Sustained Aspen Productivity on Hardwood and Mixedwood Sites

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Abstract

Sustained aspen productivity after harvesting of hardwood and mixedwood sites is dependent on the amount and quality of aspen regeneration. Aspen suckering is inhibited by low soil temperatures, and soil temperature management may be required on many sites. To enhance soil warming and to encourage adequate suckering, shading by residual trees, shrubs, herbaceous cover, *Calamagrostis* grass, and log decks should be minimized. Disturbance or removal of insulating soil organic horizons by scarifying or burning will also improve soil temperatures but should not be done after suckering has begun. Sucker densities and growth rates are reduced on skid trails and landings, proportionate to disturbance intensity. Affected areas can be kept to a minimum by optimizing layout of extraction roads and designated skid trails.

Small clumps of up to 35 residual mature trees of balsam poplar (*Populus balsamifera*) left in clearcut blocks do not significantly affect the density and growth of aspen regeneration.

Harvesting white spruce-dominated mixed stands results in successional desynchronization, early-seral microclimate but late-seral forest floor conditions, thus increasing soil temperature problems. In harvesting these mixed stands, the number and spatial distribution of aspen parent trees is critical, a minimum of 50–60 stems per hectare are required in order to obtain acceptable regeneration of aspen.

Silvicultural systems other than clearcutting in large blocks reduce aspen regeneration and future yield of aspen.

Introduction

Increased utilization of trembling aspen and balsam poplar over the last two decades in Canada and the USA has prompted the production of several review publications describing ecological and silvical characteristics of aspen and balsam poplar (DeByle and Winokur 1985; Bates et al. 1988; Peterson and Peterson 1992).

Challenges and implications to both forest management and management of other resources from the increased aspen harvest have also been examined and addressed:

- Hardwood management problems in Northeastern British Columbia: An information review (Peterson et al. 1989)
- Aspen symposium in 1989 in Minnesota (Adams 1990)
- Aspen symposium in 1990 in Alberta (Navratil and Chapman 1991)

The quality of aspen regeneration on hardwood and mixedwood cutblocks does present some real concerns (Bates et al. 1990; Expert panel on forest management in Alberta 1990; Waldron 1993) that need to be examined and resolved if we are serious about the goal of sustainable development as it applies to hardwood production.

In this paper we discuss the perceived and observed problems in achieving sufficient aspen regeneration to sustain aspen productivity after harvest of hardwood and mixedwood stands. Retrospective observations from older hardwood cutblocks in the Prairie region and results drawn from the Mixedwood Silviculture Research Program at Northern Forestry Centre, Canadian Forest Service, Edmonton will be used. Through research, a perceived problem may be found not to be a problem at all. We present the results of such a case study.

Soil Temperature Management

There are two clear relationships known to be involved in aspen suckering. The first, apical dominance, involves the ratio of growth regulators—auxins and cytokinins—in the roots. The second relationship, between soil temperature and suckering, can be the principal and controlling factor with or without apical dominance. It is generally accepted that increases in soil temperature, resulting from increased solar radiation following logging, are the most critical requirement for sucker stimulation (Peterson et al. 1989).

Low soil temperatures have been suggested in several reports as the reason for poor suckering in northern regions and on soils insulated with thick duff layers (Peterson et al. 1989; Navratil et al. 1990). In Alaska, aspen is found chiefly on southern exposures. This was attributed to low soil temperature on other exposures.

Temperature Thresholds for Suckering

Maini and Horton (1966) concluded from greenhouse assays that temperatures less than 15°C (60°F) inhibit suckering. This temperature threshold of 15°C has been repeatedly reported in the literature. Published results do not make it clear how temperature influences suckering-whether it is influenced by average temperature, temperature duration, cumulative degree days, or by maximum and minimum temperatures and variable daily temperature regime (Hungerford 1988). Zasada and Schier (1973) indicated that the diurnal change may influence suckering and that low minima may suppress suckering regardless of maxima.

There are known clonal and regional differences in suckering responses to temperature. Significant differences were observed among four Ontario clones when propagated at temperatures ranging from 15.6°C to 35°C (Maini and Horton 1966; Maini 1967). The same authors found that sucker production increased with increasing temperature up to 30.6°C while Zasada and Schier (1973) working with Alaskan aspen clones found that temperatures above 22.8°C appeared to inhibit sucker formation on root cuttings.

