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Stumping out tree root disease – An economic analysis of controlling root disease, including its effects on carbon storage in southern British Columbia

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ABSTRACT

Stumping, or removing stumps after logging, is a forestry practice used to control the level of *Armillaria* and *Phellinus* root disease in temperate forests in British Columbia (BC) and elsewhere. A comprehensive assessment of the economic rationale for stumping is largely absent. This study attempts to fill this gap by using a detailed case study of a 46-year old trial and an assessment using growth and yield model simulations of a range of managed Douglas-fir stands in the southern interior of BC. The analysis considers both timber and carbon values over a variety of management costs and site conditions. There are conditions within which stumping is an economically viable strategy, especially on public forestlands, that will improve long-term timber yields and storage of carbon on the land base. Specifically, we find stumping at the Skimikin site increases annual stand productivity by 3.29 m^3/ha/yr at age 44. Under reasonable economic conditions and an interest rate of 3%, this productivity growth leads to a minimum average increase in the soil expectation value (SEV) of $1105/ha. If carbon ($15/t CO_2) is included in the calculations, the increase is a minimum increase of $2586/ha. We find that with carbon, and under similar economic conditions and discount rate, stumping is more profitable than not stumping on even less productive sites than Skimikin. On stands with productivity of 20 m at age 50 years (SI20), we find stumping generates at least $141/ha more than unstumped stands.

1. Introduction

Removal of tree stumps and roots (stumping) is a silvicultural treatment to mitigate for *Armillaria* and *Phellinus* root diseases. These fungal root diseases have global distribution and are of particular interest in the Canadian province of British Columbia (BC) and the U.S. states of Oregon and Washington (Kile et al., 1991; Hood et al., 1991; Morrison et al., 1992). Long-term studies have shown stumping can be effective in BC and elsewhere for limiting the effects of these diseases (Cleary et al., 2012; Morrison et al., 2014; Sturrock, 2000; Vasaitis et al., 2008). In this paper, we conduct a comprehensive economic assessment of this forestry practice in the interior of BC.

There is evidence root diseases have a significant impact on forest productivity (Cleary et al., 2012). In BC, stump removal for forest health reasons has been practiced on about 2000 ha per year over the past decade (Berch et al., 2012). Operational stump removal is mainly practiced in the Interior Cedar-Hemlock ecosystem of BC because of the high tree growth potential there. The ecosystem covers an area of about 5.2 million ha in BC and extends southward into Washington, Idaho, and Montana states. Currently, stump removal is done to establish the most valuable tree species Douglas-fir, which is susceptible to *Phellinus* root disease caused by *Phellinus sulphurascens* Pilát and *Armillaria* root disease caused by *Armillaria ostoyae* (Romagn.) Herink. There are other strategies to mitigate the impacts of root disease such as planting disease tolerant species such as western red cedar [*Thuja plicata* Donne *ex* D. Don] but stump removal is the recommended method vs. no treatment (Sturrock, 2000).

The fungi that cause *Armillaria* and *Phellinus* root diseases and most root diseases in general are dependent on infected tree stumps and woody debris as their food base (or inoculum potential [Garrett, 1956]) to spread and kill the surrounding trees. Stumps created by thinning or harvesting and left in place can greatly increase the site inoculum and the distribution of both diseases, especially *Armillaria* root disease (reviewed by Morrison et al., 1992). Larger stumps have greater risk as their roots extend over more area and have more food base. Both fungi are able to move between the stump and tree and tree to tree via root

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contacts; additionally, *Armillaria* root disease spreads through root like structures called rhizomorphs. Rhizomorphs extend the infection range to about 30 cm beyond colonized roots. Spores, although formed, are rarely the source of new infection. Once a root contacts a colonized root, the fungi grow along the root, and with enough inoculum can occupy the root collar position associated with high probability of killing the tree. Both root diseases also cause tree growth reduction (height and diameter). The disease expresses itself visually aboveground as patches of dead trees scattered randomly on the site.

Stump removal to control root disease is based on sanitation of fungal pathogens that remain in stumps from rotation to rotation. The root collar and lateral roots are removed and left on top of the soil, killing the fungus. *Phellinus* and *Armillaria* root diseases are prevalent in this current study area (Interior Cedar-Hemlock ecosystem), and reduce growth and kill trees throughout the rotation (Morrison et al., 1992). Stump removal has been viewed as site remediation to remove a limiting factor in site potential, and has generally been found to increase site productivity (Cleary et al., 2013; Vasaitis et al., 2008). It has generally been assumed that benefits of stump removal would continue into the following rotation as well, but stump removal trials are not old enough to determine this. The other options to control disease are reviewed elsewhere (Cleary et al., 2013; Morrison et al., 2014, Vasaitis et al., 2008) but briefly they are to establish resistant tree species if the site permits, leave fallow, or chemically treat the stumps. Only the removal of stumps or planting resistant species is used operationally. Impacts can also be reduced, especially for *Armillaria* root disease, by limiting thinning operations. Thinning stands creates stumps with established root contacts to the surrounding trees for the fungus to travel immediately. In contrast, removal of most or all the canopy and the establishment of young seedlings provides a break in time between stump creation and root contacts. Contact between stump roots and seedlings begins about age 10 and is maximized in about 15 years (Cruickshank et al., 2011).

