Growth monitoring scheme for an operational forest fertilization program

1.0 Preamble

The Forests for Tomorrow Program has a forest fertilization strategy because fertilization is one of the most beneficial treatments in terms of both volume production and financial return (http://www.for.gov.bc.ca/hfp/fft/index.htm). The fertilization strategy will focus on the BC interior areas facing major timber supply impacts from mountain pine beetle (MPB) and high priority areas on the BC coast. To date, 10 million ha have been affected by the MPB in the BC interior (most being in the central interior) (http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/maps/magnitudeMap2007.pdf). A large program is needed to have a significant impact on future timber supply: about 130,000 ha will be fertilized over a five year period. The program will initially focus on healthy spruce and Douglas-fir stands. The highest priority stands will be those aged 40 – 79 years and the next priority level will be stands aged 15 – 39 years. In both instances, live crown should be greater than 30 percent.

Selecting the check or control area is as important as stand selection for fertilization. The control area should be similar to the treated area in all aspects, except area, in order to have an unbiased estimate of the fertilization response. The purpose of the monitoring program is to estimate the increased growth due to fertilization. Targeted stands should have good access, be fully stocked and have adequate room for the crop trees to respond to the fertilizer treatment. Non-timber resources will be protected by use of appropriate buffer zones.

Given the value of the investment, $50 million over five years, and the large area to be treated, it is critical to have a growth monitoring program that is cost efficient and effective. The benchmark against which the fertilizer-treated stands will be evaluated is the growth of untreated (check or control) stands (areas) having the same ecological attributes as the treated stands and being assessed over the same time period. Again, the control area is the crucial component of a monitoring program.

2.0 Sampling

If a sampling intensity similar to silviculture surveys were to be used, there would need to be more than 130,000 plots installed. This is neither practical nor cost effective. The first step therefore is assigning a sampling intensity for the fertilization monitoring program.

It must be kept in mind that this is not a research or growth and yield initiative but a program to monitor the effectiveness of an operational forest fertilization program from stand to landscape levels.

2.1 Selection of control area

The control area should be similar to the treated areas in all aspects: BEC subzone, site series, slope, aspect and forest cover. It should not be a wildlife tree area or a riparian zone. The control area should be close to 10 ha in area. Ideally, a natural feature of the polygon such as a road or skid trail would be used to separate the control from the treated area.

2.2 Plot selection

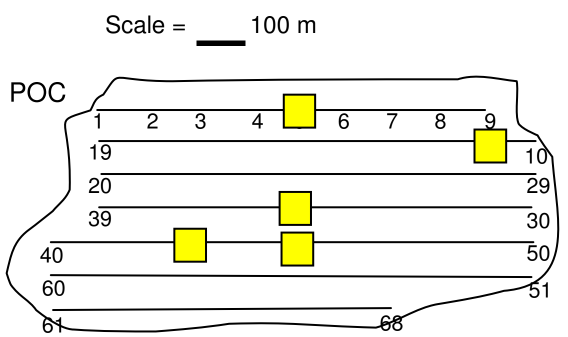
If a sampling intensity of five percent (based on a survey approach) were used, 6,500 plots would be required in the treated areas or stands plus the requisite number of plots for the check or control areas. This number of plots still is neither practical nor cost effective. Another approach is to install a small number of plots in each treated area and partner control area. A minimum of five randomly selected plots would be installed in stands (see definitions) of 100 ha or less. For stands larger than 100 ha, a plot intensity of five percent would be used up to a maximum of 10 plots per stand: e.g. a 160 ha stand would have 8 plots. See section 2.4 for additional detail. Based on mountain pine beetle and site index assessments (Hawkins unpublished work), this approach gives good results at the stand level. The protocol will be used in both treated and control areas. This approach assumes, as indicated in the guidelines, the treated areas are relatively large and as a result the monitoring program should be both cost efficient and effective (http://forestsfortomorrow.ca/GuidelinesAndStandards/Fertilization/StandSelection.html).

