WILDLIFE AND RANGE PRESCRIBED BURNING WORKSHOP PROCEEDINGS

27-28 October, 1987
Richmond, British Columbia

Edited by M.C. Feller and S.M. Thomson

Assisted by

Protection and Range Branches, B.C. Ministry of Forests and Lands
Wildlife Branch, B.C. Ministry of Environment and Parks
B.C. Conservation Foundation
Association of Professional Biologists of B.C.

The University of British Columbia
Faculty of Forestry

January 1988

IMPACTS OF PRESCRIBED BURNING ON SOIL-VEGETATION RELATIONSHIPS IN THE SUB-BOREAL SPRUCE ZONE

Evelyn H. Hamilton
British Columbia Ministry of Forests and Lands
Research Branch
1450 Government Street
Victoria, B.C. V8W 3E7

ABSTRACT

Impacts of prescribed burning on the patterns of revegetation and on physical and chemical properties of the soils in the Sub-Boreal Spruce Zone are described. The importance of fire severity to the soil microclimate and nutrient regime and to the degree of resprouting, seed bank germination and availability of suitable seed beds for off-site seeds is discussed. Implications for resource managers are discussed.

1. INTRODUCTION

More than half of the area logged in the Prince George and Prince Rupert Forest Regions, of which a considerable proportion is in the Sub-Boreal Spruce Zone (SBS), is burned (British Columbia Ministry of Forests 1986). Prescribed burning is used throughout the SBS to prepare sites for planting and reduce fire hazard. Although this burning is not done specifically for wildlife or range enhancement, these recently burned areas represent important wildlife habitat, particularly for ungulates because of the abundance of browse provided. The focus of this paper is on burning done to meet silvicultural and forest protection objectives. However, the principles and results can be extended to burning for habitat enhancement.

Although the level of monitoring of prescribed burning is increasing, detailed information on the impacts of burning in the SBS is limited. Current practices include the determination of the suitability of the site for burning through evaluation of factors including soil thickness, parent material composition, and slope (Klinka et al., 1984). Weather conditions prior to burning are monitored to enable selection of the appropriate burning conditions. The Prescribed Fire Predictor (Muraro, 1977) is used to predict fire impacts under different burning conditions, and burning is done when conditions are such that risks of severe degradation and fire escapes are minimized. Operational monitoring to determine slash and forest floor consumption has been done in a range of SBS sites. Research to assess impacts of burning on soil fertility (Macadam, 1987a) and on vegetation regrowth patterns (A. Banner pers.

comm., 1987; Hamilton and Yearsley, 1987a) has been initiated in selected ecosystems.

Reviews of the impacts of prescribed burning on forest ecosystems have been compiled by Lutz (1955), Viro (1974), Wells et al. (1979), Viereck and Schandelmeier (1980), Volland and Dell (1981), Wright and Bailey (1982), Wein and MacLean (1983) and Loucks and Radosevich (1986). Information of particular relevance to British Columbia has been summarized by Feller (1982), McMinn (1983), and Lewis (1983). Haeussler and Coates (1986) have summarized information on the response to burning of selected plant species common in British Columbia. Impacts of burning in the SBS zone are reported in Eis (1980), Ballard (1986), Taylor and Feller (1986), Hamilton and Yearsley (1987a), and Macadam (1987a, 1987b).

2. IMPACTS OF BURNING

The impacts of burning on a site will be determined to a great extent by the fire severity, which can be described in terms of duff consumption and degree of soil heating. Significant factors include:

(a) burning conditions including weather conditions prior to and at the time of burning, slash moisture content, slash loading, age and distribution, and forest floor attributes including moisture content and bulk density;

(b) burning prescription (i.e. type of burn, ignition patterns).

2.1 Impacts on Soils

The main impacts of burning on soil include changes in physical and chemical attributes through:

(1) organic layer consumption;
(2) mineral soil exposure;
(3) alteration of temperature regime;
(4) alteration of the moisture regime, and
(5) changes in the nutrient regime.

