Forest Fertilization

Trees • Water Quality • Non-Timber Forest Products • Wildlife and Range • Carbon

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Fig. 1. *Aerial application*

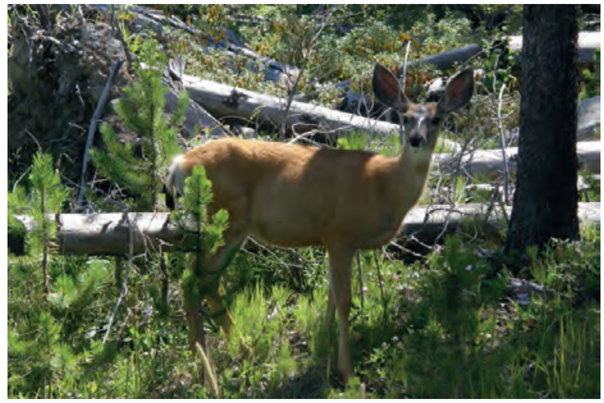
Fig. 2. *Mule deer*


Fig. 3. *Understory vegetation in fertilized stand*

Introduction

Forest fertilization is a long-standing silviculture tool that forest managers use to increase volume growth and carbon sequestration of trees in managed forests where nutrient deficiency is an issue. Fertilization can: 1) increase tree growth and forest and wildlife habitat cover; 2) increase carbon sequestration; 3) increase green-up for visual quality objectives; 4) accelerate stand development toward older stand structure including old-growth character; and 5) thereby, contribute to maintaining biodiversity. Fertilization has been widely used in British Columbia (BC) since 1981, with collaborative operations between government and industry.

The current provincial government fertilization program has been delivered through Forests for Tomorrow[1] (FFT) and Forest Carbon Initiative[2] (FCI) programs since 2004, and together around 30,000 hectares of forest have been treated annually since 2018. FFT was established in 2005 in response to the catastrophic disturbances caused by the mountain pine beetle and large wildfires with the aim of improving the future timber supply and mitigating impacts on other forest values. As part of the FFT program, forest fertilization contributes by reducing the time required for key stands to reach a harvestable size and thus it increases the mid-term timber supply. FCI was established in 2017 as a key element of B.C.'s commitment to take action on climate change. FCI helps to meet provincial and federal climate change targets through forest management activities which act to increase carbon sequestration or avoid greenhouse gas (GHG) emissions. Fertilization contributes to this program by increasing sequestration of atmospheric carbon dioxide and storage of carbon in forest ecosystems. Since 2004 approximately 120,000 ha have been fertilized across the province and these programs are continuing under the Province's Forest Investment Program.

In BC, nitrogen is often the most-limited nutrient in forest ecosystems. Nitrogen in the form of urea is, therefore, currently the most widely used fertilizer in forestry in BC with a range of application rates from 175–225 kg of nitrogen per hectare, and with one or more applications over the rotation (approximately 60–80 years) of a given stand. Fertilization is used by a wide range of field operators across forest industry sectors, including seed orchard operators, nursery operators, and commercial foresters. Although most areas are fertilized by aerial application

1 https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/land-based-investment/forests-for-tomorrow

2 https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/natural-resources-climate-change/natural-resources-climate-change-mitigation/forest-carbon-initiative

(e.g., helicopter), application from the ground can also be achieved through manual or mechanical means depending on purposes and conditions.

Application of fertilizer not only makes nutrients available to trees, but also to other plants, animals and fungi in both terrestrial and aquatic ecosystems. Thus, questions from Indigenous Peoples, stakeholders, environmentalists, and researchers regarding the impacts of fertilization on non-timber values have been asked. To date, most of the research relating to forest fertilization has focused on the volume and growth effects on trees. However, in this information brochure we focus on tree response (volume and growth) as well as the effects of fertilization on ecosystem services. This brochure highlights the impacts of forest fertilization on:

1. Trees
2. Water Quality
3. Non-Timber Forest Products
4. Wildlife and Range
5. Carbon

Footnotes are provided with links to original research papers from which this information is drawn.