The described protocol assumes all areas treated will be monitored. Doing so, would not be cost effective or practical, particularly in future years of the program when large areas will be treated. Each treated stand should have a paired control area close to 10 ha in size. All treated stands would be tallied by BEC subzone and site series designation (see below). The number of stands selected per subzone may be proportional to the number of stands treated in that subzone and the sampling intensity deemed appropriate by the Forests for Tomorrow Program and the Fertilization Working Group. For instance, one installation per 500 ha fertilized may be an appropriate sample intensity. Regardless of area treated, there should be one installation per BEC subzone and site series to ensure results from under represented stand types. This can be achieved by targeting one-half of the installations by BEC subzones and randomly selecting the other half of the installations from the treated site tally. Site selection should be overseen by a sub-committee of the Fertilization Working Group.

For the treated area, a random point of commencement (POC) is selected on the stand map. A systematic grid with plots located every 100 m is then overlaid on the stand and numbered sequentially (Figure 1). For a plot to be selected it must be two tree lengths (minimum of 60 m) from any polygon border in order to minimize edge effects. A random number list is generated for each stand: in this example there will be 68 random numbers to correspond to the 68 grid positions. As this polygon is less than 100 ha, the first five sample points on the random number list will be selected. The random number list was generated in Excel with the 'RANDBETWEEN' function is: 43, 11, 66, 30, 10, 61, 45, 35, 5, 7, 68, 29, 58, 64, etcetera. Plots 43 and 11 are more than 60 m from a stand boundary and are selected. Plots 66, 30, 10 and 61 are less than two tree lengths from a stand boundary and are not selected. Plots 45, 35 and 5 are more than 60 m from a stand boundary and are selected. The plots to be sampled for this polygon are 5, 11, 35, 43 and 45 (shaded squares in Figure 1). The process would be repeated for the control area (polygon). This exercise can be done in the office if you know the GPS coordinates of your POC. In the field, the monitor installs a plot at the appropriate GPS coordinates.

For the control area, a random POC is also used. For a plot to be selected it must be two tree lengths (minimum of 60 m) from any polygon border in order to minimize edge effects. A grid is established on (in) the control area in order to have at least five (5) plots. For example, if the area is 6 ha and it is a 200 X 300 m rectangle, a grid with 6 plots could be established. The plots would be 80 m apart in the short axis direction and 90 m apart in the long axis direction. Five plots would be randomly selected from the six (use the 'RANDBETWEEN' function) for sampling. Plots on the grid should be no closer than 50 m nor more distant than 100 m.

Figure 1. Example of random plot selection: a stand with a random point of commencement and a systematic grid. The shaded squares indicate the location of the randomly selected plots.



In some instances, you may be constrained by polygon size or shape (long – narrow): plots can be located systematically provided the location of the first plot is established randomly.

2.3 Stand stratification (pooling)

If a stand has both mesic and either submesic or subhygric areas, these should be stratified prior to random plot selection to ensure sampling from relatively uniform areas within a stand. Remember, your control area should also be representative of the strta in the fertilized area. For example in the SBS dw3 sub-zone (DeLong et al. 1993) for Douglas-fir, site series 02 and 04 would be pooled for submesic and site series 01 and 08 would be pooled for mesic while for interior spruce, site series 01, 04 and 06 would be pooled for mesic and site series 07, 08, and 09 would be pooled for subhygric. The rationale for pooling by site series is the SIBEC site index respectively for submesic and mesic Douglas-fir is 16.5 m and 18 m while respectively for mesic and subhygric interior spruce it is 15 m and 18 m (Anonymous 1997).

2.4 Time(s) of sampling

Ideally the treated and untreated areas would be sampled for baseline data prior to fertilization. When this is not possible, the following protocol should be used. Stands treated in the fall should be sampled prior to the start of the next growing season – in the central BC interior this would be prior to the end of April. Stands fertilized in the late winter – spring should be sampled immediately after fertilizer application.

Normally, follow-up measurements will be done at five year intervals unless the polygon is to be harvested before the end of the five year period or if data is needed for other reasons. For example, follow-up measurements can be done as early as the third growing season if early data is needed: treatment in fall 2005 or spring 2006 – first assessment in fall 2008. However in order to observe the maximum benefit of forest fertilization, it is best to wait for five growing seasons before doing the first follow-up measurements.