2.1.1 Forest floor consumption

In the SBS most burns are done under fire weather conditions that result in a depth of burn of only a few centimeters of the forest floor (Macadam, 1987a; E. Hamilton and H.K. Yearsley unpublished). Expected consumption can be pre-determined to some extent on the basis of the slash and forest floor moisture levels using the Prescribed Fire Predictor. Other factors, including the bulk density of the organic layer and fire ignition patterns are also important in determining consumption.

2.2.2 Mineral soil exposure

There is generally limited mineral soil exposure in prescribed burns in the SBS (Taylor and Feller, 1986; Macadam 1987a; E. Hamilton and H.K. Yearsley unpublished data 1987). However sites with thin organic layers and drier sites burned under high Drought Codes (DC) may have up to fifty percent mineral soil exposure after burning. Mineral soil exposure is predicted by the Prescribed Fire Predictor.

2.1.3 Alteration of the temperature regime

There are immediate increases in the temperature at the time of burning and longer term alterations in the soil thermal regime caused by blackening of the soil surface, consumption of the organic layer and removal of vegetation cover (DyByle, 1976; Wells et al., 1979; Feller, 1982; Macadam, 1987b).

2.1.3.1 Immediate fire impacts

Soil heating is dependent on the duration and intensity of the fire and forest floor moisture content. In the moister SBS subzones, where fires tend to be of short duration and fairly low intensity and soil moisture levels are fairly high, lethal temperatures (over 60°C) are generally restricted to the upper few centimeters of the organic layer (Figure 1).

2.1.3.2 Post fire impacts

Soil temperatures in recently burned sites would be expected to be higher, compared with unburned sites. This is attributable to the blackening of the soil surface reducing reflectivity, and the initially diminished vegetation cover and reduced organic layer, each contributing to greater soil heating. Greater fluctuations in the thermal regime would also be expected on burned sites (Fowler and Helvey, 1978; Wells et al., 1979; Feller, 1982).

Soil temperatures in a subhygric SBSj site that had been burned at the end of June 1987 averaged 13 to 16°C at 10 cm during July 1987 when average air temperatures were about 15°C. Average soil temperature at 10 cm in a subhygric site in the SBSf that had been burned the previous summer and was partially revegetated was 13°C during July (E. Hamilton and H.K. Yearsley unpublished data 1987). Average soil temperatures at this depth in comparable unburned sites in the SBSf are typically less than 10°C (D. Spittlehouse pers. comm., 1986). McMinn (1983) also reported that temperatures at 5 cm depth in the SBS rarely exceeded 15°C in unburned sites.

2.1.4 Alteration of the soil moisture regime

Burning will have varying impacts on the moisture content of the organic layer. The heat of the fire will dry out the organic layer to some extent. The development of a more hydrophobic surface layer after

