Understory protection in Alberta's boreal mixedwoods: selecting the best silvicultural system for stands with conifer understory

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Abstract

Conifer understory in deciduous and deciduous–conifer stands is a valuable resource in the boreal mixedwoods. A wide range of options is available for managing these stands and for protecting and promoting the understory component. Steps to select the most appropriate silvicultural and harvesting system are discussed using an example of aspen (*Populus tremuloides* Michx.) overstory–white spruce (*Picea glauca* [Moench] Voss) understory stands. The steps require definition of the management objectives, evaluation of stand suitability, and assessment of the wind damage risk. The rating of required wind protection level combines the trees' wind resistance characteristics, site evaluation, and windiness of the region. The expected growth response of released spruce, after harvesting aspen overstory, and spruce and aspen yields at the second harvest are examined.

Résumé

Dans la forêt mixte boréale, le sous-étage de résineux de certains peuplements de feuillus et mixtes constitue une ressource précieuse. Or, il existe une vaste gamme de méthodes permettant de gérer ces peuplements, d'y protéger le sous-étage et de favoriser la croissance de celui-ci. Nous présentons les étapes de la sélection d'un système de sylviculture et d'exploitation approprié, en prenant comme exemples des peuplements à étage supérieur de peuplier faux-tremble (*Populus tremuloides* Michx.) et à sous-étage d'épinette blanche (*Picea glauca* [Moench] Voss). Ces étapes exigent que l'on fixe les objectifs de gestion, détermine si la station convient aux méthodes, puis évalue les risques de dégâts dus au vent. Le degré de protection contre le vent est coté selon la présence de caractéristiques permettant aux arbres de résister au vent, l'évaluation de la station et le caractère plus ou moins venteux de la région. Nous examinons la réaction de croissance que pourraient avoir les épinettes dégagées, après la récolte des peupliers faux-trembles de l'étage supérieur, ainsi que le rendement en épinette et en peuplier faux-tremble que devrait produire la récolte suivante.

Selecting a silvicultural system

From the silvicultural perspective, stands with conifer understory present numerous options that can satisfy a variety of management objectives. Depending on the management objectives, the options may vary from a "do nothing" alternative to complex alternative silvicultural systems (Table 1). By definition of silvicultural systems, the first alternative—"do nothing"—falls into the category of natural shelterwood and follows the natural successional pattern of stand development. The alternatives B, C, and D involve clear-cutting systems or clear-cutting with retained seed trees. Plantation technology—alternative B—was the most often used option in the past, prevailing for boreal mixedwoods in the 1960s to 1980s and involving clear-cutting, site preparation, planting, and variable levels of tending and competition control.

The last alternative of conifer understory protection while harvesting deciduous or deciduous–conifer overstory is discussed in this paper using an example of white spruce (*Picea glauca* [Moench] Voss) understory–aspen (*Populus tremuloides* Michx.) overstory stands. Decision-making steps in selecting the most appropriate silvicultural system involve the definition of management objectives, evaluation of stand suitability, and assessment of windthrow risk (including site evaluation).

Resource management objectives

The management objectives addressed here are 1) to enhance conifer production, 2) to promote natural regeneration of spruce and aspen, and 3) to sustain mixedwoods on the site.

The silvicultural strategy follows the two-stage silvicultural and harvesting model (Brace and Bella 1988). In this model (Figure 1), a first harvest takes place when overstory aspen is 60–80 years old and understory spruce about 20–60 years old. In the first harvest, all

Table 1. Management and silviculture options for deciduous and mixedwood stands with conifer understory.

A. "Do nothing"	- extended rotation or use of other silvicultural systems at later stages of stand development - natural shelterwood system
B. Plantation technology	- clear-cutting, site preparation, planting, and tending
C. Deciduous production	- clear-cutting and no treatments
D. Deciduous production with natural regeneration of shade-tolerant conifers	- clear-cutting with retained conifer seed trees - variant of seed tree system
E. Conifer understory protection, simultaneous conifer and deciduous production	- two-stage silviculture and harvesting model - array of the silvicultural systems with the incremental levels of harvesting protection of understory; wind protection of retained understory; harvesting difficulty and conifer yield