2.4 Plot dimensions and layout

Plots will be a fixed radius of 7.98 m (0.02 ha area). This is smaller than the traditional 0.04 ha (0.1 acre) plot but the 0.02 ha plot is large enough to incorporate local variation and yet be small enough to be economical to install. All living trees within the plot will be numbered with tree marking paint. Ideally, metal number tags would be looped on wire around the base of each plot tree. Numbering will commence at the plot centre (tree 1), move north to the nearest tree, and proceed in a clockwise direction back to the origin. An alternative approach to painting numbers in older stands is to identify trees with an aluminum number tag nailed to the base of the tree below stump height. Tags should all face towards the plot centre tree. The dbh measurement location must still be marked with paint. The plot centre tree will be double flagged or double ringed with tree marking paint, and be GPS'd – to facilitate relocation.

The number of plots per installation will also be influenced by the total number of trees sampled (trees per plot). The minimum number of trees is a function of stand density. There should be at least 100 trees: if the stocking were 600 sph this would require the installation of 3 additional plots in a stand less than 100 ha (result would be 96 trees). If the stocking were 1300 sph, five plots in a block smaller than 100 ha would result in a 130 tree sample. In less dense stands, plots can be increased to a fixed radius of 11.29m (0.04 ha) to achieve the 100 tree minimum. The revised plot size should be recorded in the "Plot Data" tab of the Excel data file (available on the FFT fertilization web site). If you have any questions you can discuss them with Chris Hawkins (hawkinsc@unbc.ca) or Kyle Runzer (runzerk@unbc.ca) at the University of Northern BC.

3.0 **Data**

Tree and plot level data will be collected to describe crop tree response and shrub response (competition) to fertilization.

3.1 Data collection

The diameter at breast height (dbh at 1.37 m) will be recorded for all trees in the plot with a dbh greater than 7.5 cm as well as the crown class and vigor for each tree. The location of dbh measurements must be marked with tree marking paint. On sloped ground, dbh is taken on the uphill side of the tree. Crown classes are dominant, codominant, intermediate or suppressed. Tree health should be rated where applicable according to the Forest Health Surveys Guidebook http://www.for.gov.bc.ca/TASB/LEGSREGS/FPC/FPCGUIDE/health/healtoc.htm and abbreviated according to appendix 5 of the same. Tree vigor codes are on the sample field data sheet (Figure 2 and separate Excel file).

The heights of the site trees (see definitions) in each plot will be recorded and a core will be taken at breast height. The two selected plot site trees do not necessarily have to be the target species. The core will be used to i) establish tree age for SI determination and ii) assess growth for the five years prior to treatment (5 year growth will be expressed as a percentage of the radius of the sampled tree). In addition to the dbh core for the site tree, the following is desirable to get an estimate of pre-treatment growth. For the dominant species in the plot, take a core from the smallest tree, the largest tree and a randomly selected one in the mid dbh range. For species that represent more than 20% of the trees in the plot, take a dbh core from a randomly selected co-dominant tree. Tree cores can be sent to UNBC for accurate aging (see section 3.3). An ocular estimation of total shrub cover will be made for each plot as well as cover of the four leading shrub species. Shrubs can be recorded using common names or the first four letters of the genus and the first three letters of the species. Species identification aids in establishing site series. A sample data sheet is presented in Figure 2.

Quality control of data collection and data entry is critical to the success of the monitoring program. About one field plot in ten should be re-visited by a second team and the measurements verified. Data will be entered into a standard Excel spreadsheet developed by the University of Northern BC and Western Forest Products (available on the FFT fertilization web site). Remember to delete the sample data for the control plots if you are going to use the standard Excel spreadsheet. After the data is entered it is up to each participant to verify the quality of their data prior to sending it for storage (see below).