It is evident, therefore, that the soil temperature threshold and conditions that limit suckering need to be assessed for each region and site before soil temperature management is considered. Many cutblocks should regenerate well without any treatments, especially the locally warm sites. Some measure of temperature enhancement may be needed for the particularly cool sites where soil temperatures may never reach a temperature conducive to suckering.

The importance of local soil temperature assessment for securing high quality aspen regeneration is illustrated by the following example of soil temperature measurements in an aspen cutblock in the Peace River region of Alberta.

A profile of daily average soil temperatures in the first growing season after harvest is shown in Figure 1. The cutblock was winter harvested. Roadside debris (tops and limbs) from the decking areas was brush-raked into piles with minimum ground disturbance. Skid trails from winter logging were barely discernible. Mean thickness of L, F, H layers was 9.1 cm. Aspen sucker producing roots closest to the surface were at a depth of 8–15 cm. Mean daily temperatures at the depths of 7 and 12 cm, where the majority of aspen roots occurred, did not reach 12°C until the end of July. Temperatures of 12–14°C occurred for only 2 weeks in August. Suckers that developed in the area were numerous, but small, and were damaged by fall frost—indicating that they were initiated in the late part of the growing season.

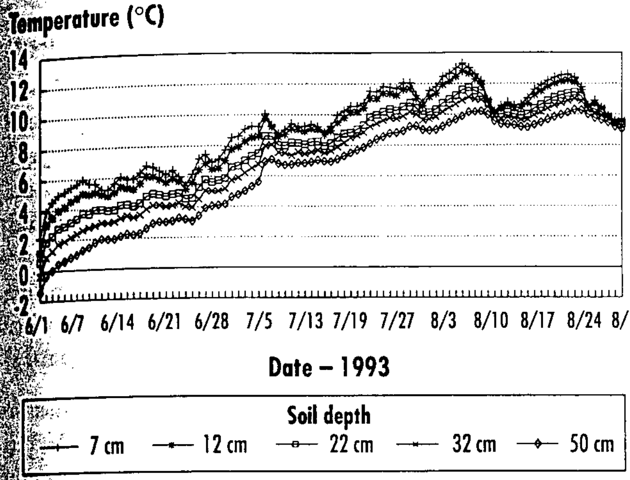

Figure 1. Mean daily temperatures, June to August, 1993, at soil depths 7–50 cm in a hardwood cutover near Manning, Alberta. (Source: Canadian Forest Service and Daishowa-Marubeni International Ltd., unpubl. data.)

Vegetative Cover

Shading by shrub and herbaceous cover can reduce solar insolation and in turn affect soil surface temperature and reduce suckering and the growth of developing suckers.

Shrubs may be a lesser problem than other vegetative cover. In Saskatchewan, a dense hazel understory was not found to be a major deterrent to aspen suckering (Peterson and Peterson 1992). Effects on soil temperature and suckering response after harvesting are not known for other shrubs that form the understory in aspen ecosystem associations (alder, willow, buffalo berry)(Corns and Annas 1986; Delong 1988; Beckingham 1993).

Field observations indicate that the dense grass cover by *Calamagrostis canadensis* can be a major deterrent to aspen suckering. *Calamagrostis*, when dominating the site, can have a two-fold effect on aspen regeneration: preventing or delaying soil warm up and exerting a competitive stress on developing aspen seedlings and suckers. John and Lieffers (1991) observed both greater mortality and lower growth rates of aspen and white spruce found in association with grass as opposed to shrubs or other trees.

The impact of *Calamagrostis* on aspen regeneration may be greatest when harvesting open stands, where *Calamagrostis* cover is well established prior to harvest and expands after harvest (Lieffers et al. 1993). A similar result is observed in open areas where soils are disturbed. Landings, for example, are rapidly colonized and dominated by *Calamagrostis* within 3 years after disturbance (Hogg and Lieffers 1991). A delayed colonization of landings by aspen of seed origin and very slow growth of aspen seedlings under *Calamagrostis* cover has been observed (Navratil 1991). In harvested areas where dense aspen regeneration captures most of the leaf area capacity of the site immediately after harvesting, *Calamagrostis* cover is reduced proportionally to aspen density.[1]

Calamagrostis Cover and Soil Temperature

Effects of *Calamagrostis* on soil temperature are substantial. *Calamagrostis* builds up a thick layer of litter that insulates the soil surface. Under a bed of *Calamagrostis* the summer soil temperatures at 10 cm were 4°C cooler than on sites with no aboveground cover. The maximum temperature in soil under grass was 12°C (Hogg and Lieffers 1991), 3° below the 15°C threshold for aspen suckering discussed previously.