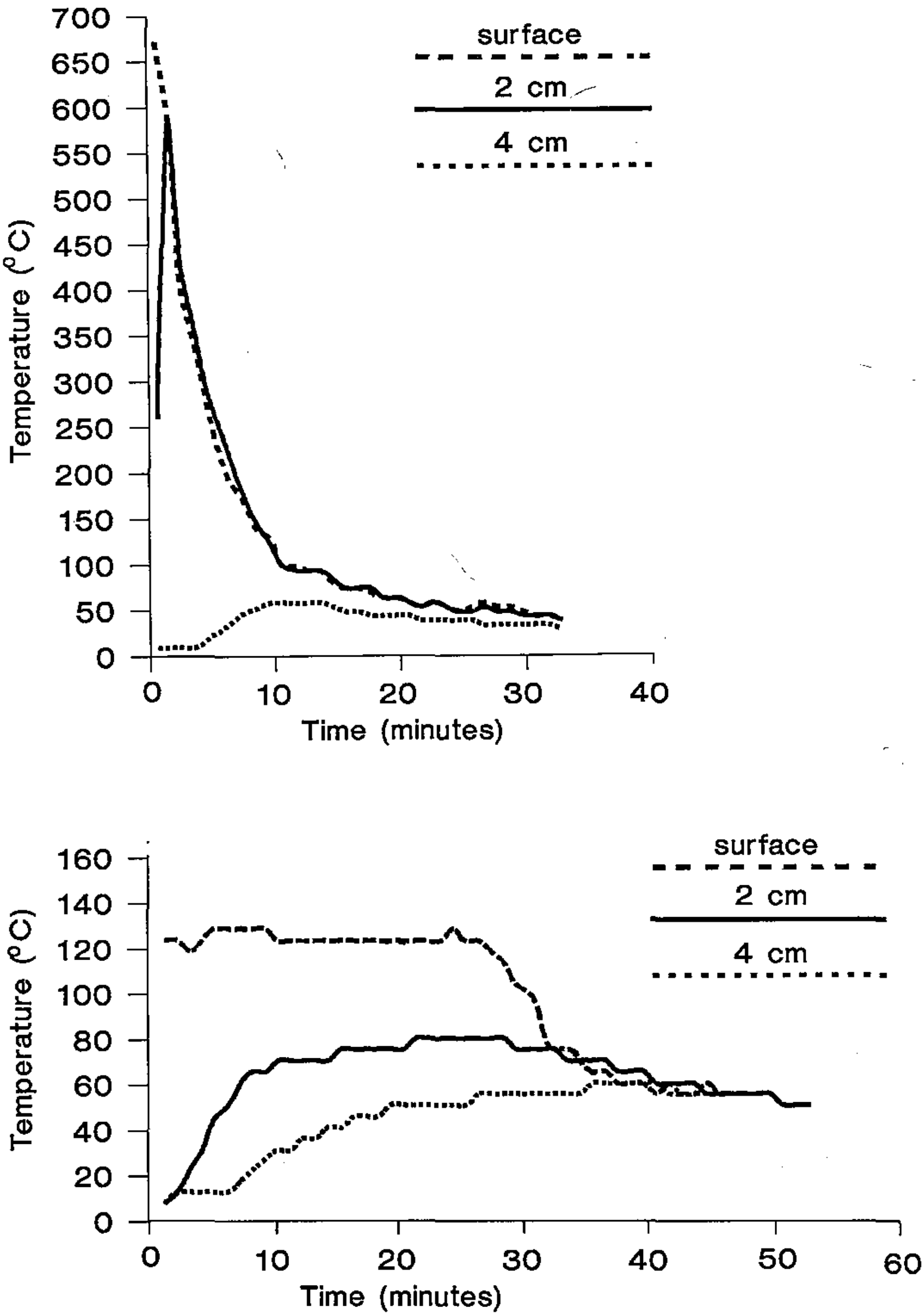

Figure 1. Soil heating at two sites during a prescribed fire in the SBSj subzone.

burning (DeByle, 1976; Wells et al., 1979) and greater overland flow due to vegetation removal may decrease moisture infiltration (Biswell and Agee, 1973). The consumption of organic layers can reduce water storage capacity (Wells et al., 1979; Feller, 1982). However, the removal of vegetation cover may increase soil moisture content by reducing transpirational water loss (DeByle, 1976). The direction and magnitude of changes in soil moisture content after burning will be dependent upon the relative importance of these various factors in different sites.

Observations in the SBS zone suggest that on the submesic sites the moisture content of the upper organic layer declines after burning, while in hygric sites moisture content may be comparable or greater on burned sites.

2.1.5 Changes in the soil nutrient regime

Changes in soil chemistry and biology expected after burning, summarized by Feller (1982) include:

(1) nutrient losses due to volatilization, fly ash loss, leaching and erosion;

(2) short term increases in pH and nutrient availability;

(3) stimulation of the activity of nitrifying and nitrogen-fixing bacteria, and

(4) increased decomposition rates due to higher temperatures.

Considerable variability in the magnitude and direction of changes in nutrient levels after burning is found in the SBS, as in other areas, because of the complex interaction between burning impact, site moisture, and nutrient regime. In general, soil nitrogen declines as a result of the volatilization during the consumption of slash and forest floor materials (Taylor and Feller, 1986; Ballard, 1986; Macadam, 1987a). Some forms of N are subject to leaching or re-immobilization so available and mineralizable N may be reduced (Ballard, 1986). The addition of ash immediately after burning will increase exchangeable cations, pH and available phosphorus levels (Taylor and Feller, 1986; Ballard, 1986; Macadam, 1987a). Mineralizable N may increase over time, especially in wetter sites, as a result of the increase in soil temperatures and accompanying increase in biological activity that may occur after burning. The increase in soil pH generally reported may increase the activity of decomposers and therefore, site fertility (Taylor and Feller, 1986; Ballard, 1986; Macadam, 1987a). However some nutrients including Cu and Fe are less available at higher pH (Ballard, 1986).