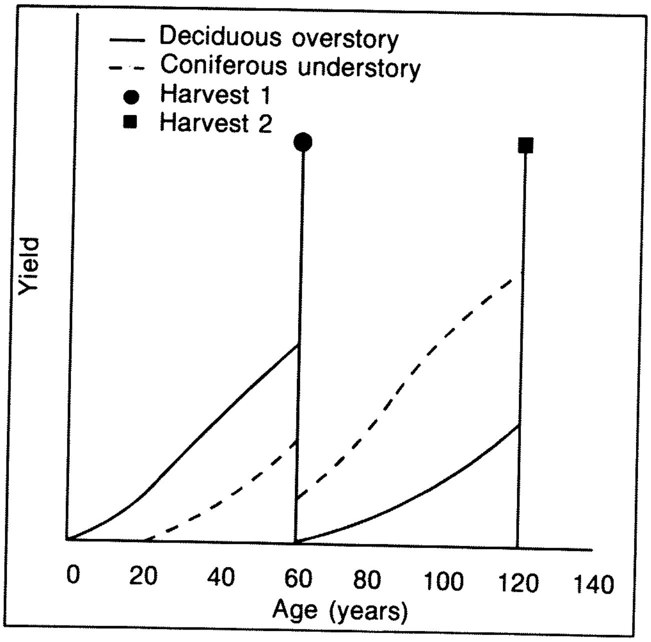

Figure 1. Generalized two-stage harvesting and silviculture model.

Source: Brace and Bella (1988).

aspen forming overstory and all spruce over a diameter at breast height (DBH) utilization limit are harvested, leaving a released spruce understory. Following harvest, aspen resuckers in the available spaces, resulting in a stand comprising species clumps as well as intermixed hardwoods and conifers.

The second harvest is taken approximately 60 years later when both aspen and spruce would be harvested. During the time between the first harvest at age 60 and the second harvest at the total age 120 years, new regeneration of spruce should occur from seed cast by seed-bearing released understory trees or from seed trees of the overstory purposely retained after the first harvest (Navratil et al. 1989).

Evaluation of stand suitability

Density and spatial distribution of white spruce understory

Results of preharvest and postharvest assessments of white spruce densities in Alberta's harvesting trials show that 40–80% of white spruce understory is destroyed or damaged while harvesting aspen overstory when intermediate and high levels of protection are employed. The amount of spruce protected can be controlled by the choice of harvesting equipment, equipment operating techniques, and levels of planning and supervision (Brace Forest Services 1992; Sauder 1992).

Based on the above estimates, the preharvest understory density should therefore be about double the targeted postharvest densities. What the targeted postharvest densities should be will greatly depend on management objectives and windthrow risk level. The maximum spruce yield (expressed in total volume at the second harvest) may be achievable if the postharvest densities exceed 850 spruce trees per hectare (Table 2) and spruce trees are uniformly distributed (Navratil[1]).

Windthrow risk assessment

Tree resistance to windthrow

Resistance of a tree to windthrow results from a combination of several tree characteristics (Navratil 1995). Height is important, because wind speed, and therefore wind load on a tree, increases exponentially with distance from the ground. In the pooled data from the Alberta harvesting trials, cumulative windthrow dam-

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[1] Navratil, S. Silvicultural systems for managing deciduous and mixedwood stands with white spruce understory. *In* Silviculture of temperate and boreal broadleaved–conifer mixtures. Proc. Symp., Feb. 28–March 1, 1995, Richmond, BC. (In press.)

Table 2. White spruce yield at second harvest in relation to understory density.

Trial location	White spruce[a] yield (m3/ha) at following densities of white spruce understory (trees/ha) after first harvest: 250	580	850
Drayton Valley[b]	162	346	468
Whitecourt	142	310	428
Hinton	132	294	411

[a] Estimated spruce age = 110 years.

[b] Projections based on calculations of five-year periodic annual increment (PAI) (the first five years after release) and compounded mortality (1% per annum) as reported in Navratil et al. (1994). Densities of 246, 577, and 851 trees/ha, respectively, were used in the calculations.

age five years after release for spruce trees with heights up to 7 m was less than 5%, whereas trees taller than 10 m had cumulative windthrow damage of 10–25%.

The slenderness coefficient, expressed as a height/DBH ratio, often serves as an indicator of wind and snow damage resistance. It is correlated with the crown size and particularly crown length. The slenderness coefficient has been intensively studied in Europe, where the importance of maintaining well-tapered trees for protection against wind and snow damage is emphasized. The desirable height/DBH ratios vary with species and site. In central Europe, a ratio of 80–90 is acceptable for Norway spruce (*Picea abies* [L.] Karst.) (Navratil 1995).

At present, in the absence of more specific local data for white spruce, we consider white spruce understory trees with height/DBH ratios equal to or greater than 100 and taller than 7 m as being in a high-risk category.

Windiness of the region

Wind gusts produce most of windthrow. Expected return periods for maximum gusts, meaning the average length of time between gusts of a given wind speed, calculated from long-term meteorological records can be useful for highlighting the areas requiring special attention in wind protection planning (Flesch and Wilson 1993).

