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HARVESTING AND SILVICULTURE SYSTEMS TO PROTECT IMMATURE WHITE SPRUCE AND ENHANCE DECIDUOUS REGENERATION IN BOREAL MIXEDWOODS

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ABSTRACT. The Canadian Forest Service and the Forest Engineering Research Institute of Canada, in cooperation with industrial and government partners, have developed innovative approaches to managing western Canada's boreal mixedwood forests. Studies at sites in central and northern Alberta are directed toward perpetuating healthy boreal mixedwoods by testing conventional harvesting equipment and various silvicultural systems designed to protect and minimize wind damage to immature white spruce residuals and encourage vigorous hardwood regeneration following harvest of the aspen overstory. Research studies include investigation of the biological response to the treatments as well as testing the efficiency of equipment and harvesting costs. This research has assisted companies in more efficiently coordinating their harvesting and stand-tending activities in order to improve forest management for both conifer and deciduous users. The research has demonstrated overational. cost-effective methods for increasing conifer fiber in the mixedwood region. As well, it has provided an operational-scale demonstration of alternative harvesting systems in a boreal mixedwood landscape for maintaining biodiversity and ecosystem sustainability.

KEY WORDS. Immature White Spruce, Aspen, Mixedwood Management, Understory Protection

INTRODUCTION

One third of the western boreal forest in Canada is characterized by non- or marginally-merchantable immature white spruce growing under a mature aspen canopy. Conventional management practice is to clearcut these stands using tree-length harvest systems, allow the deciduous species to regenerate naturally by sucker or seed, or if softwood production is the goal, plant conifer species. Protection of immature white spruce has been by avoidance of single trees during felling and skidding. However, due to stem damage from felling and skidding operations, only a few immature white spruce survive after harvest and most of these blow down soon after harvesting is completed. This loss of immature spruce may result in shortages of sawlog timber in 50-70 years. There are also concerns that loss in the conifer component will convert the mixed stands to deciduous stands that would have implications for wildlife habitat. biodiversity and aesthetics. In addition, establishing conifer plantations by seed or seedlings is' challenging because of overtopping competition from grasses and aspen and stem damage from herbivores.

Brace and Bella (1988) proposed a two-stage stand tending and harvest model as one approach to managing mature deciduous stands with an immature white spruce component. They proposed a 60 year-old mature aspen in a mixed stand could be harvested so the immature white spruce was left undamaged. The released white spruce stems are then allowed to grow along with aspen that has regeneratedin openings created by the initial harvest. After 60 years of post-harvest growth, both species are of a merchantable size and a second harvest removes both species.

Two long-term harvesting trials have been established in the boreal forests of central and north western Alberta to test innovative management strategies which would address the potential short-term decline in conifer fiber, the high costs and uncertainties associated with establishing white syruce vlantations. and to test the Brace and Bella model. The goal of the studies was to develop cost effective, practical strategies to manage both species. Stands at the study sites (Table 1) are representativeof the mixedwood landbase forest companies are managing in the region (Navratil et al. 1994).

	Overstory	Understory
Species	Aspen (*Populus tremuloides* Michx.) and Balsam Poplar (Populus *balsamifera* L.)	White Spruce (*Picea glauca* [Moench] Voss)
Height	25 m (average)	0.5-14+ m
Age	70-110 years	60 years (average)
Stand Density	653-1039 stems ha^{-1}	323-3973 stems ha^{-1}
Total Volume	180-350 $m^3 ha^{-1}$	5-107 $m^3 ha^{-1}$

Table 1. Characteristicsof stands at study sites.

CENTRAL ALBERTA STUDY

In the Central Alberta study, nine blocks were established at three relatively dry (mesic) mixedwood sites where wind damage was not an issue. The objectives of these trials were to: develop and test harvesting strategies to protect immature white spruce; determine the costs associated with the different harvesting strategies; determine the limitations and benefits of using mechanized tree-length and cut-to-lengthequipment; and assess post-harvest density/stocking and periodic growth to develop mixedwood regenerationand stocking standards.

Each of the nine blocks was harvested in one pass between 1988-1990 with harvest in the late spring, summer and fall to minimize any potential damage that could occur to residuals during cold weather. The tree-lengthharvesting equipment in these trials included feller-bunchers, grapple skidders and stroke deliibers. Cut-to-length harvesting equipment consisted of double- and single-grip harvesters and 10-tonne forwarders. All skidding or forwarding equipment was co ned to machine comdors felled by the feller buncher on blocks where immature stems were protected. The feller-buncher operator randomly located machine corridors.

Up to 61% of the immature white spruce were undamaged during harvest (Navratil et a1.1994). Growth of residual spruce ranged from 3 to 5 $m^3 ha^{-1} yr^{-1}$ during the first five years after harvest, with subsequent acceleration during the second five year period.

