in the eastern part of the region (Figure 8), corresponding to western red cedar (Cw) leading plots found in the ICH. This trend was consistent with top height (data not shown). These data summaries are using all plot data, both forested and non-forested. As many data users would be interested in only forested plots, the data could be analyzed as a percentage of forested plots rather than total plots.

Table 2. Leading species of each plot are summarized in terms of number of plots (N) and percentage (%) in the Cariboo region. Leading species occurrence is listed in ascending order.

Leading Species	N	%
SE	1	0.5
EP	2	1.0
PA	2	1.0
AC	3	1.4
CW	4	1.9
AT	5	2.4
BL	15	7.2
SX	25	12.0
no trees	32	15.4
FD	37	17.8

PL	82	39.4

Table 3. BEC zone of plots are summarized in terms of number of plots (N) and percentage (%) in the Cariboo region. BEC zone occurrence is listed in ascending order.

BEC	N	%
IMA	1	0.5
MH	1	0.5
BG	2	1.0
CMA	2	1.0
BAFA	9	4.3
ICH	11	5.3
ESSF	25	12.0
MS	28	13.5
SBS	35	16.8
IDF	44	21.2
SBPS	50	24.0

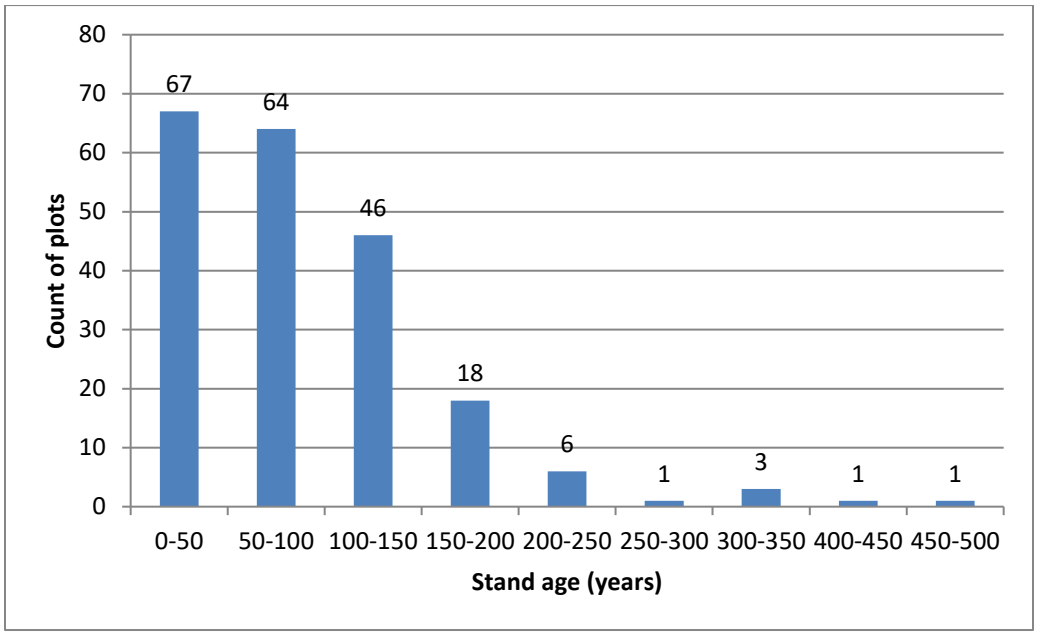

Figure 5. The number of plots found in each 50-year stand age range.

