CHANGES IN AERIAL FIRE SUPPRESSION REQUIREMENTS FOLLOWING PLANTATION PRUNING

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Abstract

A twenty-one year old white spruce plantation growing on the Petawawa National Forestry Institute (PNFI) research area was selected as a sampling site to determine the fire hazard following pruning. The total available surface fuels were sampled prior to stand treatment: combined litter and duff depths were measured, and their moisture contents and heat yield determined. The trees were pruned to a height of 1.8 metres, the pruned materials sorted into green and dry fuels and their mass and moisture contents found. The potential available energy of these pruned fuels increased the energy budget on the plantation floor by 19 percent. This addition of fine fuels would raise aerial suppression requirements by 20 percent. The cost of suppression would increase proportionately if plain water was applied, but if long-term retardants were used additional expenditures of $10.52 to $43.74 per metre of line built can be anticipated.

Résumé

Une plantation d'épinette blanche âgée de 20 ans poussant sur le terrain de recherche de l'Institut forestier national de Petawawa (IFNP) a servi à la détermination expérimentale des risques de feu après l'élagage. La totalité du combustible de surface avait été échantillonnée avant le traitement: l'épaisseur et l'humidité de la litière totale ont été mesurées et la production énergétique a été déterminée. Les arbres ont été élagués à une hauteur de 1,8 m, et les déchets de l'opération classés en combustibles verts et en combustibles secs; leur masse totale ainsi que leur humidité ont été déterminées. L'énergie potentielle de ces déchets a accru le bilan énergétique au sol de 19 %, ce qui accroîtrait de 20 % les exigences de la suppression. Le coût de cette suppression augmenterait proportionnellement si de l'eau pure était employée, mais avec des retardants à long terme, on pourrait s'attendre à des dépenses additionnelles de 10,52 à 43,74 $ par mètre de ligne établie.

INTRODUCTION

It is apparent that natural regeneration will not offset the annual demands for forest products. More planting must be initiated to ensure a stable supply of raw materials for the various forest industries. Presumably, during the life of a plantation, some form of stand tending (commercial thinning, pre-commercial thinning, or pruning) will be carried out. With increased unemployment and the advent of job creation programs, stand tending is an increasingly common activity. These activities will be of major concern to fire managers who are presently very much aware of the impact of these treatments. Any form of treatment which increases the available fuel on the forest floor compounds fire management problems.

Several studies on the increase in fire hazard following thinning have been carried out in North America. In a pre-commercial lodgepole pine (Pinus contorta Dougl. var. latifolia Engelm.) thinning operation in Colorado (Alexander and Yancik 1977), it was found that following treatment, the fuel loading increased by 12.5 tonnes per hectare, an increase of 52.7 percent, and the predicted rate of

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fire spread on this site would be approximately 3.5 times faster after thinning compared to an unthinned stand. After pre-commercial thinning in coastal douglas fir (Pseudotsuga menziesii (Mirb.) Franco) and interior lodgepole pine stands in British Columbia (Hawks and Lawson 1980), it was determined that the fuel loading increased by 94.6 and 30.1 tonnes per hectare respectively from the original loadings of 104.9 and 109.7 tonnes per hectare (increases of 47.4 and 21.5 percent). However, very little is known about the effect of pruning on fuel loading.

This preliminary study in a white spruce (Picea glauca (Moench) Voss) plantation at PNFI was initiated to determine the amount of available fine fuel that is added to the forest floor following pruning, and to determine the changes in suppression effort required to control fires in stands where improvements have been carried out.

Study area

The 2.5 hectare area chosen for sampling was planted with 2+2 white spruce stock in the spring of 1965.

Six thousand and eighty seedlings were planted at a spacing of 1.2 m x 1.2 m, with 988 stems forming the border rows. Seventeen years later (1982) the mean average diameter at breast height (dbh) in this plantation was 10.5 cm and the average height 7.2 m.

The major available combustible fuel prior to pruning consisted of white spruce litter (needles and fine twiglets) and duff, with scattered clumps of herbs, mosses, shrubs, and grasses occurring mainly in openings where trees had died. These various vegetative species contributed minimally to the fuel load, hence they were not sampled.

Field work

Fifty 0.01 m^2 litter and duff samples were collected, depth to mineral soil was measured (Figure 1) and the moisture content of extracted samples determined (Figure 2).