Harvesting trials showed that conventional tree-length harvesting was more productive than cut-to-length harvesting. Felling, harvester, skidder and forwarder equipment productivity was affected when immature spruce stems were protected. However, delimbing equipment was not affected.

The felling phase was most affected by changes in harvesting techniques. Feller-buncher productivity decreased **24-52%** when protecting immature spruce compared to clearcut felling. This occurred because there were differences in tree size and the feller-buncher operators required more time to fell and bunch mature stems when working around immature spruce stems. Feller bunchers also spent a greater proportion of their operating cycle moving when compared to clearcut felling. Harvester productivity was also less than when working on a clearcut because the operator required more time to access mature stems and the presence of small stems or brush caused the chain to flip off the bar.

Skidding productivity increased **(19-27%)** on two blocks when stems were bunched on machine corridors compared to skidding clearcut bunches because the skidder could easily pick up bunches located along the trail, it was relatively simple to accumulate bunches or the bunches were larger, and travel speed increased. Travel speed increased because the stumps along the trail were cut low. Skidding productivity decreased 46% at the third block because the operator skidded small bunches and made no effort to accumulate.

Tree-length harvesting left well-defined skid trails with islands of relatively undamaged immature spruce between the machine comdors. The cut-to-length system left trails that were less visible than the conventional equipment, however, significantly more of the understory between trails was damaged than with conventional equipment. Post-harvest surveys showed that compared to clearcut harvesting where **2-16%** of the immature spruce were left undamaged, conventional tree-length equipment working from machine corridors left **40-60%** of the pre-harvest immature white spruce undamaged and cut-to-length equipment left **20-30%.** This occurred because feller bunchers could sever a stem, carry the stem and place it in a bunch located along the trail without damaging residuals while the harvester felled stems into the stand and dragged the felled stem through the residuals when delimbing and bucking to length. This resulted in leader breakage, bark scrapes and uprooting of immature spruce residuals that did not occur with the feller buncher. The ability of the feller buncher to sever a stem and place it in a bunch on a trail without damaging residual immature spruce demonstrated the potential for felling similar stands during winter conditions when wet soils limited access to periods when the soils were frozen.

The central Alberta harvest studies showed that careful planning, proper equipment selection, on-site supervision, crew motivation, training and cooperation from other agencies are all required to minimize immature soruce damage. The studies also demonstrated that the immature white spruce left on the site can survive and aspen regeneration can infill the openings. Modifications to the normal operating techniques that increased immature spruce retention included using designated skid trails and keeping skidders to the same trail as the feller buncher, leaving rub posts at curves or to protect immature spruce clumps alongside the trails, raising the cutting height of stumps to avoid damaging residual stems, leaving single, isolated marginal-quality aspen stems standiig rather than felling. Repiling delimbed stems using a hydraulic loader reduced the amount of area required for landings.

NORTHERN ALBERTA STUDY

The second project was established in a mixedwood forest in northwestern Alberta to develop and test a range of harvesting and silvicultural prescriptions using conventional tree-length harvesting equipment to protect immature white spruce and reduce wind damage to the immature spruce residuals. Topography at the site was flat to rolling. with moisture conditions ranging from moist to wet (mesic to subhygric) and generally wetter compared to the central Alberta sites. This 530 ha operational-level applied research study was established in 1992. Harvests occurred in 1993194 and 1998199 and prescriptions were developed using experience from the studies in central Alberta. Other objectives of the study were to: imvrove the growth of immature white spruce, encourage new aspen and white spruce regeneration, provide operational-scale demonstrations of alternative harvesting systems in a boreal mixedwood, and assess harvesting productivity/costs for each treatment.

Harvesting was done during fall or winter, depending on the soil moisture conditions on the block. A range of eleven harvesting and silviculture treatments were established, with the intention of creating various levels of wind protection for the immature white spruce. These systems included: one-pass clearcuts with white spruce avoidance, one and two pass modified uniform shelterwood cuts (with uncut aspen buffers between machine corridors), two and three pass 50 and 100 m strip shelterwood cuts, two-pass alternate 50, 100 and 150 m strip cuts, a four-pass progressive 50 m strip cut as well as uncut controls. Additional information is in Navratil et al. (1994) and MacIsaac et al. 1999). Both first and second passes were harvested using conventional tree-length equipment comprised of feller-bunchers, grapple skidders and roll-stroke delimbers.