It is very likely that heavy grass cover on old skid trails is the main factor limiting ingress of aspen roots and suckers from the stocked areas adjacent to skid trails. Soil compaction may also be a factor.

A pre-harvest assessment should be done to determine the density and spatial distribution of *Calamagrostis.* If there is significant grass coverage in the understory prior to logging, there will be a rapid spread when the stand is clearcut (Lieffers et al. 1993). Unless the grass rhizomes are killed by a burn or other means, the likelihood of aspen regeneration developing at an acceptable density and growth rate is very low.

Insulation by Soil Organic Layers

The thickness of organic layers greatly affect soil temperatures in the boreal forest prior to and after harvesting. Any ground disturbance or removal of organic layers by logging, scarification, or fire results in warmer soil temperature in the upper layers of soil profile. This should result in increased density of aspen.

In the interior of Alaska, the removal of the organic layer had a remarkable effect on soil temperature. In the winter harvested area, the removal of the organic layer increased soil temperature in late June from about 12°C to about

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[1] S. Navratil, unpublished 3rd and 5th year data from vegetation management trials in Alberta.

20°C at a depth of 10 cm. In the summer harvested area, the soil warming effect was less (Dyrness et al. 1988).

In the Prince George Region there was a 6°C mean difference in afternoon soil temperatures at the depth of 5 cm between the untreated plots and plots with removed organic layers. Temperatures were intermediate on clipped plots where the vegetation cover was removed without disturbing the organic layers (Dobbs and McMinn 1977).

Use of Summer Logging for Soil Temperature Increase

Summer logging provides more disturbance to both organic layers and ground vegetation than does winter logging. It has also been reported to promote root suckering of aspen (Bella 1986; Perala 1972).

Harvesting in the frost free season, or site preparation treatments with anchor chains, have been recommended in stands with heavy shrub vegetation (Steneker 1976). Late summer harvesting in particular destroys shrub cover and exhausts its energy reserves, thus clearing the way for soil temperature increases and aspen suckering.

Consideration of summer logging to promote aspen suckering on heavy textured or wet soils should include an assessment of the risk of soil degradation and root disturbance by heavy equipment. Sensitive sites typically have poorer aspen stocking after summer harvesting as compared to winter harvesting (Bates et al. 1990; Alberta Forest Service data *In* Navratil 1991).

A detailed pre-harvest silvicultural plan, containing soil sensitivity information to guide choice of season for harvesting and its potential to optimize regeneration and minimize detrimental soil disturbance, has been accepted in practice in British Columbia (e.g., British Columbia Forest Practices Code 1993).

Use of Scarification for Enhancement of Suckering

Disturbing the surface organic layers by scarification can promote aspen suckering. The timing and intensity of treatments are crucial for achieving the high quality aspen regeneration desired. Improper timing and intensity can be detrimental to aspen regeneration and aspen quality. Scarification should be light and done immediately after harvesting, before any suckering has occurred.

Light scarification, applied in the spring to cutovers harvested in the dormant season, increased suckering both in percent stocking and in density of aspen suckers over unscarified cutovers (Weingartner 1980). Light scarification with drag chains equipped with no or one attached shark finned barrel resulted in gains of 60–78% and 16–56% density over the untreated areas in the first and second years, respectively. Slightly heavier scarification with drag chains and several barrels increased aspen density even more than light scarification, but was associated with a decline in height growth.

Heavy scarification, such as disking or disk trenching, can also promote initial aspen suckering (Sandberg 1951; Brinkman and Roe 1975),[2] but the initial gains in aspen density are short-lived and can be misleading. Since young suckers depend on the original parent root system, mortality of suckers on disturbed parent roots is higher. Furthermore, after disking, both the growth rate of the aspen stand and the internal quality of individual stems are reduced.

