# FOREST CARBON INFORMATION NOTES

## MODULE 2: FERTILIZATION

### KEY TAKE-AWAYS

- A greenhouse gas (GHG) benefit is gained when fertilization increases carbon dioxide (CO2) uptake by trees (carbon sequestration)
- Emissions from production, transport and application of fertilizer are accounted for in the estimation of the GHG benefit of forest fertilization
- Success depends on the selection of stands which will have positive responses to fertilization

Nutrient deficiency limits how fast and large trees grow and is thought to be common across British Columbia's forests. To compensate for widespread nutrient deficiencies, British Columbia has been fertilizing forests for decades. Over that time, fertilization experiments have demonstrated how young stands can benefit from the addition of nitrogen and other nutrients. Within the space of a decade, a single fertilizer application can boost growth by roughly 30 and 15 cubic metres of wood per hectare in Coast and Interior regions, respectively.

In addition to increasing timber yield, fertilization increases sequestration of atmospheric carbon dioxide (CO2) which can help meet federal and provincial greenhouse gas (GHG) emission reduction goals. Experiments have shown that adding nutrients leads to significantly greater storage of carbon in forest ecosystems; carbon that would otherwise contribute to climate change as a GHG in the atmosphere. Over a 10-year period after fertilizer is applied, forests on the Coast can sequester approximately 57 tonnes of carbon dioxide equivalent per hectare (tCO2e/ha)[1] and forests in the interior can sequester approximately 25 tCO2e/ha.

In the 10 years prior to the initiation of the Forest Carbon Initiative (FCI), the provincial fertilization program treated an average of 17,000 hectares annually. Additional investments in fertilization led by FCI will more than double the annual forest area fertilized in the province by 2020.

### HOW IS THE GHG BENEFIT FROM FERTILIZATION CALCULATED?

The GHG benefit from fertilization is calculated as the difference between the GHG balance for two hypothetical management scenarios, including a project scenario, and a baseline scenario. The project scenario describes the GHG balance of the forest assuming fertilizer is applied, and the baseline scenario describes the GHG balance of the forest assuming no fertilizer is applied. The Table Interpolation Program for Stand Yields (TIPSY) program incorporates much of the knowledge gained from nutrient addition experiments that have been conducted in B.C. Stemwood yields produced by TIPSY with and without a fertilization treatment form the basis for estimating the GHG balance for the scenarios. The yield curves are then used to drive an inventory-based carbon balance model that estimates how carbon cycles through ecosystems[2] and harvested wood products[3].

While TIPSY directly accounts for the increased amount of carbon stored in stemwood caused by fertilization, the ecosystem model assumes that net primary production responds proportionally, such that fertilization additionally boosts the production of foliage, branches, bark and roots, which also collectively increase the amount of carbon that is stored in total tree biomass and dead organic material, including litter, dead trees, and soil organic material.



[1] The term "carbon dioxide equivalent" is used to describe the impact of all types of GHG emissions, including methane and nitrous oxides, via a common comparable unit, see module 1.
[2] Kurz et al. CBM-CFS3: A model of carbon-dynamics in forestry and land-use change implementing IPCC standards. Ecol. Model. 220, 480-504 (2009).
[3] Dymond, C. Forest carbon in North America: annual storage and emissions from British Columbia's harvest, 1965–2065. Car. Bal. Man. 7 (2012).

Although the project scenario boosts carbon sequestration, it also produces GHG emissions, which must be accounted for to truly understand the GHG benefit from fertilization. Operational GHG emissions arise from manufacture of urea fertilizer, transport prior to application, transport during application, and GHG emissions from the ecosystem itself following application of urea. On average, operations are assumed to emit 1.8 tCO2e per hectare of area treated (Table 1). These operational emissions are subtracted from the gross GHG benefit (from carbon sequestration) to determine the net GHG benefit of the area treated.

FCI considers operational emissions in the calculation of GHG benefit to ensure that fertilization is, indeed, an effective climate change mitigation activity, however FCI only reports out on the GHG benefit calculated from the difference between carbon sequestration and emissions from ecosystem losses (decomposition) and disturbance (harvesting), as operational emissions (production and transportation) are reported by the energy sector.

