Some Slashburning Effects on Soil and Trees in British Columbia

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Studies on slashburning effects in British Columbia have yielded a range of results. On some sites, fire effects on soil temperatures or competing vegetation may account for better tree growth on burned than unburned areas. In some cases, short-term effects on browse damage may temporarily obscure long-term effects on height growth. Slashburning effects on tree nutrient status vary between study areas, but significant impairment of nutrition as a result of burning, which has been inferred in the central interior, was not found in coastal studies. On some coastal study sites, post-burning VA mycorrhizal colonization and several soil and foliar nutrient variables are related to one or more of: fire severity class, residual duff thickness, consumption of fine and medium fuels, and change in mineral soil exposure. However, it is not yet known whether such relationships apply at other locations.

INTRODUCTION

Several studies in British Columbia have examined slashburning effects on soils, trees, and competing vegetation. A major review of such studies was published by Feller (1982). Dissimilar results have been obtained in some of the studies, making regional generalizations difficult. The objective of our paper is to review some findings, identifying disparities and suggesting possible reasons for them. Our intent is not to catalogue the results of all studies in detail, but to focus on a few which might provide insight about variables responsible for some dissimilar findings.

CENTRAL INTERIOR BRITISH COLUMBIA SLASHBURNS

Analysis of slashburning effects on spruce in British Columbia was begun in the early 1980's. White spruce plantations (3 to 8 growing seasons after planting) over a wide range of soil and site conditions were selected by Ministry of Forests personnel in the Prince George West, Prince George East, and Horsefly areas (52° to 55° N, and 700 to 1300 m elevation). In each plantation, the planted tree nearest to each of several randomly selected points was considered as a candidate for foliage sampling and analysis (using methods of Ballard and Carter 1986) and height increment measurement. Each candidate tree was classed according to its planting stock type and the soil disturbance in its immediate vicinity. A total of 15 such randomly selected trees was accumulated in each class present. For purposes of the present study, plantations with mechanical site preparation were excluded, and disturbance classes indicating mechanical disruption of soil horizons were excluded, as such disruption (inferred to have resulted from skidding) could obscure differences attributable to burning. Also, for the present study, data for different stock types in the same cutblock were averaged, data for multiple cutblocks in the same locality were averaged (to avoid excessive weighting for that locality) and data from two plantations near mineral ore bodies were excluded because of nutritional anomalies (abnormally high copper levels). These procedures yielded averaged data for each of 16 plantation localities, which were compiled for Mann-Whitney U tests to compare leader lengths and foliar concentrations of eleven nutrients on burned vs. unburned areas (Table 1). Leader length was greater ($\alpha = 0.005$), while foliar "active" Fe and N concentrations were lower ($\alpha = 0.02$ and 0.05, respectively) on burned areas. Concentrations of a few other nutrients also tended to be lower on burned areas, but these other differences were less significant.

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Table 1. Slashburning effects on leader length and foliar nutrients concentrations in young white spruce in central interior British Columbia. [‡]

X	[†] R_u	$\bar{R}_u > \bar{R}_b$?	U	α	Conclusion from test
Leader	18	no	52	0.005	Leader length greater on burned areas
Foliar Fe	63	yes	48	0.02	Foliar Fe is lower on burned areas
Foliar N	61	yes	46	0.05	Foliar N is lower on burned areas
Foliar S	60	yes	45	0.07	Foliar S lower; significance marginal
Foliar P	59	yes	44	0.09	Foliar P lower; significance marginal
Foliar Mg	58	yes	43	0.10	Foliar Mg lower; significance marginal
Foliar Mn, Zn, B, K, Ca				> 0.10	No significant difference

[†] R is the rank sum, $\bar{R}$ is R/n, where n is the number of observations, α is the probability level associated with the U statistic for $n_u = 5$ and $n_b = 11$.

[‡] H_o : X is the same on burned (b) and unburned (u) sites.Mann-Whitney U tests; higher rank is assigned for greater X.

Lower foliage N levels on burned sites are of concern because nitrogen deficiency is common in these boreal forests. Swan (1971) suggested using 1.5, 1.3 and 1.1 percent foliar N as thresholds separating sufficiency and mild, moderate and acute deficiencies in white spruce. Of the 16 plantation-locality data sets considered here, only 3 are N-sufficient, and 3 (all on burned sites) are acutely N-deficient, according to these criteria. The frequency of "moderate" and (or) "acute" N deficiency on burned areas is significantly higher than on unburned areas (alpha = 0.013), as seen in Table 2. (Although a similar test involving foliar Fe would be of interest, well documented thresholds for interpreting Fe status are not available for spruce.)