A decrease in height growth was noted up to 10 years after disking (Sandberg 1951). We have found a direct relationship between the degree of root segmentation by disking and height growth of suckers after treatment.[3]

A combination of heavy scarification and treating after suckering has begun is particularly detrimental (Basham 1988). Measurements 10 years after disking a 3-year-old aspen sucker stand revealed substantial reductions in aspen growth. Damage to the parent root system significantly reduced stem growth, and the effects were still increasing 10 years after scarification. The extent of advanced stem decay averaged 7% in severely wounded, scarified stems as compared to 0.2% in non-scarified aspen suckers. Basham (1988) concluded that the scarified trees will likely be of lower quality at harvestable age and more susceptible to windthrow or breakage.

Prescribed Burn

In regions with cool soils or on sites with heavy grass cover, prescribed burning may be necessary for managing for aspen. Where fire can be safely used it has been an efficient regeneration tool, not only for promoting aspen suckers, but also for generating suitable exposed mineral soil seedbeds for aspen seedlings to exploit (Perala 1991).

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[2] Navratil and Hayward, Can. For. Serv. (in press).

[3] Ibid.

In a prescribed burn on an aspen site in Idaho (Hungerford 1988), soil temperatures to the depth of 30 cm were as much as 13°C warmer than those on an unburned site. From June to August in the first year after burning, soil temperatures were significantly higher in burned areas. However, by the second year, there were no temperature differences for most months, due to rapid regrowth of vegetation and emergence of aspen suckers. Temperatures on burned plots were favourable for higher levels of sucker initiation than temperatures on unburned plots (Hungerford 1988).

Prescribed burning may be particularly useful when harvesting late successional stages of mixedwood stands, with aspen as the reforestation goal. Such stands are characterized by thick duff layers and sporadic distribution of aspen under a white spruce canopy. Amelioration of soil temperature by prescribed burn or other measures may be needed to obtain adequate aspen suckering from sparse parent root systems. Clearcutting of a predominantly white spruce stand, followed by broadcast slash burning, resulted in temperatures twice as high as those in areas clearcut only (Dyrness et al. 1988).

Burning at low and moderate fire intensities or when the surface soil is damp may be needed to protect shallow aspen roots. High intensity fires on sites with heavy coniferous slash can be detrimental to suckering. Strategies for prescribed burning on aspen sites are described by Perala (1974), Alexander (1982), and Brown and Simmerman (1986).

Harvesting Patterns and Silvicultural Systems

The intolerance of aspen to shade and the temperature requirements for suckering dictate that as many residual trees should be removed during harvest as economically practical. There is a close relationship between the residual canopy and aspen stocking, particularly if the residual canopy contains spruce (Waldron 1963).

Shading by residual trees and adjacent stands reduces soil temperature and hence the growth of suckers. Openings of about 0.4 hectares provide minimally acceptable conditions for regenerating aspen (Perala and Russell 1983).

Clearcutting in strips and longitudinal cutblocks should maximize the amount of light and insolation. Clearcut strips aligned north-south with a width equal to or less than stand height received proportionally less daily light as compared to a nearby open field (Berry 1964). In Northern Ontario, 20 m wide strips with the long axis in a north-south direction had lower aspen density than the adjacent clearcut.[4]

Solar exposure can be maximized in strip clearcuts by varying the orientation, shape, and sizes of cutblocks. This may be a worthy objective for simultaneous regeneration of aspen and white spruce where higher soil temperatures are desirable. Guides and programs are available to aid in designing cutovers to meet particular forest management objectives (e.g., Halverson and Smith 1979; Harrington 1984).

Sustained aspen productivity can only be achieved with the clearcutting, even-aged silvicultural system. Partial cutting leads to a decline in stocking and growth of aspen (e.g., Doucet 1989).

The concept of a two-staged harvesting system, as applied to mature aspen stands with immature white spruce understories, relies on the concurrent yield of white spruce and aspen in the second harvest (Brace and Bella 1988). Aspen is expected to regenerate after the first harvest of aspen overstory and release of white spruce. However, the released white spruce understory may provide enough shade to reduce aspen stocking and growth to less than adequate levels. Furthermore, the canopy space available for aspen at rotation age may be limited and vary greatly depending on the density and spatial distribution of the released white spruce.[5]

Log Decks on Landings

Log decks kept on site for an extended time during the growing season tend to delay soil warm-up and may have an additional negative impact on suckering. The ongoing respiration in aspen roots can exhaust carbohydrate supplies if there is no replenishment from the aboveground shoots or new suckers. This may eventually lead to the loss of root vitality, and the inability to initiate suckers.