A composite sample of litter and duff was ground, pelletized, and the available energy (k J/g) was determined in the laboratory using an Oxygen Bomb Calorimeter.

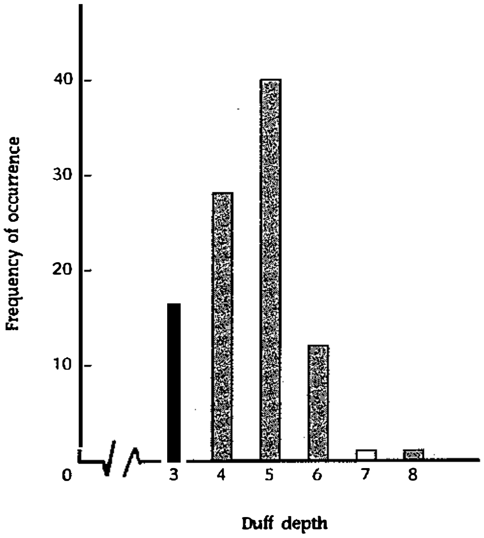

Figure 1. Frequency of duff depth occurrence by centimetre class.

Tree diameters were measured to the nearest 0.1 cm dbh and summarized in 2 cm dbh classes on every 5th row throughout the plantation (excluding the border rows), and heights of randomly selected trees were measured to the nearest 0.1 m. The size class distribution predominated at the 10 and 12 cm dbh classes (Figure 3).

The branches on the sampled trees were pruned to a height of 1.8 m above ground level, sorted as live or dead and the two classes were weighed to the nearest 0.05 kg. The mass distribution of the pruned live and dead fuels varied somewhat from one diameter class to another (Figures 4 and 5).

Separate samples of live needles and green branchlets, live branchwood, dead branchlets, and dead branchwood were collected in the field, transported to the laboratory, and their respective oven-dry moisture contents were determined (Figure 6).

RESULTS

The data in Figure 4 indicate that the fuel mass added by pruning tended to increase

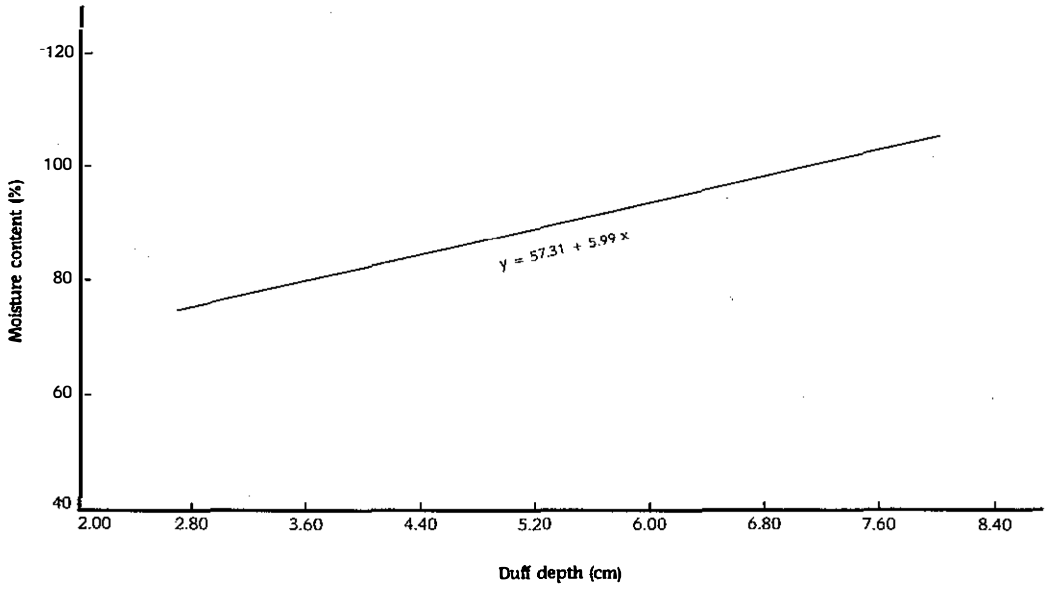

Figure 2. Relationship of moisture content to duff depth.