Trees

The response to fertilization varies with tree species, site, and stand conditions. In coastal BC, additions of nitrogen alone or in combination with phosphorus have resulted in increased growth rates of Douglas-fir, western redcedar, and spruce (1,4). In interior BC, spruce, Douglas-fir, and lodgepole pine responded positively to nitrogen fertilization in terms of magnitude and consistency of response. Even greater increases in stemwood growth may occur as a result of repeated fertilization through time (1,5,6,23).

Water Quality

Direct fertilization of streams and water bodies is avoided altogether and application treatments maintain a buffer distance of >10 m from them.[3] Of the

3 Forest Planning and Practices Regulation, Reg. 64/2021 s. 63

nitrogen that is applied, less than 3% is leached from the upper mineral soil horizon (10,12). Therefore, even allowing for natural levels of nitrate in the stream, elevated levels by fertilization with conventional doses (i.e., 175–225 kg of nitrogen per hectare) are thought to be low in BC (22). Water quality monitoring is regularly conducted in drainages being fertilized by government funded treatment programs. If detected, the nutrient concentrations have been found to remain well below maximum levels[4] set out by the Ministry of Environment for both drinking water and aquatic life. No studies to date have reported adverse effects to aquatic ecosystem life or the quality of drinking water (2,3,11,15,22).

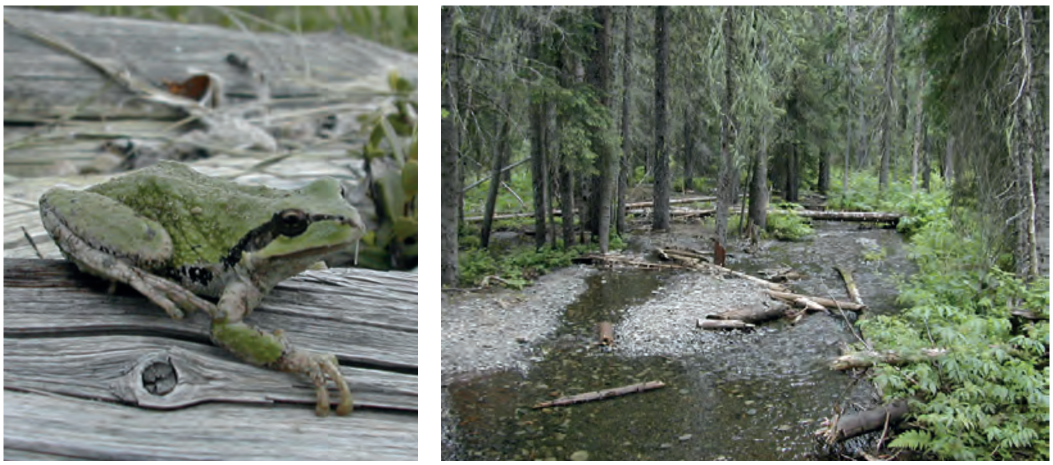

Fig. 4. *Pacific tree frog and forest stream*

Non-Timber Forest Products

Non-timber forest products (NTFPs) consist mainly of plants, wildlife, and fungi that may be used for a variety of cultural, subsistence, recreational, and commercial purposes. NTFPs have been and continue to be harvested throughout North America for traditional uses by local Indigenous Peoples and those with rural livelihoods. Understory herbs and shrubs in particular have been used for millennia by Indigenous Peoples for a variety of uses to support livelihoods, including medicinal, edible plant products, cultural purposes, and trade. However, there is concern that forest fertilization may have undesirable effects on NTFPs.

4 https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/wqg_summary_aquaticlife_wildlife_agri.pdf

Understory herbs + shrubs

Understory vascular plants are comprised of herbs, shrubs, and understory trees. In a long-term BC study, 54 herb and shrub species were identified as potential NTFPs. Mean total abundance of plants and specifically the total herb NTFPs were significantly greater in fertilized than in unfertilized stands. For example, in the interior of BC, mean abundance of total herbs, grasses, and fireweed all increased up to 3–4 times with repeated fertilization compared with unfertilized controls (7,9,17,18,28,31). In contrast, in Scandinavia where research has also been conducted, nitrogen fertilization had variable and contradictory effects on berry crops (*Vaccinium* spp.) with respect to site fertility. However, fertilization had no harmful effects on the nutrient concentrations of the berries. The decline in berry crops after fertilization on fertile sites may be related to the enhanced growth of grasses, forbs, and tree cover on those specific sites (13).