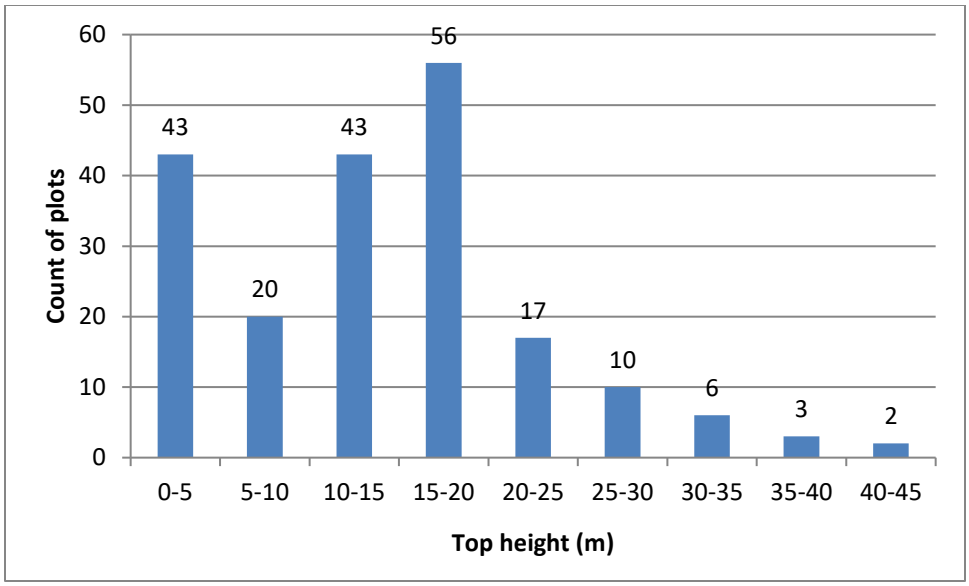

Figure 6. The number of plots found in each 5m top height range.

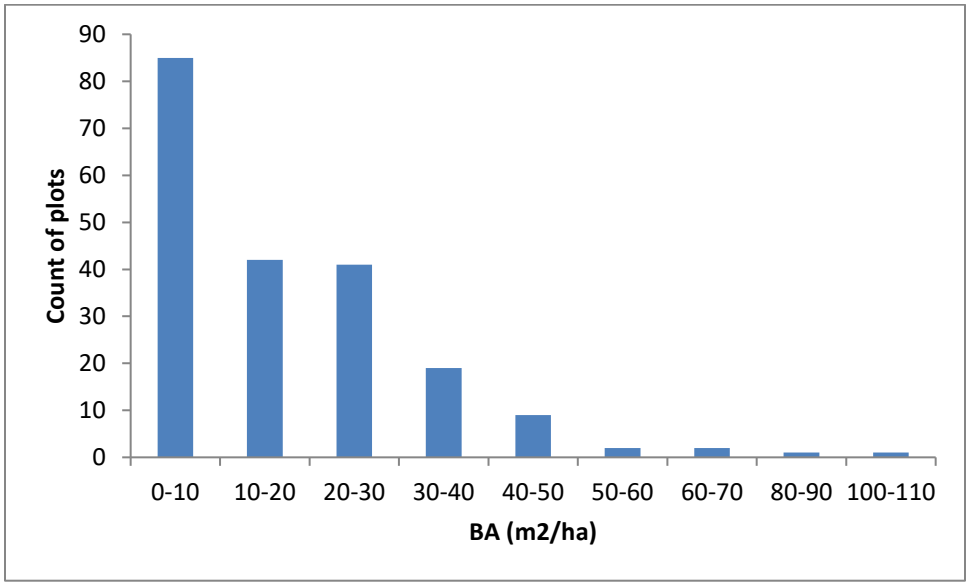

Figure 7. The number of plots found in each 10 m2/ha basal area (BA) range.