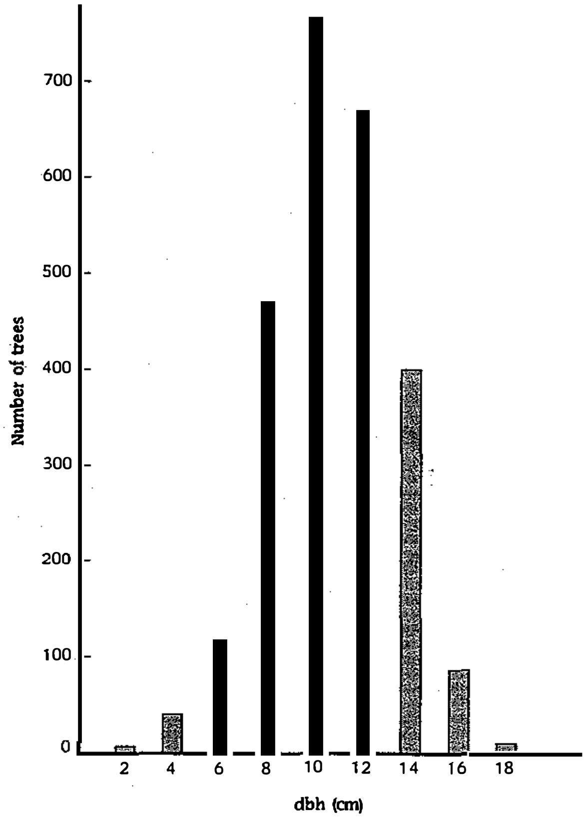

Figure 3. Number of trees per hectare by diameter class.

as the diameter class increased. The major contribution to mass increase was the greater proportion of dead branch mass per dbh class. The estimated fuel mass contributed by each dbh class towards the total, on a per hectare basis expressed as a percent percentage, was:

dbh cm	% added
6	11.4
8	13.9
10	17.4
12	17.4
14	21.2
16	18.7

There was a significant amount of fuel added by carrying out light pruning relative to the original fuels (Figure 5). Prior to pruning, available fuel in the form of litter and duff totaled 3.024 kg/m^2 with a potential energy value of 60.97 MJ/m^2. Pruning added 0.686 kg/m^2 with a potential energy value of 14.69 MJ/m^2 (a 19 percent increase).

The average oven-dry moisture contents of the sampled materials were: litter and duff, 85 percent; live needles

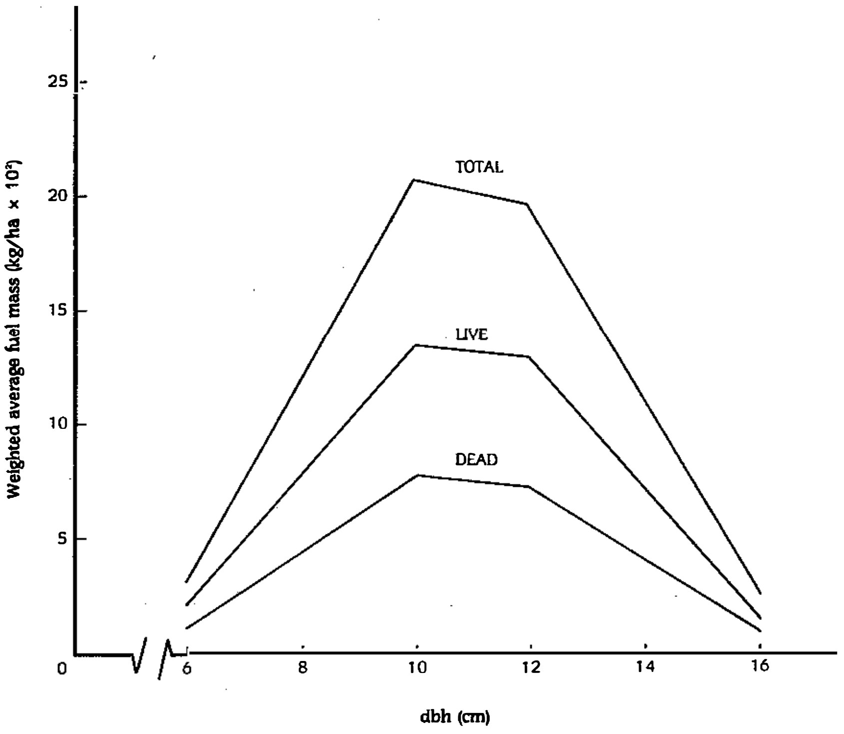

Figure 4. Average mass of pruned fuels added to site per tree by diameter class (oven-dried basis).