All of the dominant grasses and forbs recorded in the BC studies may serve as summer forage for mule deer, moose, elk, and woodland caribou. Grasses and dominant herbs in fertilized stands provided excellent forage and cover habitat for hares and voles (*Microtus* spp.) in Canada and Scandinavia (28,30,31).

Fig. 5. *Fireweed in understory of fertilized stand*

Some shrubs that are important forage in fertilized stands, such as Saskatoon berry, prickly rose, raspberry, and willow species, eventually increased in abundance after fertilization (21). All of these shrubs are readily eaten by deer, moose, and elk, and their structural attributes provide security and improved opportunities for thermal cover. Willow was a major shrub forage species for all three ungulates. Mule deer rely heavily on Douglas-fir and moose on subalpine fir for winter forage (21).

Fig. 6. *Saskatoon berry*

Fig. 7. *Prickly rose*

Fig. 8. *Raspberry*

Some dwarf shrubs such as kinnikinnick, twinflower, and dwarf blueberry declined in fertilized stands in the interior of BC, with a similar pattern in Scandinavia. An increasing competition with rapidly growing crop trees and nitrogen-loving herbs and grasses in fertilized stands may also have contributed to the decline of some dwarf shrubs (21).

Fig. 9. *Kinnikinnick*

Fig. 10. *Twinflower*

Fig. 11. *Black huckleberry*

Mosses + lichens

Mosses and terrestrial lichens often comprise cover on the forest floor. Some studies reported that the abundance of these plants (bryophytes) declined after fertilization. In BC, mosses and terrestrial lichens declined in repeatedly fertilized stands compared with unfertilized stands in an interior long-term study. In fertilized stands, mean abundance of mosses returned to comparable levels in unfertilized stands 5 to 10 years after the last fertilization treatment, however, terrestrial lichens did not. It is important to note that these results were from repeatedly fertilized stands. Fertilization is applied infrequently or only once in a rotation and these reductions in mosses and lichens are not as pronounced (21). Reductions in terrestrial, and potentially arboreal lichens, in fertilized stands could have potential impacts on woodland caribou who rely on these forage sources during winter (21,28).