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[4] D. Weingartner, OMNR, personal communication, 1993.

[5] Unpublished TASS simulations by B.C. Ministry of Forests Research Branch and Canadian Forest Service.

Soil Moisture Management

The sensitivity of suckering to soil aeration has been known for a long time. Besides the first report in 1911 (Weigle and Frothingham 1911), the published experimental data are limited to one report by Maini and Horton (1964). In a greenhouse assay they found that the maximum number of aspen suckers developed at the 7% moisture content level of the soil (rooting medium). Suckering was reduced at 10–20% soil moisture and no suckers were produced under saturated (25%) and flooded (27%) moisture conditions.

Field observations attributing poor aspen suckering to poor soil aeration are common. Examples are noted on level sites (Bates et al. 1990), those with a high or elevated water table, and on sites with interrupted drainage patterns (Crouch 1986; Expert panel on forest management in Alberta 1990 Sims et al. 1990). Suckering failure and subsequent sucker mortality has been observed in Colorado where the water table, raised by clearcutting, combined with higher precipitation, caused harmful soil moisture conditions (Crouch 1986).

The areas of cutblocks affected by excessive soil moisture can be large or small. Poor regeneration can be limited to small areas of depressions, that in the parent stand prior to harvesting were likely occupied by balsam poplar. Enclaves of depressions can be delineated by pre-harvest silviculture prescriptions and should preferably be left standing. These wet areas commonly do not successfully regenerate to aspen and as islands of mature trees (usually balsam poplar) they function in water removal through transpiration as well as providing benefits to other forest resources (see the section "Balsam Poplar Residuals").

Large areas of poor drainage may be inherent to the site or may result from interrupted drainage by roads or ruts and from reduced transpiration after harvesting. Prevention of excessive soil moisture is difficult. Improved harvest planning, including a detailed site inspection prior to harvest, can help avoid inappropriate road construction or harvesting in the wrong season, which create ruts that impede lateral water flow.

Harvesting Disturbance

In all regions where aspen is commercially harvested, observations indicate that areas with severe harvesting disturbance to soil and roots have not regenerated and that the lack of regeneration has been long lasting (Zasada and Tappeiner 1969; Jones 1975; Jones 1976; Schier et al. 1985; Bates et al. 1990; Shepperd 1993).

In older hardwood cutovers harvested by conventional systems in Saskatchewan and on more recent cutovers in Alberta a 20–30% site disturbance due to soil compaction on skid trails and landings, and interrupted drainage was observed (Expert panel on forest management in Alberta 1990; Waldron 1993).[6] This has raised the concern about potential understocking and relatively poor growth of aspen. In one area a falldown of 15% in AAC was postulated (Waldron 1993).

Localized disturbances are differentiated into three types: extraction roads, landings, and skid trails.

Extraction Roads

Constructed for hauling wood from the cutblock, roads can be temporary or permanent. In forest estate planning, in general, a network of roads is judged to be an asset and an investment. It seems very unlikely that any amount of reclamation could bring the hauling road landbase into full productivity for hardwoods. The opportunities exist to optimize road design and road spacing in harvest plans by utilizing long reach and long distance forwarding, techniques which minimize all three types of disturbances.

Landings

With winter harvesting, when log decks are hauled prior to the spring thaw, landings should have limited impact on aspen regeneration. The removal of surface soil horizons during the construction of landings, and spreading them back afterwards, is not acceptable on hardwood sites. Such a practice destroys roots and damages the regenerative capacity of aspen.

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[6] Unpublished TASS simulations by B.C. Ministry of Forests Research Branch and Canadian Forest Service.

Landings with heavily disturbed soils are dominated by *Calamagrostis* within about 3 years (Lieffers et al. 1993). At the same time, they are gradually colonized by aspen and balsam poplar seedlings. Stocking of aspen on landings in one study area ranged from 40 to 60% (Navratil 1991). Aspen on landings (predominantly of seed origin) was of a substandard size and growth and unacceptable for maintaining original stand productivity. Seeding of landings with conifers may be a viable alternative, providing enclaves of wildlife cover and adding to the forest's biodiversity.