To date, there are few economic studies of stumping to control root rot. A study by Self and MacKenzie (1995) conducted an economic analysis of stumping for the management of *Armillaria* spp. in second-rotation *Pinus radiata* in New Zealand. Using log prices instead of standing timber values, they found a potential economic benefit to the practice. Although the authors did not present net economic benefits, adding together their calculated average future revenue gain ($ 6249/ha) with costs compounded at 8% rate of interest over a 28-yr rotation ($ 3623) results in a future net benefit of $2626 per hectare (1990 dollars). Russell et al. (1986) found stumping significantly reduced damage from *Phellinus sulphurascens* in a coastal Douglas-fir (*Pseudotsuga menziesii*) forest in Washington State. On this highly productive site (estimated tree height of 40 meters at age 50), they found stumping to be profitable and a better option than not stumping or planting Red Alder (*Alnus rubra*), a disease tolerant species. Specifically, at a 7% discount rate, stumped Douglas-fir stands improved stand present net worth by $968/ha over no stumping and $882/ha over Red alder, respectively. Finally, Brunette and Caurla (2016) compared different treatments of *Heterobasidion annosum* in *Pinus pinaster* forests in coastal France. They considered stumping only affected trees (local stump removal), stumping all diseased and surrounding trees (total stump removal), an application of a chemical, and leaving the stand fallow for 5-years after harvest. They found that local stump removal generated higher land expectation values than fallow, chemical, or total removal treatments, though the results depend on when the stand is infected. If contamination occurs during the second thinning of the stand then fallow treatment is better than local stumping.

As there is currently no comprehensive economic assessment of the practice of controlling *Armillaria* root disease by means of stump removal on interior temperate forests of western interior North America, we aim to fill this gap with this study. This information should be useful to forest managers considering the practice of stump removal, as it is an expensive practice, limited to slopes less than 30% to limit impact on soils, and could have impacts on some ecosystem services (Hannam, 2012; Berch et al., 2012). We follow an existing long-term stump removal trial to demonstrate that the technique is effective in reducing the impacts of root disease, and then use the BC stand simulator TASS to project forward. Since this stand has only one density and site index, we provide further modelling using the BC stand growth and yield TIPSY model to ascertain where stump removal might be financially viable over a range of conditions encountered in BC.

2. Materials and methods

We take two different courses of analysis. The first involves a case study of the oldest existing long-term study of stump removal, at Skimikin in the interior of southern BC, and then use the Tree and Stand Simulator (TASS) model to make forward projections. The Skimikin site is one of the oldest stump removal sites in existence that specifically demonstrates the biological underpinnings of stump removal. The second analysis uses simulation results from the Table Interpolation Program for Stand Yield (TIPSY) model to investigate stumping practices across a wider scope of forest conditions in BC. In both sets of analyses, discounted cash flow analysis is used to compare management options. The results apply to the Cedar-Hemlock biogeoclimatic zone (Lloyd et al., 1990) in BC where Douglas-fir is frequently planted.

2.1. Disease impact and growth and yield models

Growth and yield models (like TYPSY) typically do not account for risk factors such as disease and, therefore, must be added separately (Cruickshank et al., 2016). Disease impacts (mortality and growth reduction) were estimated from the Skimikin site (Morrison et al., 2014) and other sites of various ages (Cruickshank 2016; Cruickshank et al., 2011). The resulting disease impact factors and their application to TIPSY (outlined in Stearns-Smith et al., 2004) cover the highest and lowest impacts (called high and low disease impacts) plus a mid range impact category. The impacts were determined at ages 20, 50, 80 and 100 which represent important disease expression events. The low, medium and high impacts and the four stand ages are necessary in order to simplify the analysis, but in reality form a continuous response surface. The study parameters were chosen to determine boundaries where yield/impact combinations would economically support stump removal or not.

2.2. Case study: TASS simulation of the Skimikin site

The case study involves a long-term stumping trial at Skimikin (50°48′N, 119°26′W) near Salmon Arm in the interior of BC. The trial was established in 1968 to determine if removing stumps would reduce mortality from *Phellinus sulphurascens*. The planted species at the trial have been studied, reported on roughly every five years (Morrison et al., 2014), and represent one of the oldest planted stands in the BC interior. During the course of the study it was discovered that *Armillaria ostoyae* (Romagn.) Herink was the principal disease agent of all conifers and hardwoods; although *Phellinus sulphurascens* Pilát is also attacking the Douglas-fir in two plots. The study consisted of 64 0.04 ha plots in a contiguous area. 32 plots were logged and planted and 32 plots were logged, stumped and planted. The plots were planted with either one species or two species. Fig. 1 illustrates the study. Six plots (three stumped and three unstumped) were planted with interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.)Franco) at 1.5 m spacing (4444 stems/ha). The last measurements of surviving and dead trees occurred in the summer of 2012. A site index, or average height in meters of dominant trees at age 50 years, of between 25 and 29 m was estimated for the plots.

Current and future merchantable volume and forest biomass was estimated using the Tree and Stand Simulator (TASS) for the Skimikin site. Stands planted with only interior Douglas-fir were modelled, as the