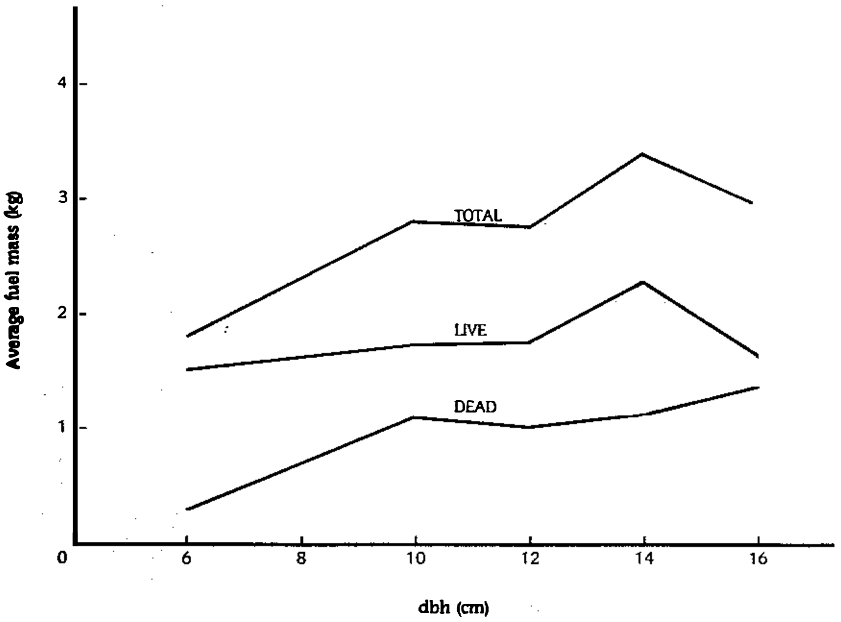

Figure 5. Estimated mass of pruned fuel deposited on site on areal basis by trees of various diameter classes (mass on oven-dry basis).

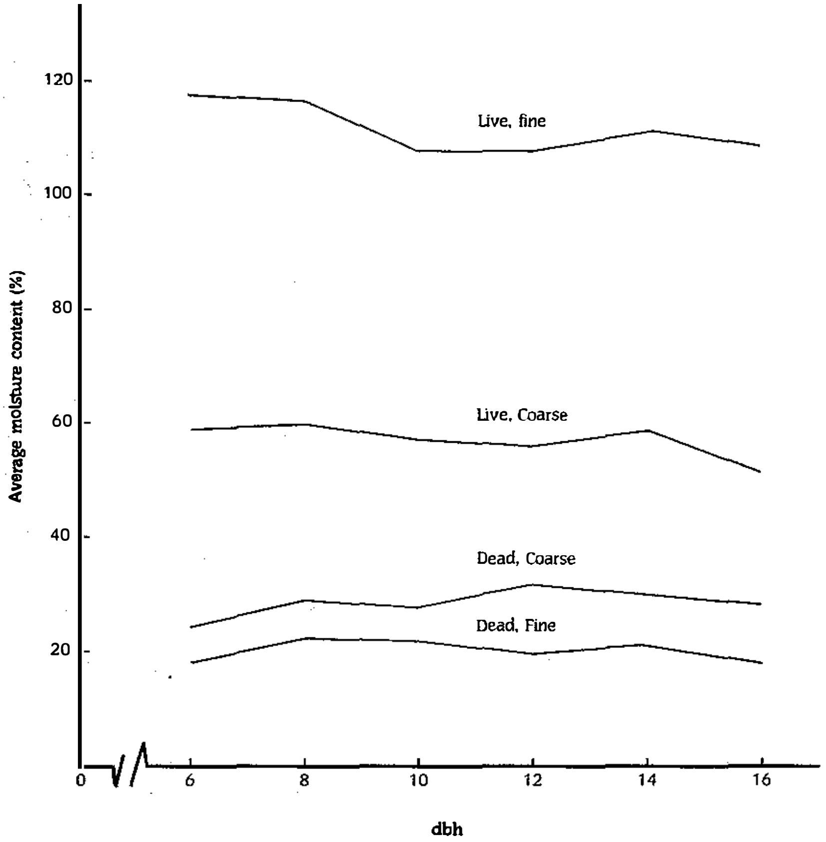

Figure 6. Average moisture content of pruned fuels by diameter class.