**Figure 1: Greenhouse gas fluxes for two fertilization projects in coastal and interior regions of British Columbia, assuming no subsequent harvest.**

| Description | Coastal Forests (tCO2e/ha) | Interior Forests (tCO2e/ha) |
|---|---|---|
| **Energy Sector** | | |
| Production, shipping, and fertilizer application[4,5] | -0.57 | -0.57 |
| **Forest Ecosystem** | | |
| Biomass + dead organic matter | 57.00 | 24.60 |
| Volatilization[4,5] | -0.31 | -0.31 |
| Denitrification[4,5] | -0.94 | -0.94 |
| **Harvested Wood Products** | | |
| Emissions from combustion and decay of wood products and waste | 0.00 | 0.00 |
| **Cumulative Net GHG benefit** | 55.00 | 23.00 |

## WHAT ARE THE GHG AND ECONOMIC BENEFITS OF FERTILIZATION?

Forest fertilization research and modeling of coast and interior stands have shown a cumulative net GHG benefit of fertilization (with all emissions deducted) of 55 tCO2e/ha for coast areas and 23 tCO2e/ha for interior areas at 10 years post treatment. The coast and interior examples suggest that fertilization provides a secure, short to medium-term GHG benefit for the FCI program.

In addition to increased timber supply and reduced GHG emissions, fertilization also has economic benefits. The employment and GDP impacts of fertilization work out to be 4.5 full-time equivalents (FTE) and $2.7M per 10,000 hectares of treatment, respectively (Table 2)[6].

## HOW CAN WE IMPROVE OUR CHANCES OF SUCCESS?

A forest's response to the addition of fertilizer is dependent on several factors including:

- soil properties (moisture, drainage, texture and bulk density),
- chemical properties (nutrient availability, labile carbon, soil pH and C/N ratio),
- local climatic factors (temperature, rainfall and relative humidity), and
- stand characteristics (species, age, health, density).

The standard fertilization responses in growth and yield modelling (TIPSY) suggest that the GHG benefit will vary by tree species, Biogeoclimatic

[4] Sonne, E. Greenhouse gas emissions from forestry operations: a life cycle assessment. J. Environ. Qual. 35, 1439–1450 (2006).
[5] Scott, M., Perry J., Winter, R. Fertilization and carbon sequestration in BC forests. BC Forest Professional. (2009).

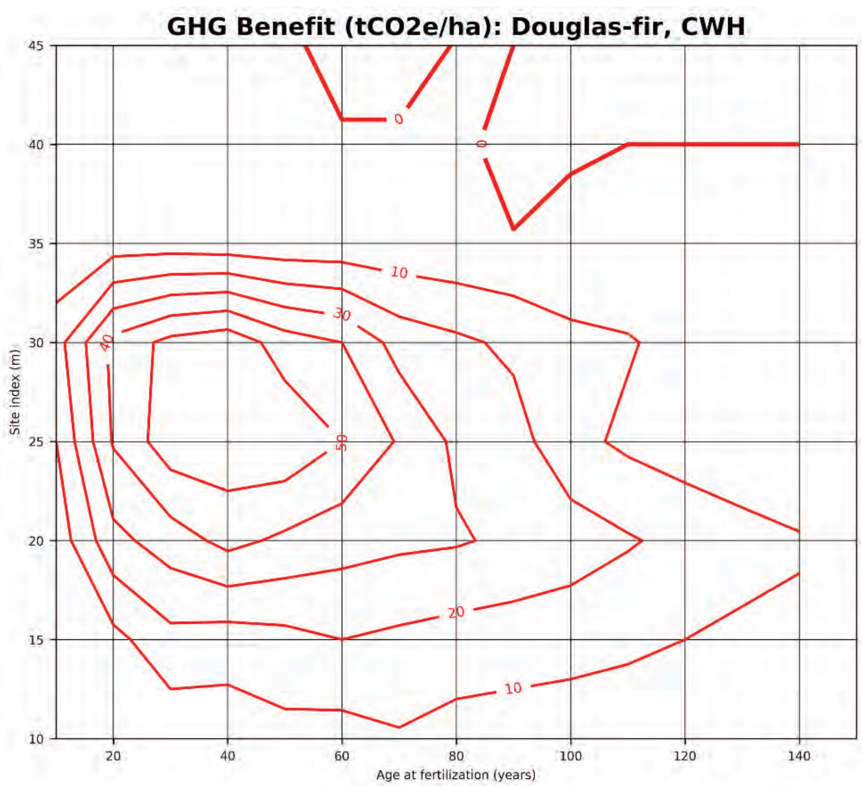
Classification (BEC) zone, and by stand age at time of fertilization. Examples given in Figures 1 and 2 indicate differences in GHG benefits between the Coast and the Interior according to age at fertilization and site index. Candidate stands are assessed and evaluated for their ability to demonstrate a fertilizer response based on the above factors. In some cases, foliar sampling is required to determine if multiple nutrients are deficient in stands. Prescriptions are then developed for suitable stands based on all these factors as well as timing, rate of application, and if a fertilizer blend is required for each treatment area.