Skid Trails

Severe soil structural damage occurs where skidding results in deep ruts. Heavily disturbed skid trails resist aspen ingress from the adjacent areas and can be visible for 15–30 years after harvest. Regeneration by suckering can be poor or absent. Growth decline can occur on trees growing on skid trails, even where no surface soil disturbance is visible. Less visible damage is associated with compaction and other physical changes in soil and can also be long lasting. Soil compaction in the boreal forest of Alberta may persist for several decades due to characteristics of local soils (Corns 1988). Increases in soil bulk density in aspen cutblocks have persisted for up to 12 years after harvest in Colorado (Shepperd 1993).

From a detailed study of skid trails in Colorado, Shepperd (1993) concluded that:

- significant compaction can occur regardless of soil moisture conditions;
- high organic matter content in the upper soil profile can decrease the compaction effect;
- compaction increased with each succeeding pass of a tractor where later passes contributed less to the total compaction effect; and
- root damage, especially to fine roots, can occur without apparent disruption of the soil profile and is more extensive in wet soils.

In the retrospective study of skid trail impact on aspen regeneration in central Alberta, we assigned a light, moderate, or heavy impact to various parts of skid trails according to an estimated amount of traffic (Table 1).

Table 1 summarizes aspen density and growth on the wheel tracks of skid trails, in between the tracks and off the trails in the adjacent stand. The greatest reduction in aspen density and growth was in the areas of wheel tracks and slightly less in the centre parts of skid trails when compared to the adjacent undisturbed stand.

Table 1. Density and growth of aspen on skid trails of different impact classes (means from five cutblocks)

Impact class	Location	Density (trees/ha)	Density reduction relative to stand (%)	Total height (cm)	Height reduction relative to stand (%)	Annual mean height in last 3 years (cm)	Annual mean height reduction relative to stand (%)
Low	Stand	39 934		192		19.7	
	Trail centre	18 553	54	133	31	17.8	10
	Trail track	10 395	74	132	31	16.5	16
Moderate	Stand	51 765		223		25.6	
	Trail centre	20 196	61	150	33	21.4	16
	Trail track	10 000	81	141	37	19.2	25
High	Stand	64 285		203		27.4	
	Trail centre	18 333	71	108	47	15.8	42
	Trail track	7 619	88	98	52	13.6	50

All three aspen variables—density, total height, and 3-year mean periodic height increment—showed a reduction when going from low to moderate to heavy impact. In the heavy impact parts of skid trails the reductions in density and total height of aspen were 71–88% and 47–52%, respectively. Reductions in the mean periodic height increment in the last 3 years indicate that soil disturbance continues to reduce growth several years after harvest.

Skid trail impacts on aspen regeneration are evident. What does it mean in terms of aspen productivity and how much should we invest to rectify it? Our ability to predict the degree to which compaction will affect site productivity for hardwoods is limited (Alban 1991). Thus, at present, cost-benefit analysis (weighing costs of reducing skid trail impact versus the gains in yield) may not be possible.

The most biologically appropriate way to minimize soil disturbance on skid trails is to harvest only when soils are frozen or covered with snow. Another feasible approach would be to minimize the affected area by restricting skidding to pre-planned, designated skid trails. In fact, data from European coniferous forests, where networks of designated skid trails are common, show that very little productivity is lost because the trees adjacent to skid trails utilize available light and compensate by increasing radial growth (Eriksson Chroust 1989; 1987).

Work on site sensitivity rating systems has begun in Alberta and British Columbia,[7] and will be helpful in deciding where to employ low impact equipment such as wide tired skidders, or deciding which blocks must be sequenced for winter harvest.

Balsam Poplar Residuals

Balsam poplar grows in association with aspen to varying degrees. In the Prairie region, balsam poplar commonly comprises a significant proportion (30% or more) of aspen stands (Winship 1991). In Alberta, balsam poplar represents about 15% of the provincial deciduous inventory.

Until recently most hardwood operations did not utilize balsam poplar. Individual trees or groups of balsam poplar were bypassed and retained as standing residuals. The residual trees in groups provide the benefits of cover for ungulates and of nesting sites for cavity nesters. Other benefits include aesthetics, increased biodiversity, and a possible reduction of the effects of a rising water table after harvesting.