2.2 Impacts on Vegetation

Factors important in determining overall revegetation patterns after burning include:

(1) the rate of resprouting and growth of fire tolerant plants;

(2) the germination and establishment success of seed banking species;

(3) the establishment success of off-site seeds;

(4) species replacement dynamics (successional pathways, competitive abilities); and

(5) site temperature, moisture and nutrient regime.

Fire severity will affect some of these parameters.

The ability of resprouting plants to survive burning will be determined by:

(1) burn severity (i.e. depth of organic matter consumed and degree of soil heating);

(2) vegetation phenology and vigor prior to burning; and

(3) depth of any perennating organs.

Intolerant species, which are destroyed by fire and lack a viable seed bank that survives burning, may be lost from the site or may seed-in over time. Many of the bryophytes and lichens and smaller shrubs and herbs that lack substantial underground storage organs, i.e. bulbs or rhizomes, are consumed by fires and re-establish very slowly.

For plants that rely on buried seeds to re-establish, survival success will be influenced by:

(1) severity of the burn since some burns may consume the seed bank;

(2) ability of seeds to survive long burial, predation and decomposition; and

(3) survival success once germinated.

For intolerant species that neither resprout nor have bank seeds that survive burning, rates of re-invasion through seeding-in will be determined by:

(1) the timing of the fire in relation to the period in which seeds are viable;

(2) proximity of seed source;

(3) suitability of seed bed;

(4) establishment success; and

(5) growth rates.

Examples of tolerant species in the SBS include thimbleberry, horsetail and aspen, which often resprout immediately after burning. Other plants such as black huckleberry and black twinberry are somewhat tolerant of burning, but slower to regrow. Seed banking species include elderberry, red raspberry, trailing black currrant, fireweed, and several sedge species.

2.2.2 Overall trends in vegetation development after burning in the SBS

Seed-banking species germinate immediately and in the year following burning. They appear to be especially common where the pre-burn shrub and herb vegetation was limited because of poor site conditions or dense conifer canopies. Resprouting species are particularly abundant after burning where forest canopies had been more open and site conditions conducive to the development of a dense understory. Additional species establish through seeding-in over time where a suitable seed bed exists.

Fireweed is the dominant component of most sites for the first ten or more years. Hardwood cover generally develops most rapidly on drier sites, since these sites generally have the greatest abundance of aspen, which suckers prolifically after burning. Regrowth of forest understory plants is generally most rapid on wet rich sites and slower on drier poorer sites (Figure 3) (Eis, 1980; Hamilton and Yearsley, 1987a).

In some of the drier sites, typical in the SBSe and drier subzones, much of the pre-burn vegetation may be killed and revegetation will result largely from germination of buried and newly arrived seeds (Figure 2). In the SBSj and SBSf subzones many of the plants survive burning and there is often evidence of resprouting within a few weeks after a fire (Figure 3).

Species-replacement patterns will be influenced by the relative growth rates and shade tolerances of the plants that are successful in establishing in a site (Hamilton and Yearsley, 1987a).

2.2.3 Response to burning of plants important to wildlife

The following plants are important forage for key wildlife species in the SBS zone (Blower, 1982).

2.2.3.1 Paper birch (*Betula papyrifera*)

Although fairly slow to establish from seed, birch is often quite abundant by ten or more years after burning in the mesic and drier SBS sites, but is generally not present in wetter sites (Hamilton and Yearsley, 1987a). Root crown sprouting is also evident after burning.

Figure 2. Vegetation development four years after burning in a submesic site the SBSj subzone.

Figure 3. Vegetation development one year after burning in a subhygric site in the SBSj subzone.

2.2.3.2 Trembling aspen (Populus tremuloides)

Aspen suckers prolifically after burning in the SBS, and is especially common in the drier sites that would have had a greater abundance of aspen pre-harvest. Although seeding-in is known to occur in some areas (McDonough, 1979), seedling establishment has not been reported in the SBS.