The directional analysis of maximum gusts is essential for the planning of the sheltering effect of stands located upwind from the stands requiring protection (released white spruce understory). Figure 2 illustrates a simplified diagram of wind behavior where a sheltering stand is on the windward side of the open area. The open area may represent a cutblock with released white spruce understory. Wind speed changes depicted in Figure 2 show that when a wind leaves the stand, it accelerates to about 30%; at 50 m into the clearing, it reaches 80%; and at about 100 m, it reaches 100% of the original speed.

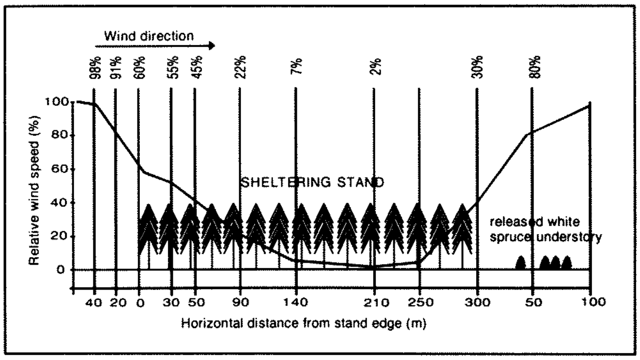

Figure 2. Example of wind speed in a forest stand and adjacent open areas.

Source: Navratil (1995).

Site evaluation

Site, primarily soil characteristics, directly affects windthrow hazard of released spruce. Susceptibility to windthrow is related to the effectiveness of root anchorage, which, in turn, is governed mainly by the depth and size of structural roots.

Windthrow risk is expected to be higher on moist and wet sites. The presence of endemic windthrows with flat root systems and signs of gleying in upper soil horizons may assist in diagnosis of these sensitive sites (Navratil 1995). The rise of soil moisture on moist sites after harvesting aspen overstory could seriously affect wind stability of released spruce.

The overall windthrow risk can then be estimated from the assessments of wind resistance characteristics of understory trees, site evaluation, and windiness of the region and site. Subsequently, the required level of wind protection can be assigned—low, medium, high—which, in turn, will guide the choice of silvicultural and harvesting system to be used.

There are three ways in which windthrow damage can be minimized by the appropriate silvicultural system:

- improving the windfirmness of understory trees *prior to* total removal of aspen canopy using variants of the shelterwood system;
- reducing wind damage in released white spruce *after* removal of aspen canopy using the sheltering effect of stands, strips, and windbreaks; and
- combining shelterwood and sheltering effects in one design.

Table 3 lists applicable silvicultural systems with the incremental levels of wind protection, type of wind

Table 3. Silvicultural systems for reducing wind damage in released white spruce understory.

System	Type of protection	Level of protection against wind damage	Level of harvesting difficulty[a]
Clearcut; total removal of aspen canopy	None	None	Easy
Clearcut; total removal of aspen canopy; some clumps of standing balsam poplar (*Populus balsamifera* L.) and aspen	Mutual support of neighbor trees and reduced wind speed within clumps	Low, varies with size and spatial distribution of standing residuals	Easy
Clearcut; removal of the aspen canopy with retained long windbreaks of aspen/balsam poplar	Reduced wind speed on lee side of windbreaks	Medium to high, varies with porosity and distance between windbreaks	Easy
Alternative strip cutting in two passes:	Sheltering effect of stand on windward side	High after first pass, low after second pass, varies with width of strip	
50 m wide			Difficult
100 m wide			Moderate
150 m wide			Moderate
Uniform shelterwood, 50% removal of basal area	Improved stability of understory between first and second passes	Medium	Not compatible with feller-buncher harvesting
Modified uniform shelterwood, one pass	Improved stability of understory and sheltering effect of retained narrow strip	Very high	Moderate
Modified uniform shelterwood, two passes	Improved stability of understory between first and second passes	Very high after the first pass, medium after the second pass	Moderate
Combined shelterwood strip system, two passes	Sheltering effect and improved stability of understory	Medium to high	Moderate to difficult
Combined shelterwood strip system, three passes	Sheltering effect and improved stability of understory	High	Moderate to difficult
Progressive strip clear-cutting	Sheltering effect and height gradient of spruce deflecting wind	High	Moderate to difficult
Wedge strip cutting	Sheltering effect and height gradient of spruce deflecting wind in a wide angle	Very high	Unknown

[a] Feller-buncher felling.

Source: Navratil et al. (1994).

protection, and different harvesting difficulties when using feller-buncher felling. For details of the designs and harvesting layout and harvest sequencing, see the diagrams in Navratil et al. (1994) and Navratil (1995).

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