In contrast to these benefits, concerns have surfaced regarding the potential negative impact of balsam poplar shading—lowering soil temperature and affecting aspen regeneration. Foresters have also observed a post-harvest increase in the proportion of balsam poplar versus aspen, and have expressed concern about the influence on such changes in stand composition on stand development, growth, and yield of regenerated aspen (Navratil et al. 1990).

A study designed to answer some of these questions compared aspen density and growth within and outside of 11 clumps of balsam poplar residuals 4–6 years after harvesting hardwood cutblocks in west central Alberta. The effects varied with the sizes of the clumps. Aspen density was significantly less (by 56%) inside the largest clump (consisting of 117 balsam poplar trees) as compared to density outside the clump. In two other clumps, consisting of 63 and 12 balsam poplar trees, the aspen density was 22% less (significant at P=0.06 and P=0.08). No significant difference in aspen density was found in the remaining nine clumps that ranged from 7 to 35 balsam poplar trees when compared to density outside the clump.

From these investigations we concluded that balsam poplar residuals in clumps with more than 35 stems reduce aspen density within the residuals, but effects did not extend outside of the clumps (Figure 2).

The effects on growth rates of aspen regeneration were minimal, and occurred only within the largest clumps but not outside them. The areas within the clumps and up to a distance of 10–15 m had balsam poplar densities ranging from 1000 to 5800 stems per hectare. This represents a 10% proportion of balsam poplar in a regenerated aspen balsam poplar stand.

It appears that the benefits to other forest resources from retaining balsam poplar groups in hardwood cutblocks outweigh any likely reductions in density and growth of aspen regeneration.

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[7] R. Kabzems, B.C. Ministry of Forests, personal communication.

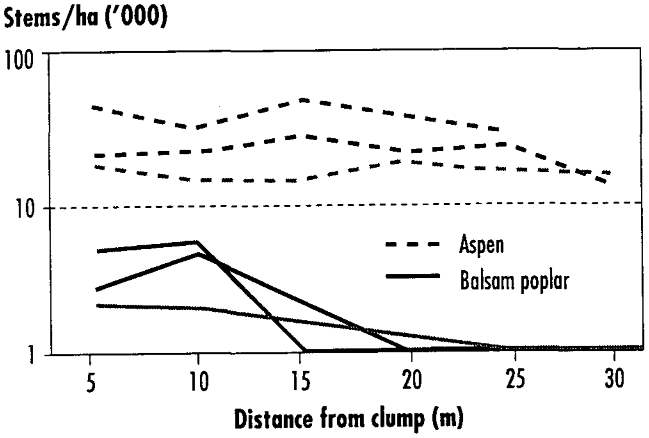

Figure 2. Aspen and balsam poplar densities in relation to the distance from the edge of three balsam poplar clumps.

Aspen Regeneration after Harvesting Mixedwoods

In the mixedwood sections of the Prairie provinces (Rowe 1972) the successional pathway of mixed aspen white spruce stands leads to an increasing proportion of white spruce in the canopy. The late successional stages are white spruce dominant stands characterized by greater litter accumulation, thicker surface organic layers, increased moss cover, and scattered distribution of aspen in the canopy, plus a few smaller, whip-type aspen under the canopy.

In the context of ecological implication, clearcutting of the late stage mixed stands results in successional desynchronization (Kimmins 1989). Clearcutting with minimal soil disturbance results in early seral microclimates but late seral forest floor conditions. These forest floor conditions, without scarification or burning, are less conducive to soil warming and thus to aspen regeneration. Desynchronization of microclimatic and soil conditions may be rectified by burning, scarification, or other treatments.

The number, spatial distribution, and vitality of aspen parent trees in the stand required for adequate suckering must also be considered.

Low numbers or poor distribution of aspen trees may indicate insufficient root densities needed for full aspen regeneration. About 4–5 m^2 basal area of aspen/ha are recommended for adequate regeneration (Perala 1983; Doucet 1989; Perala 1991). As a simple guideline, assuming a mean dbh of aspen to be 30 cm, approximately 50–60 aspen trees per hectare are needed for full aspen regeneration.