2.2.3.3 Willows (Salix spp.)

Willows are most common in the wetter sites in the SBS after burning. Many species not common in the forested stands establish through seed rain. Resprouting of pre-existing plants is also common. The most abundant species include Salix discolor, S. bebbiana, S. drummondiana, S. sitchensis, and S. scouleriana (Hamilton and Yearsley, 1987a; Roberts, 1986).

2.2.3.4 Red-osier dogwood (Cornus sericea)

Red-osier dogwood is occasionally present in forests in the SBS and appears to increase in abundance after logging and burning in moist sites. Similar trends are evident in the Interior Cedar Hemlock zone (ICH) (Ketcheson et al., 1985). Forest canopy removal alone is thought to enhance the species abundance (Harcombe et al., 1983). Fire stimulates seed germination, thereby promoting the abundance of the species (Rowe, 1983).

2.2.3.5 Saskatoon (Amelanchier alnifolia)

Saskatoon appears to be slow to recover from the burning intensities observed on some sites in the SBS but survives and is fairly common in mesic and drier sites in the SBSj subzone (Hamilton and Yearsley, 1987a).

2.2.3.6 Black huckleberry (Vaccinium membranaceum)

Black huckleberry is set back by burning in the mesic and drier sites in the SBS zone. Cover was reduced by burning and recovery was very slow in the SBSe1 subzone (A. Banner unpublished data, 1987). Slow regrowth was also reported in the first ten years after burning in the SBSj subzone (Hamilton and Yearsley, 1987a).

2.2.3.7 Prickly rose (Rosa acicularis)

Prickly rose appears to be tolerant of typical burning conditions on the mesic and wetter sites, but is diminished by burning on drier sites in the SBS zone. R. acicularis increased in abundance after burning and mechanical treatments in the submesic and wetter sites in the SBSj, and was most common in the Horsetail sites.

Rose decreases immediately after wildfire, gradually increases, and then declines as forest canopy closes in the boreal forest (Foote, 1983). Ahlgren and Ahlgren (1960) reported that R. acicularis was only common after light burns in the boreal. Wright and Bailey (1982) report that R. acicularis is favored by fire although less fire tolerant than other species of rose. Decreases in species abundance after logging and burning were found in the ICH (Wittinger et al., 1977).

2.3 Burning/Soil/Vegetation Interactions

The response of ecosystems to burning will depend upon the interactions of fire severity, site, soil and vegetation factors (Figure 4). Weather conditions prior to burning will determine fuel moisture content, an important determinant of burning severity. Burning severity will directly influence both the impact on soil nutrient levels and the amount of mineral soil exposure and will determine, in part, plant survival and therefore vegetation regrowth patterns. The amount of mineral soil exposure will influence the floristic composition, since some species establish almost exclusively in mineral soil. Nutrient levels, soil moisture regime and soil temperatures, which are influenced by burning severity, will have a direct effect upon overall vegetation regrowth rates.

Where there is an increase in available nutrients and higher soil temperatures after burning, rates of vegetation growth of surviving species would be expected to be enhanced over pre-burn levels. However, where burning is of sufficient severity to kill pre-existing vegetation it may take quite a while for revegetation through off-site seed establishment to occur, and therefore revegetation will be slow.

3. SUMMARY

Post-burning vegetation development patterns can be predicted to some extent if one has information on:

(1) fire severity;

(2) impacts of burning on soil temperature, moisture and nutrient regime;

(3) nature of pre-burn vegetation
- tolerance of species to burning
- seed bank composition;

(4) availability and survival success of off-site seeds;

(5) vegetation growth rates, competitive ability including shade tolerance in particular, and species replacement patterns.