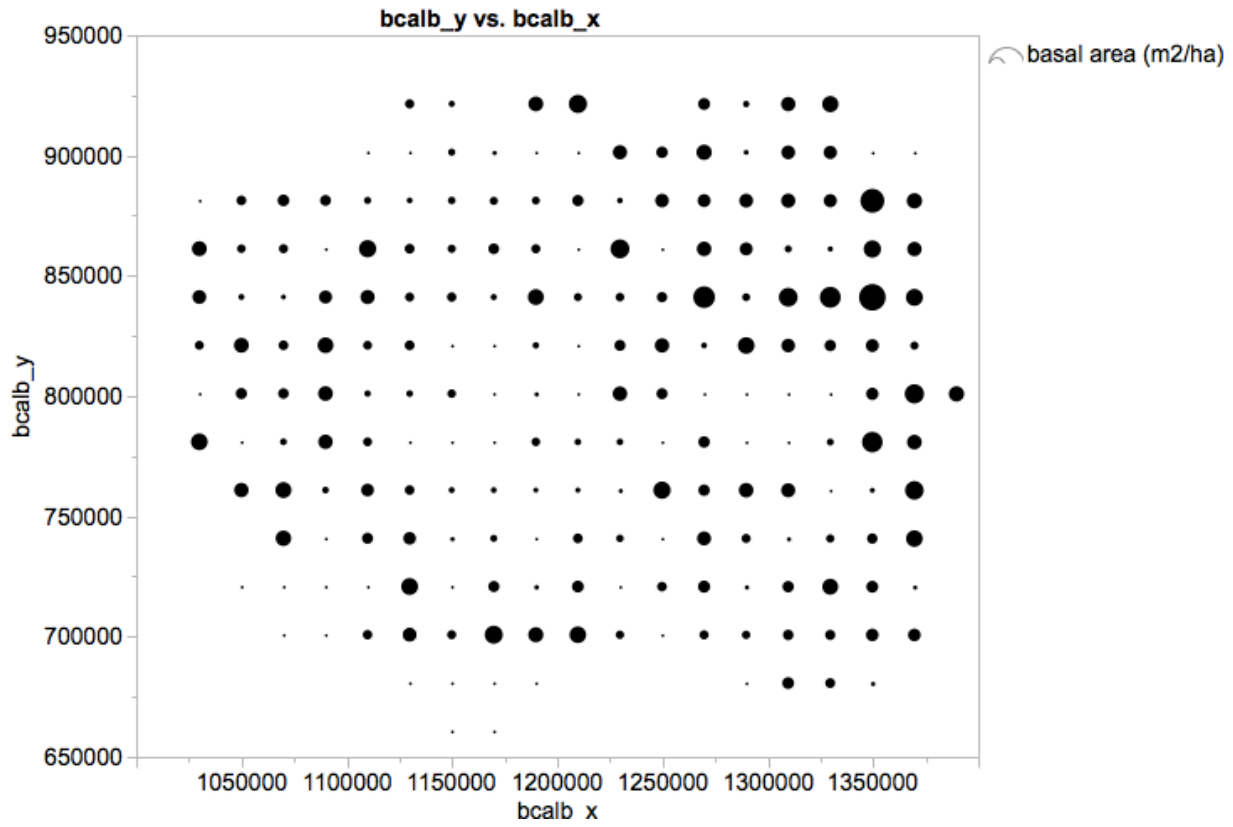

Figure 8. Basal area (m^2/ha) displayed spatially across the region with larger dots indicating higher values.

Stand-level tree details are collected on ground plots that are not able to be estimated on photo plots. Therefore, ground plot data would need to be used if information on mortality, canopy condition, cored tree age, regeneration, wildlife use or damaging agents is required. These data could be considered on plot level summaries or individual tree basis. As an illustration, the ground plot CAR-0621 was used. Tree crown class distribution within this plot was primarily co-dominates and then intermediates (Figure 9). Tree height distribution of this plot followed a normal bell shaped curve around 11-15m (Figure 10) as did dbh class around 10-12 cm (Figure 11).

