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). To date, 8.5 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/2005MPBsurvey.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 and the stand site index (SI base age 50) for spruce should be between 15 and 24 m. 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 (control) stands (areas) having the same ecological attributes as the treated stands and being assessed over the same time period. This is a 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 initiative but a program to monitor the effectiveness of an operational forest fertilization program from stand to landscape levels.

2.1 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 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 and at an intensity of five percent, to a maximum of 10 plots for stands greater than 100 ha. Based on mountain pine beetle and site index assessments, 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://www.for.gov.bc.ca/hfp/fft/fertilization/standselection.htm).

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 at least 5 ha in size. All treated stands would be tallied by BEC subzone and site series designation (see below). Areas for monitoring (treated and control) would be randomly selected from each tally. The number of stands selected per subzone would be proportional to the number of stands treated in that subzone and the sampling intensity deemed appropriated by the Forests for Tomorrow Program and the Fertilization Working Group. For instance, monitoring one-third of the stands treated may be suitable.

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 100 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 100 m from a stand boundary and are selected. Plots 66, 30, 10 and 61 are less than 100 m from a stand boundary and are not selected. Plots 45, 35 and 5 are more than 100 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.

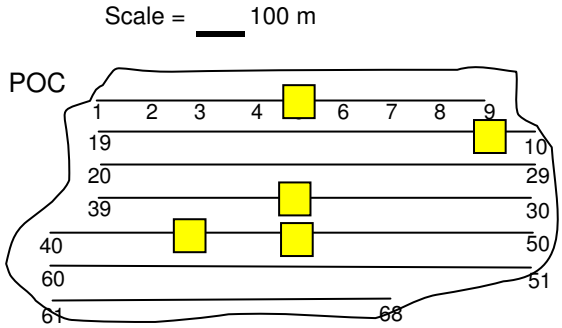

Figure 1. An example of a stand with a random point of commencement and a systematic grid for random plot selection. The shaded squares indicate the location of the randomly selected plots.

2.2 Stand stratification

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. 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).

2.3 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.

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, if possible, it would be better to wait for four or 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 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. The plot centre tree will have PVC pipe driven at its base, be double flagged, and be GPS'd – to facilitate relocation.

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 as well as the crown class and health vigor for each tree. Crown class will be dominant, codominant, intermediate and suppressed. Tree health will be rated 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 will be rated as thrifty, moribund or dead. The heights of the two site trees (see definitions) in each plot will be recorded and a core will be taken at breast height. 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). An ocular estimation of total shrub cover will be made for each plot as well as cover of the four leading shrub species. Species identification aids in establishing site series. A sample data sheet is presented in Figure 2.

3.2 Data interpretation

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.

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 area – a subset of a stand not fertilized or another polygon not fertilized but having the BEC attributes (subzone, site series, aspect) as the fertilized stand. Establishment of these areas is critical to the success of the monitoring program.

SEM – standard error of the mean.

Site tree – 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 stand.

UNBC FOREST FERTILIZATION SAMPLE DATA SHEET

Date: _____ **Forest Cover Polygon:** _____

Grid Number: _____ **BEC:** _____

Sub-zone: _____

Treatment: _____ **Site Series:** _____

Surveyor's _____ **Plot Center UTM:** **N Northing-** _____

Easting- _____

Tree	Species	Dbh (cm)	Crown Class	Health Vigor	Comments
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
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13					
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35					
36					
37					

Site Tree:	Height (m)
# _____	A: _____
# _____	B: _____

Codes	
0	Alive
1	Dead Top
2	Complete Dead
3	Stem damage
4	Leaning
5	Forked
6	Broken Top
7	Lateral takeover
8	Chlorotic
9	Dead

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.