Table 2. Slashburning effect on frequency of "moderate" and (or) "acute" N deficiency in young white spruce in central interior British Columbia.

H_o : Proportion of burned sites is not greater than proportion of untreated sites with "moderate" or "acute" N deficiency in spruce. [Threshold between "moderate" and "mild" deficiency is taken as 1.30 percent N, from Swan (1971).]

	burned	unburned	total
"Moderate" or "acute" deficiency	8	0	8
"Mild" or no deficiency	3	5	8
TOTAL	11	5	16

$\alpha = 0.013$ [One-tailed Fisher exact test]

Conclusion: Reject H_o ; "moderate" and (or) "acute" N deficiency is more common on burned sites.

About 1970, the Canadian Forestry Service had measured various slashburn severity parameters on burn treatment plots near McLeod Lake, at about 55° N. In the mid-1980's, growth and nutrition of planted white spruce on these plots were evaluated (Ballard and Hawkes 1989). Simple regression analysis of plot average data (average of, usually, m = 15 observations per plot) was carried out for n = 9 plots which had been pre-selected on the basis of physiographic similarity. Spruce foliar N concentration and soil (0-15 cm) mineralizable N (anaerobic 2-week incubation at 30°C) 13 years after burning were negatively related to exposed mineral soil, evaluated immediately after burning ($r^2 = 0.50$, $P < 0.05$; and $r^2 = 0.47$, $P < 0.05$, respectively). Spruce foliar Cu concentration 13 years after burning was negatively related to exposed mineral soil, evaluated immediately after burning ($r^2 = 0.72$, $P < 0.01$). Spruce current annual height increment 13 years after burning was negatively related to residual duff thickness evaluated immediately after burning ($r^2 = 0.43$, $P < 0.1$).

In these Central Interior studies, the growth improvement is attributed to increased soil temperature during the growing season. Late summer soil temperature measurements, fitted to a model of soil temperature variation (Ballard and Hawkes 1989) indicated that at a depth of 10 cm from an intact mor humus surface, these soils are unlikely to exceed 10°C for a significant period during the growing season. Dobbs and McMinn (1977) had shown that spruce growth was extremely limited at soil temperatures of 10°C or lower and that removal of vegetation and humus can dramatically increase root zone temperature. One may speculate that siderophore reduction (Perry *et al.* 1984) and higher pH after burning may have affected Fe availability and uptake, higher pH may have reduced Cu availability, and volatilization losses (Knight 1964, DeBell and Ralston 1970) may have resulted in reduced available, as well as total, N levels. The implication is that on very cold, mor humus sites, growth may be benefited by slashburning, although nutrition may be impaired.

COASTAL SLASHBURNS

A study by Knight (1964) concerned a 1956 slashburn on Vancouver Island. Knight concluded that there was a substantial N volatilization loss, that burning had no significant effect on soil water content (measured over the first 3 years following the fire), and that fire had no significant effect on foliar concentrations of N, P, K, Ca or Mg; but that tree growth rates were significantly lower in burned areas. Knight's finding of growth reductions helped arouse concern about possible detrimental effects of burning in the province, and provided a frame of reference for comparison with subsequent studies. Pertaining to a single site, however, it was uncertain whether the findings were site-specific or whether they were more widely applicable. In 1987, we re-measured trees on Knight's study area. Mean Douglas-fir heights on burned and unburned areas were virtually identical, 20.6 and 20.5 m, respectively ($n_1 = n_2 = 15$). Evidently, the detrimental effect of burning on growth was temporary.

Vihnanek studied salal-dominated sites on the dry, east side of Vancouver Island (Vihnanek and Ballard 1988). The age of the burns ranged from 5 to 15 years. Non-parametric sign tests showed that Douglas-fir height growth and basal diameter were greater on burned areas; foliar concentrations of P, K, Ca, Fe and B were greater on burned areas; foliar concentrations of N, Mg, S, Zn and Cu were similar on burned and unburned areas; and salal height and cover were less on burned areas (Table 3). It is plausible (but not proven) that improved nutrition and improved growth of Douglas-fir on burned areas were due to reduction of the severe competition from salal.

Vihnanek classified burns according to fire severity, inferred from examination of residual fuels. With high burn severity, salal cover and height were much lower, while Douglas-fir height growth and stocking were higher than on unburned areas; with low burn severity, the differences were not as great. Such findings suggest another reason for discrepancies between findings of some studies: some effects of light burning might be obscured by inherent site variability, while effects of severe burns might be detected more consistently.