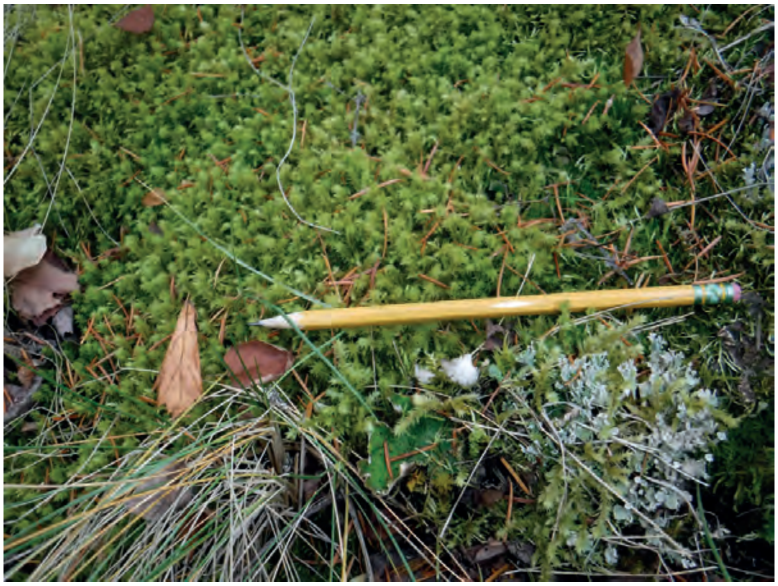

Fig. 12. *Mosses and terrestrial lichens*

Wildlife and Range

Wildlife may be directly affected by exposure to nutrients in their concentrated form immediately after application, and indirectly through growth enhancement of understory plant species. In terms of potential direct effects on animals, amphibians and domestic mammals have the potential to be sensitive to urea used in fertilization programs. Amphibians absorb moisture and oxygen through their skin membranes and could possibly come into direct contact with urea on the forest floor which laboratory experiments have shown can be harmful to some species. However, the greatest potential wildlife hazard is probably in the rare and accidental cases where fertilizer spills at storage or transfer facilities may occur and large amounts of urea are consumed. Ruminant animals including wild ungulates may ingest urea, which is rapidly converted to ammonia but is only susceptible to toxicity following large ingestion of urea. Safety protocols for prompt clean-up of spilled fertilizer and standards for handling and storing fertilizer are in place for all government-funded fertilizer applications in BC so that such risk to wildlife ingestion of fertilizer is unlikely or very minor (27,28).

Relative abundance of mammal species

Impacts of fertilization on forest plant species may have important consequences for the nutrition, cover, and survival of herbivores, particularly in winter which may have indirect effects on wildlife (21). After fertilization, habitat quality and forage quantity generally remain consistent; however, in some situations, studies have indicated that there may be a temporary shift in understorey vegetation, which may favour some mammal species over others. Similarly, relative habitat use by ungulates such as moose and mule deer either increased or did not change in response to fertilization. Quantity of forage mirrored the reported results for abundance of herbs and shrubs for most of these same studies. In all but two cases (i.e., 24 out of 26 cases), forage quantity appeared to increase or not change (24,25,27,28).

In general, both small and large herbivorous mammals responded positively to nutrient-enriched vegetation within fertilized forests. Mammalian predators followed the pattern of mammalian prey population fluctuations, and hence may have benefitted from positive prey responses by voles and snowshoe hares to nutrient-enriched vegetation. Lynx and coyotes, major predators of snowshoe hares, showed increased use of fertilized sites during the peak year of hare abundance. Red fox and weasel were more common in fertilized than non-fertilized sites.

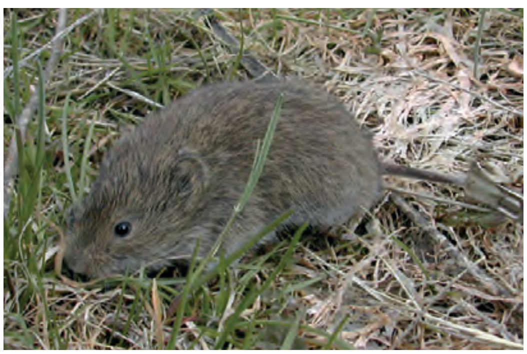

Fig. 13. *Meadow vole*

Fig. 14. *Snowshoe hare*


Fig. 15. *Mule deer*


Fig. 16. *Moose*

Forest fertilization consistently improved forage production for livestock by the increased abundance of herbs and grasses. Fertilization may result in sufficient forage production in the understory vegetation of these forest ecosystems to compensate for cattle grazing that reduces the live forage biomass (17,18).


Fig. 17. *Cattle grazing in fertilized stand*

Fig. 18. *Herbaceous forage within (right) and outside (left) of a cattle exclosure in a fertilized stand*

Fertilized-induced changes in abundance of shrub species showed some increases, some declines, but most showed no change. Only total grasses (increase), prickly rose (increase), and dwarf blueberry (decline) were significantly affected after one application of fertilizer. Repeated applications of nitrogen fertilizer may enhance abundance of some additional forage forbs and shrubs but reduce some dwarf shrubs, mosses, and lichens (21). High nitrogen and crude protein content in forage provides greater nutrition for animals. At five years after the most recent application in BC, fertilization increased crude protein content of pinegrass, a major forage source for wildlife and cattle (18).

Birds

Fertilization either has no effect or some benefits for birds that catch insects from coniferous foliage or ground surfaces particularly in winter feeding habitat. Fertilization may provide winter feeding habitat for those insectivorous birds in some cases. For example, six species of forest grouse showed no response to fertilizer treatments. Repeated fertilizer applications had no effect on bird species richness in spruce forest with mixed canopy closure, but numbers of the seven most abundant species increased by 46% over three years. Another report found that repeatedly fertilized stands had 38% more species and 21% more individuals than unfertilized stands. These responses in the bird community may have been related to changes in food resources (e.g., terrestrial invertebrates) or increased structural complexity in the forest canopy promoted by fertilization (28).