and green branchlets, 111 percent; live branchwood, 66 percent; dead branchlets, 24 percent; and dead branchwood, 29 percent. The moisture content varied slightly among diameter classes (Figure 6).

Rainfall records obtained from a weather station located approximately 11 km away indicated that 209.2 mm fell during the August to October study period but this amount of precipitation did not have any appreciable effect on the moisture content of live material. However, the dead branchlets, branches and the litter did respond immediately following rainfall.

DISCUSSION AND CONCLUSIONS

Pruning added 0.686 kg/m^2 of fuel and increased the energy budget by 14.69 MJ/m^2, an increase of 19 percent. This added fuel, made up of materials predominantly less than 3 cm in diameter, fell within the fine fuel classification. The material would be extremely flammable under most burning conditions. A 1.2 m x 1.2 m spacing is sufficiently dense that after pruning, the accumulation of branches formed an essentialy uninterrupted layer of loose fine fuel throughout the plantation.

Coupled with existing litter and duff, a more hazardous condition was created, particularly during the short period when needles are in a cured state but are still attached to branches. When the needles dried to the drop-off stage, formerly live woody branches had not yet reached air dry conditions; consequently, their burning rate was considered to be much slower than that of the dead pruned branches. Highly flammable conditions will persist into the second year following pruning until the snow pack compacts the fuel. Pruning and thinning will stimulate and increase growth of grasses and herbs due to greater forest floor exposure and solar penetration for the first several years. This vegetation will increase the supply of flash fuels prior to green-up in spring and following frost-kill in fall.

The major outcome of the addition of fine woody flammable fuels would be the increased probability of crowning due to higher attainable fire intensity and more rapid energy release to preheat overhead fuels. It is conceivable that small plantations would be destroyed before any initial attack force could reach the fire site. The probability of losing the whole plantation, the future crop, plus the investment of establishing and tending the stand is very high if a fire occurs.

The degree of fuel consumption by fire is highly dependent on the Buildup Index (BUI). The moisture contents of surface fuels (litter) and duff are reflected in the numerical value of the BUI. This numerical rating is indicative of the total amount of fuel available for combustion by virtue of its dryness. McRae (1980) tabulated estimates of slash consumption for fires burning in upland spruce slash (diameter range 0 to 6.99 cm). His numerical ratings for preburn slash loadings of less than 1 kg/m^2 and for duff consumption, when transformed into graphical form and plotted together with the number of days the BUI attained certain values, are predictors of the severity of fires that can occur and the frequency of such conditions (Figure 7). 1982 was considered to be a normal year and 1964 was an extremely dry year for the PNFI area.

The slash resulting from the pruning operation did not exceed 3 cm in diameter; therefore, slash consumption by fire would be much higher on this site than predicted by McRae. Total slash consumption on this site will probably occur at all BUI levels exceeding 50. All the duff will also be consumed when the BUI is at 50 or higher. Total duff and slash consumption would have occurred on 13 days in 1982 and 62 days in 1964 (7 and 31 percent of the days in each fire season respectively). Because young spruce are very susceptible to fire damage (Brown and Davis 1973) mortality would have taken its toll on 41 days or 22% of the fire season days in 1982, and 94 days or 47% of the days in 1964 (Figure 8). The probability of losing the plantation was very high should a fire have occurred.

Assuming that an air tanker is dispatched to take initial action on a fire in a pruned plantation, the increase in fire intensity will have a marked effect on its line building capability. Under the untreated stand the release of energy during the combustion of the litter and duff would be retarded by the moisture content of fuel and compaction of the fuel mat. If burning occurred under moist conditions, the lightest surface fire would still consume at least the top 1 cm of the fuel mat and would release 10 MJ/m^2 of energy, but if burning takes place under drought conditions, the entire organic mantle will be consumed and the average energy release will be 60.97 MJ/m^2.