The benefits from a single fertilizer application can take up to 10 years or more to occur. To capitalize on the maximum carbon benefit, stands should not be harvested for at least ten years after the fertilizer application.

**Table 2. Climate change mitigation and economic benefits of a hypothetical forest fertilization project.** Estimates are based on fertilization of 40-year-old coastal Douglas fir stand with site index (SI) = 30 m in the Coastal Western Hemlock zone (Coast) and 40-year-old lodgepole pine stands with SI = 18 m in the Sub Boreal Spruce zone (Interior).

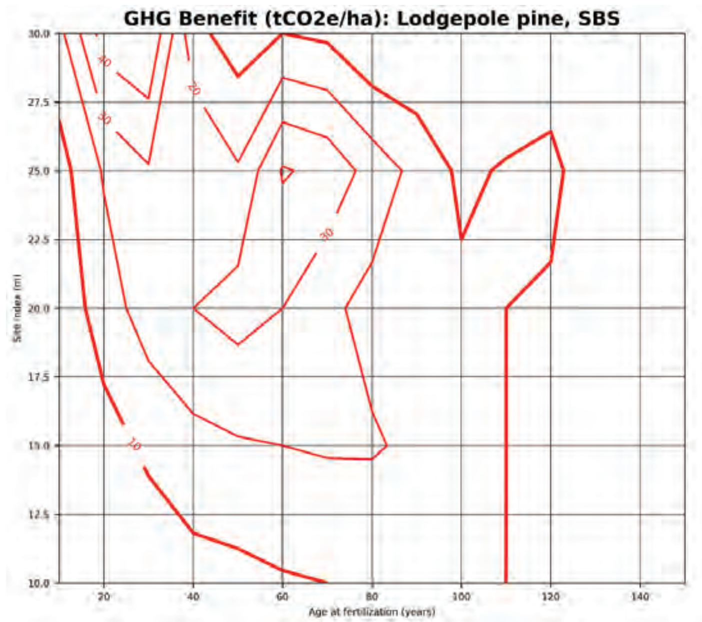
| Area | Cumulative Net GHG Benefit (tCO2e/ha) | | Cumulative Cost of CO2e in 2050 | Economic Benefits for 10,000 ha treated | |
|---|---|---|---|---|---|
| | 2030 | 2050 | ($/tCO2e) | FTE | GDP ($million) |
| Coast | 55 | 55 | $9.60 | 4.5 | 2.7 |
| Interior | 23 | 23 | $23.00 | 4.5 | 2.7 |

**Figure 1.** GHG benefits of the fertilization of Douglas fir (Pseudotsuga menziesii) stands in the Coastal Western Hemlock biogeoclimatic zone according to age at fertilization and site index




[6] Economic impacts are defined here as the estimated employment and gross domestic product (GDP) generated as a direct result of project investment. The standard cost of treatment ($500/ha for fertilizer and application and $30/ha for survey) is then multiplied by the relevant sectoral GDP multiplier in the national Input-Output model from Statistics Canada. The employment requirement for a standard fertilization activity in BC is assumed to be 0.1 work-day/ha, based on 220 eight-hour work days per year.