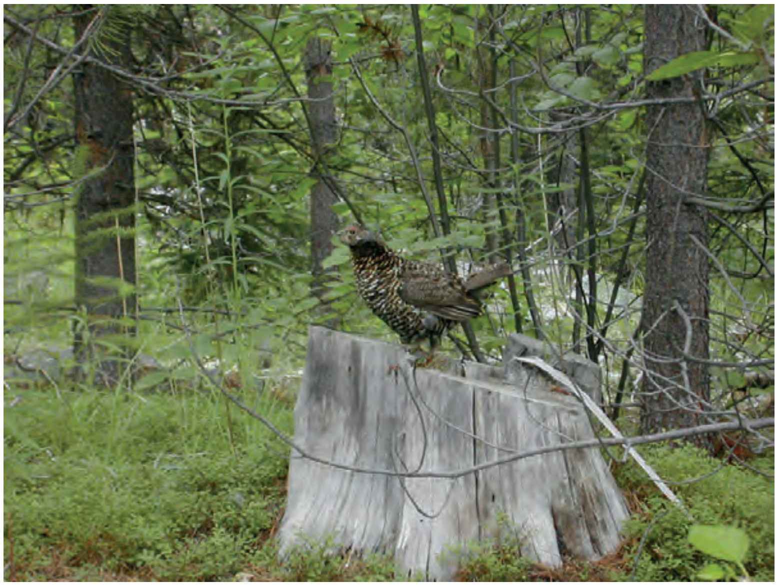

Fig. 19. *Grouse*

Soil biota

Responses of soil animals (mesofauna) to nitrogen fertilization appeared to be species- and dose-specific and ameliorated or accentuated by surrounding micro- and macro-habitat characteristics (28). Responses of ectomycorrhizal fungi showed some shifts in species composition with added nitrogen but no severe losses in diversity, and perhaps most importantly, there was no evidence that fertilization effects were long-lasting (32).

Carbon

Impact of fertilization

Aerial application of nitrogen fertilizer is a cost-effective way to increase carbon sequestration and storage in the forest sector over the short term. Experiments have shown that adding nutrients leads to greater storage of carbon in forest ecosystems, mainly through an increase in tree growth. The greenhouse gas benefit takes into account the net impact of greenhouse gas emissions from the manufacture and transport of the fertilizer, greenhouse gas emissions from the ecosystem following application of the fertilizer, and changes in biomass, dead organic matter, and soil carbon pools. Total greenhouse gas emissions from manufacture and transport of fertilizer are small (~1.8 tCO_2e) in comparison to the incremental carbon that is stored in the forest sector. Emissions of nitrous oxide following application are a significant source of greenhouse gas that must be subtracted from incremental carbon storage(14). Forest disturbance such as harvesting and losses from natural disturbance on stands that were fertilized will reduce, but not entirely eliminate, the carbon benefit, thereby suggesting that it is a rare opportunity for synergy between timber supply and climate change mitigation.

Trees are only one component of carbon storage and soil organic matter may also increase in response to repeated nutrient additions (4,8). The net effect of repeated fertilization on carbon sequestration and greenhouse gas emissions needs to consider variability in forest sites with respect to tree species, soils, and fluxes in carbon pools (8).

Please see the following link for more information: https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nrs-climate-change/mitigation/forest-carbon-initiative/module_2_fertilization_web.pdf.

As forests have complicated structures and provide diverse ecosystem services, their responses to forest fertilization should be examined from various perspectives. A series of studies conducted in BC and other regions have consistently implied that potential adverse impacts of forest fertilization on forest ecosystems would be minor or short-lived. However, there are still large uncertainties for environmentally sound and cost-effective forest fertilization practices. The provincial government is committed to continued investments in forest fertilization research to understand the benefits and consequences to a variety of ecosystem services and provisions.

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Notes

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