Laboratory test data* based on controlled white spruce slash fires indicated that release of 60.97 MJ/m^2 of energy at the rate of 0.72 MJ/m^{2}s required an approximate application of 0.15 cm of water to stop fire spread. Because there is no data on water application requirements for fires burning in litter and duff beneath a white spruce stand, the assumption here is that the same application levels as those determined for slash will suffice. The addition of 0.686 kg/m^2 of fine flash fuel will increase energy output by 14.69 MJ/m^2 to a total of 75.66 MJ/m^2. Aerial water application requirements will increase to 0.18 cm (Figure 9). Under high BUI conditions, the energy release rate will rise to 0.9 MJ/m^{2}s.

These application levels do not account for the fraction of the load that remains on tree crowns. Geiger (1966) reported that the crown wetting value amounted from 0.1 cm to 0.3 cm but actual interception was far in excess of 0.3 cm, depending on amount and duration of rainfall. Based on air tanker drop tests conducted in New Brunswick in 1981, suppressant recovery at ground level

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*On file at PNFI.

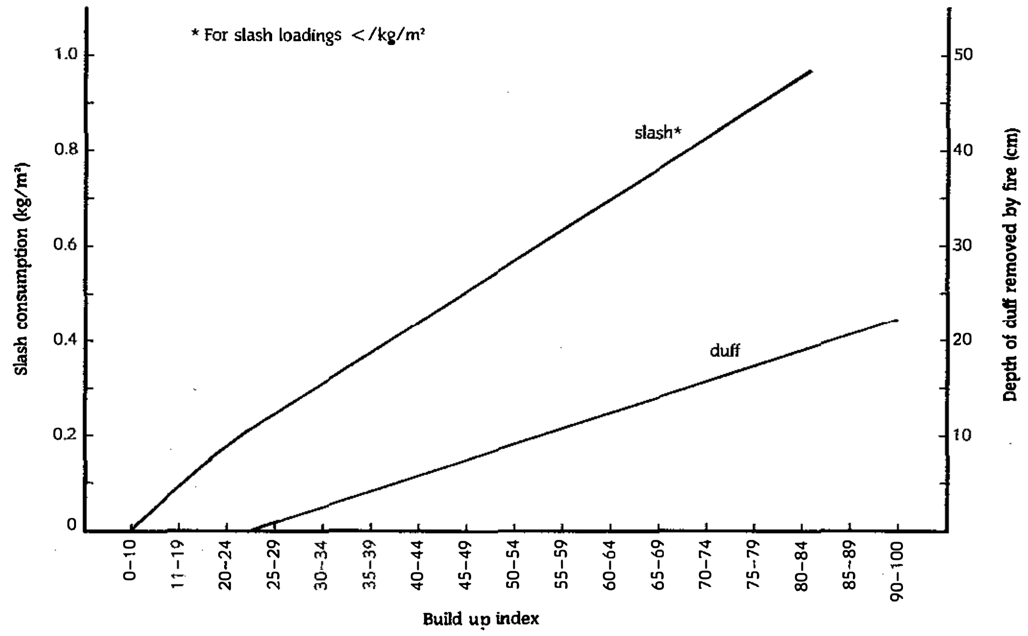

Figure 7. Relationship of slash consumption and duff removal by fire to BUI (McRae 1980).