Data have been collected on the areas occupied by suckers that have developed on the root systems of single aspen trees.[8] In aspen-lodgepole-pine associations in the Alberta foothills the mean radius of single tree root systems ranged from 8 to 14 m, with the overall mean being 10.8 m. Using a 10.8 m radius, a minimum of about 30 aspen trees/ha would be needed for full aspen regeneration if they are uniformly distributed. It is prudent to use a number higher than 30 trees/ha since this calculation does not allow for clustering of aspen parent trees and overlap of root systems.

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[8] S. Navratil, unpublished data.

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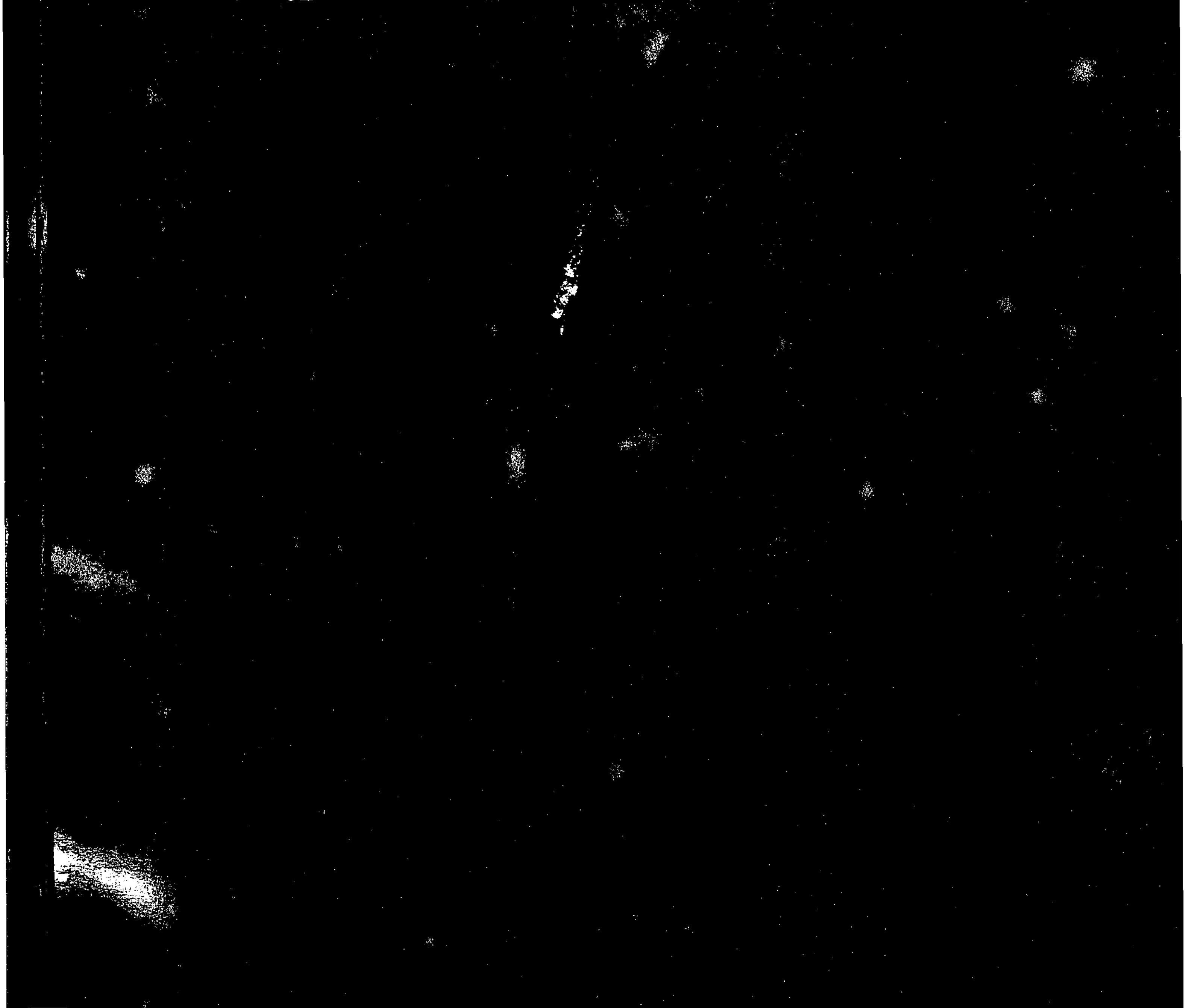

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