Short- and long-term effects of fire on tree growth are not necessarily similar. For example, a Norwegian study (Braathe 1973) noted that, on some sites, although early growth might be improved by burning, growth in the longer term might be worse on burned areas. However, the tree height-over-age curves obtained by Vihnanek and Ballard (1988) show essentially similar or better growth on burned areas, with no longer-term tendency for a relative growth decline. Our recent re-measurements on Vihnanek's study areas extend that finding to periods up to 18 years after burning. However, short-term trends do not always persist: in a few cases we found that a long-term tendency for greater tree heights on burned areas followed an early period of slightly lesser heights which possibly reflected browse damage. An example is the 16 year old plantation illustrated in Fig. 1; at this site, 56% of the trees on the burned area showed symptoms of browse damage, while no trees on the burned area were browsed. Thus, early post-burn evaluation of the fire effects on tree heights may yield a poor prediction of long-term trends.

Table 3. Comparison of Douglas-fir plantations in paired burned and unburned areas on salal sites, eastern Vancouver Island. Summary of non-parametric sign tests (n = 20), from Vihnanek and Ballard (1988).

Probability level (P)	**Conclusion**
<0.05	H A : Tree height growth greater on burned.
<0.001	H A : Tree basal diameter greater on burned
<0.05	H A : Tree foliar P, K, Ca, Fe B greater on burned.
>0.1	H O : Tree foliar N, Mg, S, Zn, Cu same on burned.
<0.001	H A : Salal height less on burned.
<0.01	H A : Salal cover less on burned.

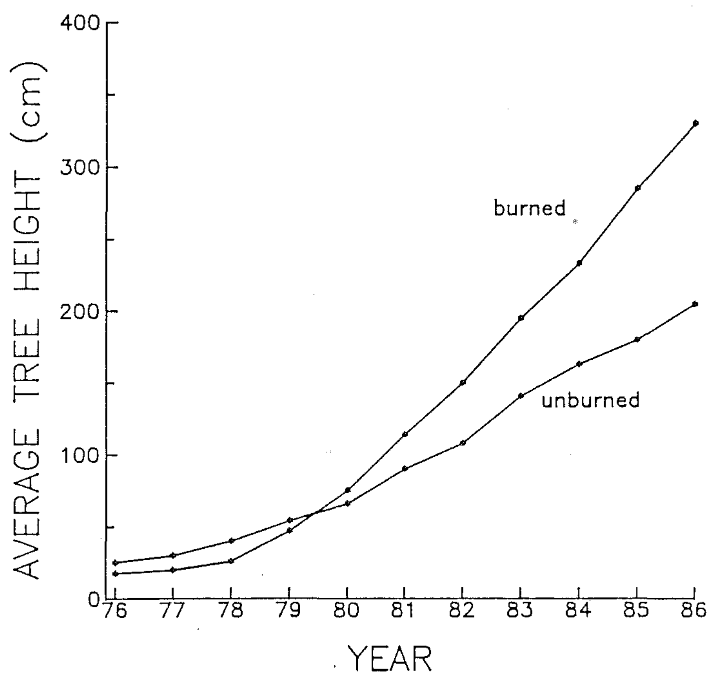

Fig. 1 Comparison of average tree heights on burned and unburned areas, from re-measurements on a site studied by Vihnanek and Ballard (1988). The last year of measurement is 16 years after the burn.

Characteristics of numerous small plots in areas slashburned in 1938, at Franklin River on Vancouver Island, were documented by T. Wright in 1941 and 1942. Using Wright's detailed notes and a metal detector (to find railroad spikes placed at plot centres), Curran has accurately relocated and sampled these plots. Diameter at breast height of trees in 1985 tended to be negatively related to salal cover evaluated by Wright in 1942; this was true for Douglas-fir ($P < 0.15$) and western hemlock ($P < 0.15$) at "Branch 16", and for western hemlock ($P < 0.1$) and western redcedar ($P < 0.1$) at "Branch 17". These very weak but recurrent relationships, discernible on 47-year-old burns, are consistent with the unconfirmed hypothesis suggested above, that better tree growth may result where fire reduces substantial salal cover. (However, because pre-burn salal data are not available from Wright's study areas, the salal relationship there cannot be definitely attributed to fire effects.)