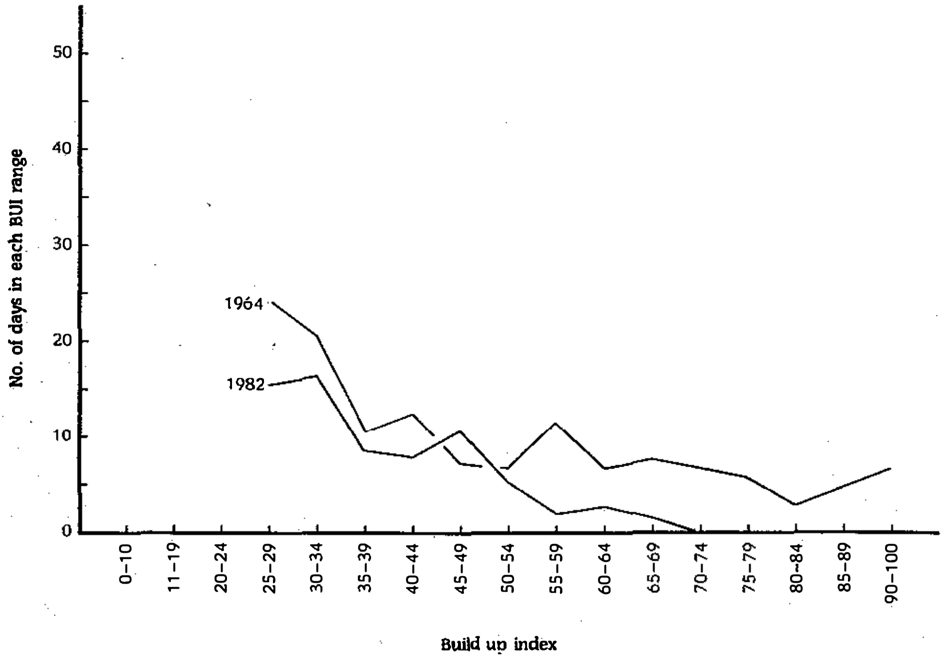

Figure 8. Number of days during 1964 and 1982 fire season that fell in the various BUI ranges at PNFI.

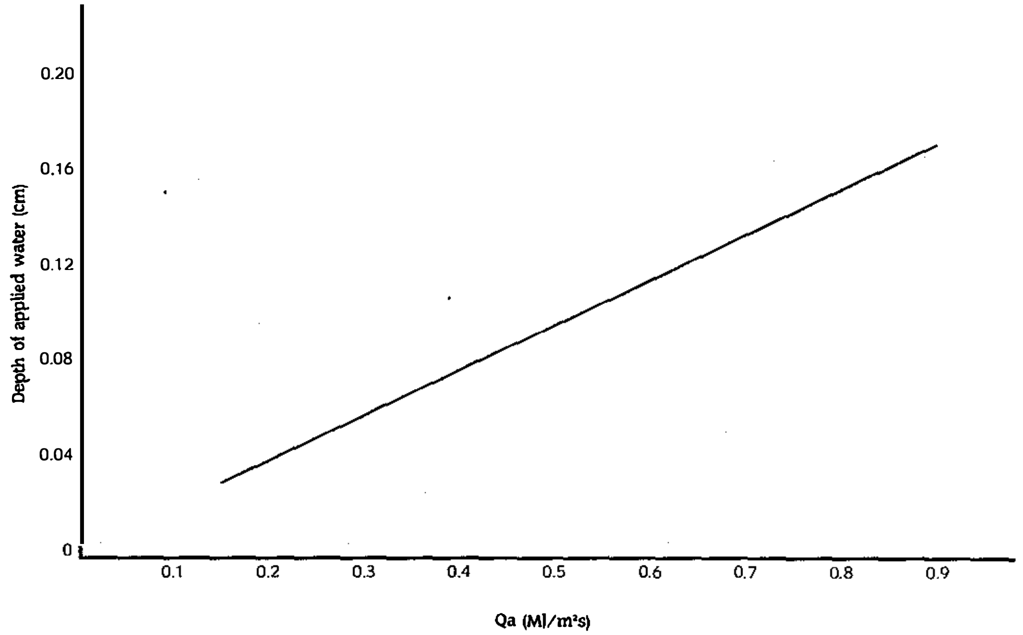

Figure 9. Amount of water required to suppress fire in white spruce slash for a range of energy output levels (test data on file at PNFI).

beneath a black spruce (Picea mariana (Mill.) B.S.P.) stand having a crown closure of 30 percent was only one-third the amount that reached the ground in the open. This open canopy intercepted what amounted to an application of 0.10 cm. A higher crown closure, such as the plantation sampled at PNFI, would result in a proportionately higher interception. The interception by the white spruce canopy will be at least 0.10 cm; therefore, water requirements must be increased to 0.25 and 0.28 cm respectively.

The approximate number of metres of line that can be adequately controlled per drop, according to Stechishen et al. (1982), at the two application levels as indicated in Table 1, ranged from 1 to 62 m depending on the type of air tanker and amount of water required. However, if the air tankers dispatched for initial attack were carrying one of the long-term unthickened retardants which have a superiority of 2.5 times relative to water, the required application would be reduced to 0.16 and 0.17 cm respectively.