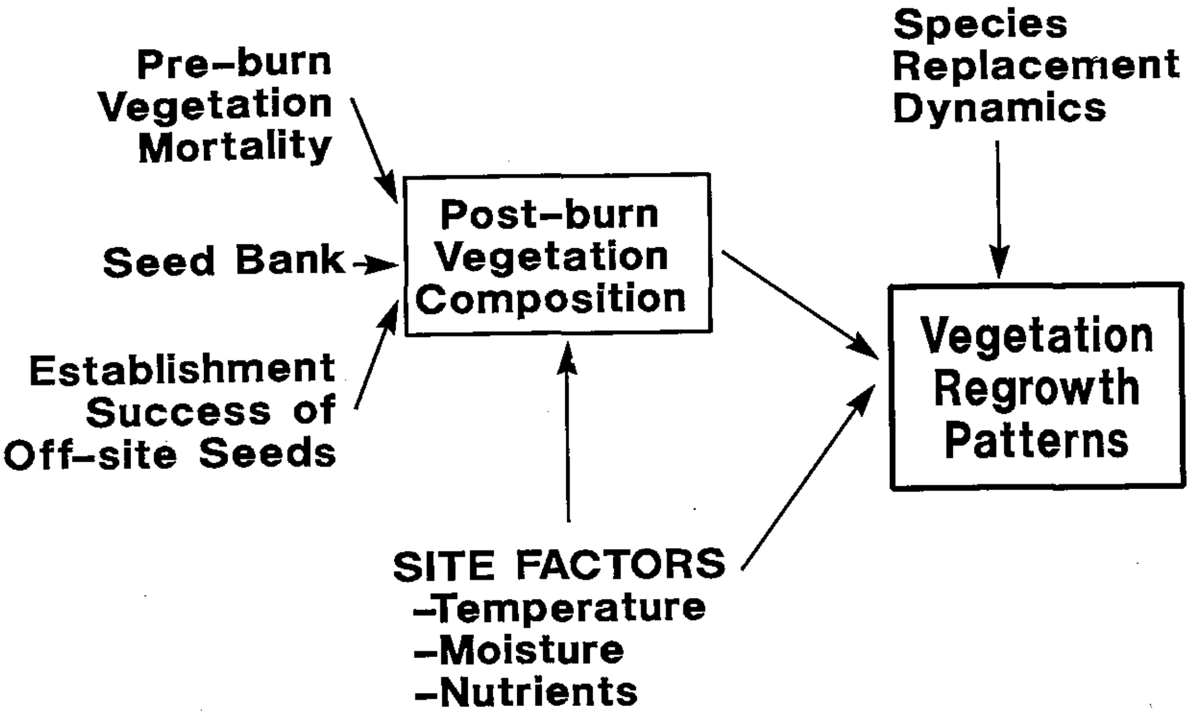

Figure 4. Relationships between fire impacts, soils and vegetation development patterns.

In the SBS zone burning is generally done under fire severity conditions that result in consumption of less than 40% of the forest floor and less than 10% mineral soil exposure. Heating of the upper organic layer during a fire will kill some of the pre-existing vegetation. However, resprouting of many species, in particular thimbleberry and aspen, may be expected on most sites the following year. Soil heating also appears important in stimulating the germination of seed-banking species like elderberry and red raspberry. The degree of organic layer consumption and mineral soil exposure has implications for the establishment of species that require a mineral soil seed bed as well as for the soil thermal regime. Increases of several degrees in the temperatures in the organic layer after burning, reported from some SBS sites, may increase nutrient availability and enhance vegetation growth. However, significant nutrient losses may occur if burning impacts are excessive and these losses, along with soil drying resulting from burning, would be expected to slow revegetation rates. Moisture regime changes are expected after burning, although the direction, magnitude, and importance of any change is dependent upon the interaction of burning severity, vegetation cover, and thermal regime and is therefore difficult to predict. Once established, the relative growth rates and competitive abilities of different species will determine revegetation patterns.

4. MANAGEMENT IMPLICATIONS

The burning prescription selected will determine fire severity, which will affect site factors including soil temperature, moisture and nutrient regime and post-burn vegetation development patterns, and therefore future wildlife habitat and range values.

5. ACKNOWLEDGEMENTS

Thanks are extended to cooperators H.K. Yearsley and B. Hawkes, to A. Macadam, A. Banner and J. Muraro, who provided information from their research and to J. Parminter for providing information from the operational burning monitoring program. Appreciation is also extended to the reviewers including A. Banner, T. Ballard, M. Feller, A. Macadam, A. MacKinnon, J. Parminter and D. Spittlehouse for their helpful comments.

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