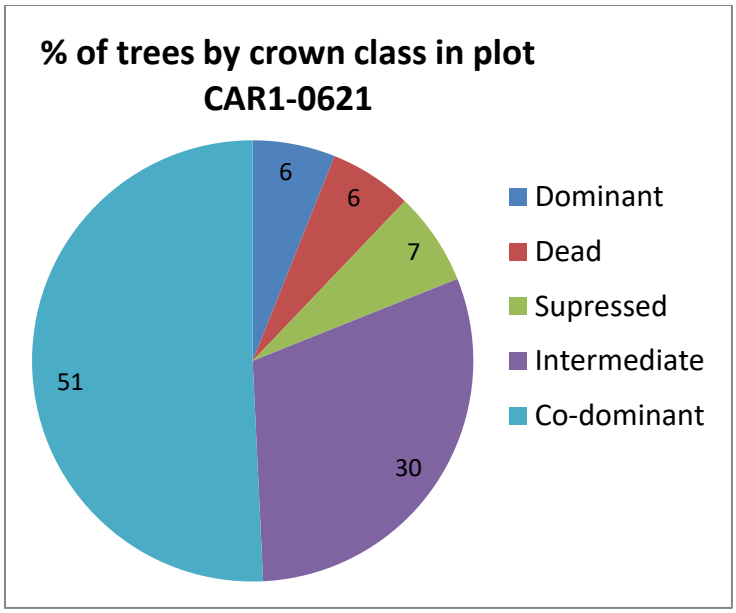

Figure 9. Percent of trees in each crown class within plot CAR1-0621.

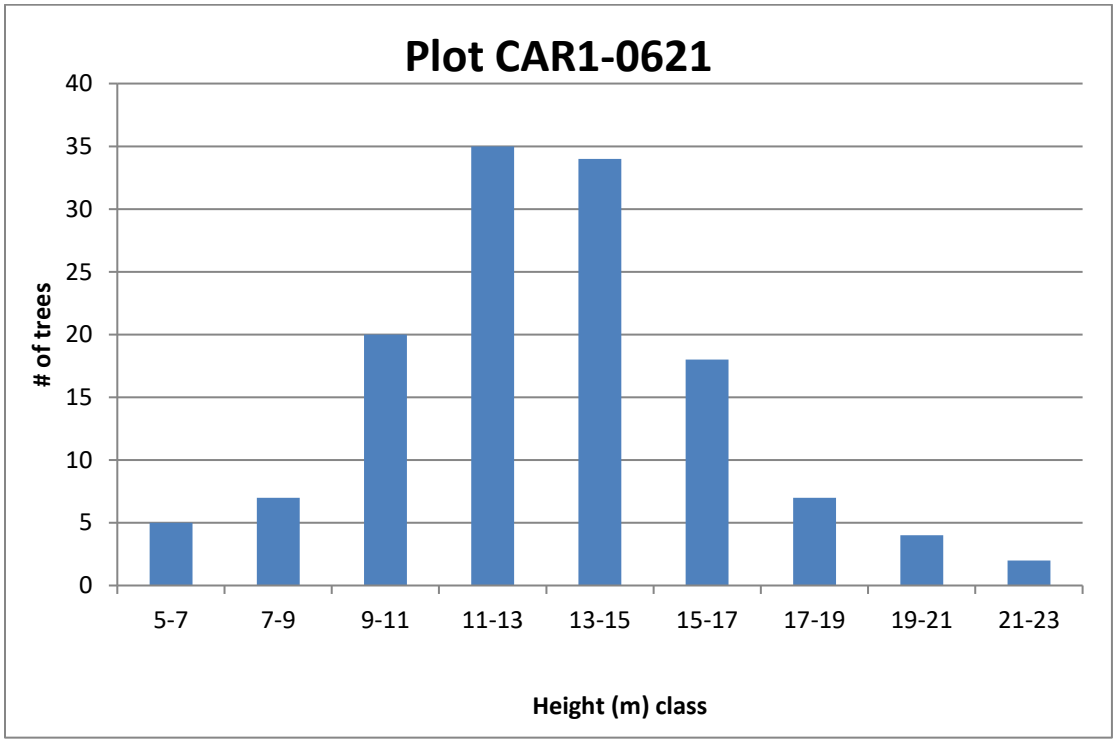

Figure 10 . Number of trees in each height (m) class within plot CAR1-0621.