Fire effects have commonly been evaluated by analysis of variables averaged over large treatment plots, which may be so few as to limit severely any statistical confirmation that differences were caused by burning. An alternative is to collect pre- and post-burn data at "microplots" within treatment areas, enabling pairing of data (e.g. duff reduction and tree growth) from each of several locations within a large treated area. Such data are available from some well documented burns carried out by the Canadian Forestry Service from 1968 to 1970, at Mission Tree Farm, about 50 km east of Vancouver. Each of the large treatment plots typically contains 25 microplots (16 m^2 at 20-m spacing in a 1-ha grid), which were permanently marked with metal stakes, where we have been measuring tree growth, foliar nutrients, and soil properties.

Table 4 presents regression relationships between some 1985 tree data and the CFS fire data obtained in 1970 on one of these plots (Lafferty, R. 1972. Regeneration and plant succession as related to fire intensity on clear-cut logged areas in coastal cedar-hemlock type: an interim report. Can. For. Serv. Pac. For. Res. Centre, Victoria, B.C. Internal Report BC-33. Unpublished). Residual duff and fuel consumption variables appear to account for approximately one-fourth to one-half of the variation in tree height, foliar N and foliar Fe, three variables substantially affected by fire in the Central Interior studies. It remains to be seen whether such relationships apply over a larger area.

Table 4. Some relationships of 1985 tree data with CFS (Canadian Forestry Service) fire data measured in 1970 on CFS Plot T10 at Mission Tree Farm.

Species	Dependent variable	Regression		Independent Variables	
		r^2	P	Sign	Variable
Douglas-fir	Total height	0.269	0.023	-	Residual Duff
	Foliar N conc.	0.463	0.001	-	Large fuel consumption
	Foliar Fe conc.	0.299	0.013	-	Residual Duff
Western hemlock	Total tree height	0.368	0.021	+	Residual Duff
	Foliar N conc.	0.237	0.040	+	Fine fuel consumption
	Foliar Fe conc.	0.564	0.007	-	Residual duff †(0.004)
				+	Medium fuel consumption (0.072)
				-	Incr. mineral soil exposure (0.016)

†Numbers in parentheses are P values for individual variables in the multiple regression.

Table 5. VA mycorrhizae on western redcedar. Growth chamber study using burned and unburned soils sampled at a site near Sproat Lake, Vancouver Island.

	Unburned Soil	"Light" Burn	"Severe" Burn
% of roots colonized, averaged for all trees	11	28	4
colonized trees/total trees, as %	40	41	22
% of roots colonized, averaged for colonized trees only	28	39	18

Fire effects on early nutrition and growth of plantations may be influenced by mycorrhizal development. With help from W. Beese and MacMillan Bloedel Ltd., we sampled soils at a slashburn area near Sproat Lake on Vancouver Island, before and after burning. From various fuel and residue data, the post-burn soils were classed as "lightly" or "severely" burned. Western redcedar was grown in samples of these soils in a growth chamber, and roots were subsequently examined for VA (vesicular-arbuscular) mycorrhizae. The percentage of colonized roots per tree was averaged for all trees in a treatment, to give the first row of figures in Table 5. The light burn resulted in higher colonization of roots, and the severe burn resulted in lower colonization, compared with the control. The light burn also increased the percentage of trees which were colonized by VA fungi, shown in the second row of figures in Table 5.

Such fire effects on mycorrhizal development are not universal. W. Chapman (unpublished) looked at ectomycorrhizae on Douglas-fir and western hemlock in a similar growth chamber study, with pre- and post-burn soils we sampled from a recent burn at Mission Tree Farm. He found that burned or unburned, light burn or severe burn, made little difference: there was abundant colonization of roots, regardless of treatment.

CONCLUSIONS

In a large area of central interior British Columbia, tree nutrition tends to be impaired, but growth is usually improved (probably because of ameliorated soil temperatures) where cold, mor humus sites were slashburned. In south coastal British Columbia, the detrimental effect of burning on early height growth reported by Knight (1964) at one site has given way to no significant effect in a re-evaluation 31 years after the fire. Browse damage soon after a fire is one factor which can obscure longer-term effects on height growth. On eastern Vancouver Island, some positive effects of fire on tree growth and nutrients may partly reflect a reduction of salal competition by burning. Fire effects are likely to be less obvious and less consistent where fire severity is light or variable.

Thus, it is plausible that such variables as soil temperature, stand age, plant competition, and fire severity are implicated in some of the disparate results discussed here. Retrospective samplings of past burns, such as those described here, cannot rigorously explain such results. However, because few experimental burn studies with elaborate design and treatments existed in British Columbia until recently, the retrospective approach continues to have some usefulness in evaluating and attempting to predict longer-term effects.

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