3.2 Data interpretation (performed by staff at University of Northern BC)

The mean (± SEM) SI will be determined for each stand based on the mean of the sampled plots. The mean quadratic dbh will be calculated for each plot and then converted to basal area per ha. A mean (± SEM) quadratic dbh and basal area per ha will then be calculated for each stand. Using TIPSY and the calculated SI, basal area per ha will be converted to volume per ha for each treated and untreated stand (stand pair). There will be three TIPSY outputs per stand treatment: the mean, the mean – SEM, and the mean + SEM. This will allow a range of confidence to be put on treatment response. The difference in rate of change in basal area and volume per ha will be reported for each stand pair and an average response reported for each year of fertilizer treatment. For example in the SBS dw3, stands fertilized in the fall of 2005 had a mean annual increase in growth of x m^3 per ha with a range from y to z m^3 per ha. Results can also be reported at the landscape level (a rollup of all stands treated in each year). This allows the efficacy of the program to be viewed at three different scales: stand, subzone and landscape. Time zero data can be used as a covariate to minimize dbh differences at the time of treatment.

3.3 Data storage

Data will be stored by the University of Northern British Columbia Mixedwood Program. The contacts are Chris Hawkins (Phone 250.960-5614; email hawkinsc@unbc.ca) or Kyle Runzer (runzerk@unbc.ca). If the data is entered by the proponent, it should be similar to the data sheet with each tree being a unique record (see sample standard Excel spread sheet on the FFT fertilization web site). The UNBC Mixedwood Program will enter the data for the proponent for a fee for service. The UNBC Mixedwood Program can also process the dbh cores for a fee.

4.0 Monitoring protocol

The above monitoring protocol is random, accounts for growth prior to fertilization and differences among BEC attributes, has a control area for reference, accounts for growth after fertilization, has statistical rigor, has many small plots, provides early data and should have a relatively low cost per plot.

5.0 Definitions

Baseline data – stand metrics prior to any response to fertilizer treatment and the basis for assessing the efficacy of fertilization. It can be used as a covariate in future analysis.

Control or check area – a subset of a stand not fertilized or another polygon not fertilized but having the BEC attributes (subzone, site series, and aspect) as the fertilized stand. Generally the control should **not** be a riparian areas or a wildlife tree patch. Establishment of these areas is critical to the success of the monitoring program.

SEM – standard error of the mean.

Site tree – dominant tree with the largest diameter and no health or vigor defects in the plot.

Stand – polygon on a forest cover map.

Stand pair – the treated and untreated areas being compared for each polygon.

UNBC FOREST FERTILIZATION SAMPLE DATA SHEET

Date: ____________________ **Forest Cover Polygon:** ____________________

Grid Number: ____________________ **BEC:** ____________________

Sub-zone: ____________________

Treatment: ____________________ **Site Series:** ____________________

Surveyor's ____________________ **Plot Center UTM:** **Northing-** ____________________

Easting- ____________________

Elevation (m)- ____________________

Tree	Species	dbh (cm)	Crown Class	Vigor	Health	Comments
1						
2						
3						
4						
5						
6						
7						
8						
9						
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11						
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32						
33						
34						
35						
36						
37						

Site Tree: **Height (m)**

_______ **A:** ____________

Age____________

_______ **B:** ____________

Age____________

Shrubs#

1 ____________

2 ____________

3 ____________

4 ____________

#, Use common name or first 4 letters of genus and 3 letters of species

Vigor Codes	
0	Alive
1	Dead Top
2	Moribund (declining)
3	Stem damage
4	Leaning
5	Forked above dbh*
6	Broken Top
7	Lateral takeover
8	Chlorotic
9	Dead

*, if forked below dbh - tag and record as more than one tree

FIRS project number: ____________

Figure 2. Sample data sheet for operational forest fertilization monitoring.

6.0 References

Anonymous. 1997. Site Index Estimates by Site Series for Coniferous Tree Species in British Columbia. Forest Renewal BC – Canada-British Columbia Partnership Agreement on Forest Resource Development, Victoria, BC.

DeLong, C, Tanner, D, Jull, MJ. 1993. A field guide for site identification and interpretation for the southwest portion of the Prince George Forest Region. Land management Handbook 24; BC Ministry of Forests, Victoria, BC.