**Figure 2.** GHG benefits of the fertilization of lodgepole pine (Pinus contorta) stands in the Sub-Boreal Spruce biogeoclimatic zone according to age at fertilization and site index




## FCI FERTILIZATION STAND SELECTION CRITERIA

FCI has developed a suite of stand selection criteria that are in close alignment with those currently used by the Forest for Tomorrow (FFT) program. See appendix 1.

Given that the sequestration of CO2 is the primary objective of FCI, there are three notable exceptions:

- FCI fertilization treatments are not required to achieve a 2% return on investment (ROI), however priority will be given to stands with lower costs per tCO2e;
- It is preferred if areas treated under FCI remain un-harvested within the growth-response period (minimum of 10 years); and
- FCI fertilization treatments can occur both inside and outside the timber harvesting land base (THLB).

## CO-BENEFITS

- Increased harvest volume, increased harvest value through increased piece size, and acceleration of stand operability
- Acceleration of the development of specific age classes for wildlife habitat as fertilized forests develop older stand characteristics quicker through increased growth rates
- Boost in wildlife forage production in areas where canopy closure has not yet occurred
- Increased employment opportunities

## CONTACT

Inquiries about the Forest Carbon Initiative may be directed to: forest.carbon@gov.bc.ca

This information note was prepared for Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) staff, the Forest Enhancement Society of British Columbia, contractors, Indigenous Nations and stakeholders to communicate the potential benefits and opportunities in mitigating climate change through such activities, and to offer robust, evidence-based advice on best practices.

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## APPENDIX 1: FCI STAND SELECTION CRITERIA

All else being equal, priority at the stand level will be given to units with the highest fertilization response. Preference will be given in the following order:

| Region | Species | Age | Site Index |
|---|---|---|---|
| Coast | 1. Fdc<br>2. Cw<br>3. Ss/Sx[7]<br>4. Hw[8] | 1. 15-39[9]<br>2. 40-59<br>3. 60-80 | 1. SI 24-38[10]<br>2. Northern Vancouver Island Cw fertilization SI 17-32 |
| Interior Wetbelt - ICH | 1. Fd<br>2. Cw<br>3. Sx | 1. 15-39[9]<br>2. 40-59<br>3. 60-80 | 1. Fd SI 20-27[11]<br>2. Cw SA 15-25[12]<br>3. Sx SI 20-25 |
| Central Interior | 1. Fdi[13]<br>2. Sx/Sw<br>3. Pli | 1. 15-39[9]<br>2. 40-59<br>3. 60-80 | 1. SI 15-25 |
| Northwest | 1. Cw/Fdi<br>2. Ss/Sx/Sw[14]<br>3. Pli | 1. 15-39[9]<br>2. 40-59<br>3. 60-80 | 1. SI 18-32 |
| Southwest | | 1. 15-39[9]<br>2. 40-59<br>3. 60-80 | 1. SI 15-25 |

### OTHER CONSIDERATIONS (ALL REGIONS):

- Must be minimal forest health hazards present - a forest health specialist should be consulted in situations where insect, disease, animal or abiotic factors may affect the priority rating of candidate stands
- For Fd recommended Height: Diameter ratio < 85 for treatment
- No treatment of stands where Height: Diameter ratio > 100
- Favourable stand structure (adequate room for crown expansion and live crown ratio >30%)
- Higher priority to recently spaced stands

[7] In the coast-interior transition zone
[8] Western hemlock response to fertilization is variable. Site-specific opportunities may exist (i.e. SCHIRP sites), however these sites will require a more detailed evaluation of opportunities and treatment regimes.
[9] Where trees are >2m above competing vegetation
[10] Mesic sites with relative nutrient regimes of B or C
[11] Zonal site series, mesic sites with poor to moderate nutrition
[12] Avoid fertilization of Cw on sites limited by moisture availability
[13] Exclude stands in the Interior Douglas Fir (IDF) Biogeoclimatic zone.
[14] Only where there is no spruce leader weevil hazard