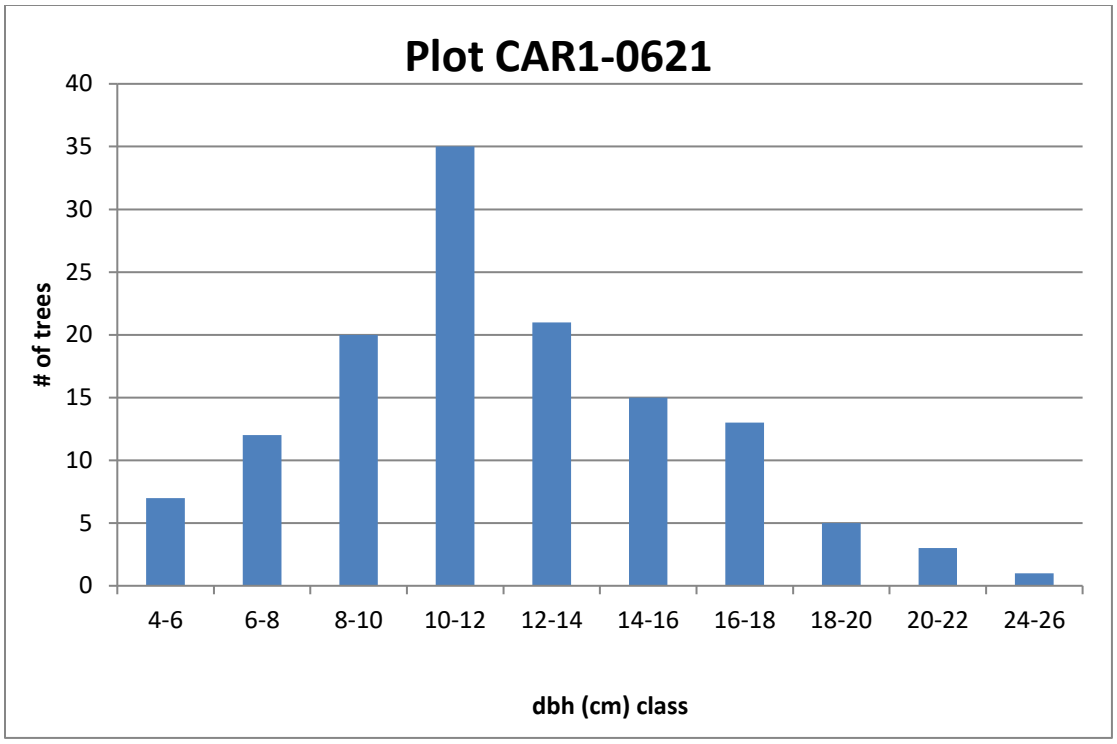

Figure 11 . Number of trees in each dbh (cm) class within plot CAR1-0621.

Summary

- The goal of the Provincial Monitoring Program is to provide unbiased long-term re-measurement data that can be used to summarize current forest characteristics, monitor change on the landscape, validate spatial inventories, and address critical emerging issues.
- The systematic sample design of this monitoring program with plot locations on a grid makes the data flexible for many purposes.
- This program can facilitate national and international collaboration because it is similar to the Canadian National Forest Inventory and US Forest Inventory and Analysis (FIA) program sample designs.
- Data from the Provincial Monitoring Program complements and supports other Inventory Section objectives by validating growth-and-yield models and spatial inventories while providing unique information.
- Data quality is ensured by standard sampling procedures, validation rules in the electronic data collection software, random quality assurance checks of 10% of a contractors work, and during analysis.
- The data from all plots on crown land are freely available to the public with coordinates for all monitoring plots are generalized to the nearest km.