Retardants having high fluid viscosities adhere to all fuels in considerably greater quantities than water and, therefore, presumably to the crowns. The increase in the amount of thickened long-term retardant that adheres to white spruce slash was reported by Stechishen et al. (1982) to be greater than 250 percent. Taking 200 percent as a more conservative increase, the quantity that will be intercepted will be the equivalent of a 0.30 cm application based on 0.10 cm interception for water. This indicates that only those air tankers with the capabilities of delivering high application levels can succeed in getting their load to penetrate through the closed canopy of a plantation. It is realistic to assume that interception equivalent to 0.20 cm is a workable estimate for high viccosity fluids. By doubling the interception amount, declines in line productivity reduce air attack effectiveness by 17 to 80 percent depending on air tanker application capability. The reductions in effective length per drop (Table 1) are not consistent with payload volume differences.

Irrespective of where or when used, the improved suppression capabilities of long-term retardants are expensive. To indicate the need to look at the economics of using these products, estimates of the added cost of line production based on 33 cents/L for unthickened (viscosity <100 m Pa•s) and 40 cents/L for gum thickened long-term retardants have been tabulated (Table 2). The increased cost per metre of line, ranges from $10.52 to $30.53 for unthickened and $22.45 to $43.74 (excluding the Turbo Beaver) for thickened retardant, depending on application levels and air tanker.

SUMMARY

The addition of 19 percent more fuel to the surface beneath the plantation did not initially appear to be significant; however, as the fuel resulting from the pruning operation was predominantly a flash fuel, the suppression requirements were significantly increased. Stand tending will require forest and fire suppression managers to collectively plan the management and protection of each plantation area to optimize pruning/thinning costs, and to insure that the operation is conducted in such a manner that ensuing fire hazards are minimized. This may even mean conducting the operation in stages in each plantation over several years. Following stand improvement, those responsible for fire protection will have to adjust their plans and resources to compensate for increased fire risk and suppression requirements.

This pilot study points to the need to conduct more research on those crown lands where plantation improvements are contemplated. Provincial protection agencies will require "stand change" data to facilitate revisions of their fire management plans. More specifically, forest and fire suppression managers will require this additional knowledge to permit them to plan and co-ordinate the propagation and protection of plantations.

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Table 1. Estimated meters of line built per drop at various application levels by air tankers

AIR TANKER	WATER		LONG-TERM RETARDANT			
	Interception (0.10 cm)		Interception (0.10 cm)		(0.20 cm)	
	0.25 cm	0.28 cm	Unthickened		Thickened	
			0.16 cm	0.17 cm	0.26 cm	0.27 cm
	(m)		(m)		(m)	
Turbo Beaver	3	1	10	9	2	2
Otter	17	14	26	25	16	15
Twin Otter	20	17	31	30	19	18
Canso	36	34	46	43	35	34
CL-215 (Salvo)[1]	46	44	54	52	45	44
CL-215 (Trail)[2]	62	58	96	93	60	59
M-18	23	20	47	46	21	20

[1] Both tank doors opened simultaneously.

[2] Doors opened in sequence with a fractional delay between tank door openings.

Table 2. Estimated long-term retardant cost to build a metre of line by various tankers

AIR TANKER	Retardant cost per load ($)[1]		INTERCEPTION 0.10 cm Unthickened ($ per m)		INTERCEPTION 0.20 cm Thickened ($ per m)	
	Unthickened	Thickened	0.16 cm	0.17 cm	0.26 cm	0.27 cm
Turbo Beaver	188.76	228.80	18.88	20.97	114.40	114.40
Otter	296.34	359.20	11.40	11.85	22.45	23.95
Twin Otter	525.69	637.20	16.96	17.52	33.54	35.40
Canso	1078.77	1307.60	23.45	25.09	37.36	38.46
CL-215 (Salvo)	1587.76	1924.40	29.40	30.53	42.75	43.74
CL-215 (Trail)	1587.76	1924.40	16.54	17.07	32.07	32.62
M-18	494.34	599.20	10.52	10.75	28.53	29.96

[1] Estimated cost per litre: Unthickened, $0.33; Thickened, $0.40.