As expected, there was a wide range of blowdown response, with periodic five-year white spruce blowdown rates ranging from 72% in the white spruce avoidance blocks to less than 6% in the most protected shelterwood blocks. Spruce release has resulted in at least a doubling of MAI five years after harvest, from 0.8-1.2 $m^3 ha^{-1} yr^{-1}$ pre-harvest to 1.8-3.6 $m^3 ha^{-1} yr^{-1}$ post-harvest (based on total block area, exclusive of landings). There was substantial regeneration along the machine corridors and on the landings five years after harvest. with up to 15.000 stems ha^{-1} of aspen and up to 5,000 stems ha^{-1} of spruce. However, it is unknown if the aspen regeneration along the machine corridors will be overtopped by the released spruce.

The harvesting operations monitored at the northern Alberta site showed that feller-buncher productivity decreased 20-30% for fall harvested blocks and 10-40% for winter harvested. compared to clearcut operations. Felling production was related to similar factors as the central Alberta studies: tree size and the additional time required to avoid immature stems or fell and bunch stems. Winter felling productivity and especially night operations were also negatively influenced when felling in stands with heavy canopy snow loads. Overall, felling productivity increased to about 10% of clearcut felling production as operators gained experience. There was no difference in skidding and delimbing equipment productivity between treatments.

The harvesting prescriptions used at the northern Alberta site were based on experiences learned in central Alberta, and modifications were made to the second-pass northern Alberta harvest based on the first pass harvest. Machine corridors were aligned perpendicular to the prevailing wind direction and road, and spaced twice the reach of the feller-buncher apart to minimize the amount of area in trails. Feller-buncher operators minimized trail width by falling a corridor slightly wider than the track width of the machine with allowance for the tailswing when operating perpendicular to the travel direction. The sheltenvood prescription was modified from leaving mature stems uniformly distributed between trails to leaving an uncut strip between felled corridors. The sheltenvood yrescriytion required feller-buncher oyerators to focus on maneuvering the felling head between immature spruce and aspen residuals. Increasing trail spacing so that an uncut buffer remained between the felled trails allowed the feller-buncher operator to fell all mature stems within the machine's reach, while retaining an effective wind buffer. This reduced operator frustration and increased productivity.

Overall, in all prescriptions, there were acceptable levels of machine damage to white spruce and trail widths were minimized. It was found the width of trails was not only related to the machine dimensions but also the width of crowns on the aspen stems. For most trails, there was insufficient room to deck stems felled for the machine corridor and stems felled adjacent to the corridor. As a result, the treatments were felled in two yasses. Pre-flagging trails allowed the feller-buncher to operate during day and night shifts. Preliminary planning, on-site supervision and enthusiastic operators were keys to achieving the objectives.

This research has demonstrated that up to 60 percent of immature white spruce (exclusive of deck areas) can be protected during harvest. It has also demonstrated that immature white spruce stems greater than 7 m tall or in cut areas greater than 80 m wide are most susceptible to blowdown. From our studies, it would appear the tradeoff between spruce growth response and wind protection is best met with 10-20% aspen retention.

SUCCESSFULLY APPLYING UNDERSTORY PROTECTION

Our studies have shown that silvicultural prescriptions designed to protect white spruce understory should be simple and achievable. Supervisors and feller-buncher operators require clear objectives that can be used to describe the post-harvest stand conditions. Paper planning can evaluate the potential for success. and detailed harvest plans need to be developed based on site reconnaissance. Pre-flagging trails minimizes reductions in felling productivity and allows for night-shift operations. On-site supervision and training are required for proper implementation especially in the early stages. Additional harvesting costs can be offset by reduced costs associated with not having to establish a new conifer crop. There should be good interaction and full support of company, contractors and ALL crew. Emphasis on harvesting operations should initially focus on quality of achieving the silvicultural objectives and then move to increasing equipment productivity as operators gain confidence and skill in new work cycles. It is important to properly compensate contractors for any additional costs incurred and for operators paid on a piece-rate basis.

Selecting individual stems for felling while avoiding damage to immature spruce is challenging for operators. Rather than leaving mature stems scattered uniformly between machine comdors, it is more productive for the felling equipment and equally as effective for wind buffering to leave an uncut strip as a buffer by simply increasing the spacing between **corridors.** When possible, one-pass harvest prescriptions are most cost effective, however they may also result in a higher proportion of mature stems left in permanent buffers. Multi-pass prescriptions offer the potential to reduce or recover mature stems left as buffers. However, costs may rise because there is less volume to offset mobilization costs, access to the block has to be maintained and regeneration established on previous passes can be damaged if operations are not careful.

CONCLUSIONS

The most promising techniques and innovative silvicultural and harvest prescriptions designed in these studies are being used operationally by forestry companies throughout Western Canada in the following manner: The two stage harvest and stand tending model and white spruce protection techniques have been widely adopted. Pre-harvest planning, layout, designated machine corridors and wind buffers of mature aspen are now in use. Modifications of these harvesting methods are being tested in research and field demonstrations by a variety of organizations. In conclusion, it is important to note that white spruce protection is only one tool in mixedwood management, albeit a very important one.

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