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Returning Roadside Processing Debris to the Harvested Site: Effects on Planting Microsites on South-Facing Slopes in the Alberta Foothills

Technical report no. 21 - March 2017

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ABSTRACT

Forest companies in the Alberta Foothills are experiencing winter seedling mortality due to desiccation associated with the regions warm, chinook winds. In many cases the result has been costly replanting treatments. This 2015 trial looked at five treatments that involved returning roadside processing debris to the cutover for the purpose of providing modified microsites that would protect the seedlings from winter desiccation. The results showed that the density of microsites located near debris increased significantly after the treatments, but the density of microsites near obstacles reduced. The cost of returning debris to the cutover was similar to the cost of piling and burning it, but returning the debris may have the added benefit of precluding the need to fill plant, thus avoiding that cost.

ACKNOWLEDGEMENTS

This project was financially supported by Natural Resources Canada under the NRCan/FPInnovations contribution agreement.

The author thanks West Fraser (Sundre Forest Products) and Ichi Resources for their cooperation during the trial.

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INTRODUCTION

As the available harvesting landbase shrinks, for many Canadian forest companies the need to expand operations into more challenging terrain is becoming more common. This trend is occurring in Alberta as companies seek to access timber from steeper ground in the foothills along the slopes of the Rocky Mountains.

Winter chinook winds in southwestern Alberta can remove insulating snow cover and increase air temperatures by 25^{o}C or more within a few hours. The root systems of tree seedlings exploit only a small amount of soil to meet their moisture requirements. The warm dry air associated with chinook winds creates a moisture demand the seedlings cannot meet, which consequently increases the potential for winter desiccation.

Slope and aspect both affect solar radiation. A 20% south-facing slope could experience 15% more solar radiation than a flat surface and 40% more solar radiation than a 20% north-facing slope (Spittlehouse & Stathers, 1990). The effects of solar radiation are greatest in early spring, late fall, and winter. South-facing slopes have an earlier snow melt, and sloping terrain often has a drier moisture regime and higher soil temperatures than level, moisture-retaining terrain (Spittlehouse & Stathers, 1990).

In the Alberta Foothills, northwest of Calgary, Sundre Forest Products Ltd. is experiencing up to 30% seedling mortality from winter dessication on southwest-facing slopes, primarily during the first and second years after planting. This mortality has resulted in expensive reforestation programs based on the need for fill plantings to maintain desired stocking levels.

Sundre Forest Products typically performs a chain-drag scarification treatment after harvesting. When cone surveys indicate there are insufficient cones (<5000/ha), a supplemental planting is completed to ensure that target reforestation levels are achieved. Over the last 5 years, Sundre Forest Products has scarified approximately 48% of its harvested ground and left it for natural regeneration.

In the summer of 2015, FPInnovations conducted a trial at a Sundre harvesting site as part of a larger study that included evaluating harvesting systems on variable slopes (Byrne, 2016) and machine fuel efficiencies (Rittich, 2016). The goals of the silvicultural component were to determine if returning roadside processing debris to the cutover, in combination with chain-drag scarification treatments, could be done efficiently on southwest-facing, 20-to-45% slopes, and to calculate the productivity and costs of the debris carry-back treatments. Monitoring of stocking level will determine if returned debris helps reduce winter dessication by providing seedlings with some protection from sun and wind exposure. If the technique is successful, the need to fill plant could be avoided, and the need to pile and burn would be eliminated.

Background

Studies have indicated the presence of harvesting debris in some situations can increase the chances of seedling survival. Klappstein et al. (2005) found an advantage for seedling survival and growth in microsites provided by slash and stumps when planting Douglas-fir in the Porcupine Hills in the Montane Natural Subregion of Alberta.

Landäusser (2009) found cut-to-length treatments in high-elevation lodgepole pine stands in the Rocky Mountains resulted in a 12-times-higher natural-regeneration density on scarified ground even though the cone count was lower than on unprepared ground. Soil temperatures were higher, mortality of planted seedlings was lower and growth was better, on site-prepared ground than on unprepared ground. Jacobs & Steinbeck (2001) found tree shelters in southwest Colorado "could provide an effective method of improving high-elevation Engelmann spruce reforestation". The lightest shade of tree shelters performed better than the other, darker shades of tree shelters; the survival associated with the lightest shade was higher than that for the control treatment, which used obstacles such as logs, slash, and vegetation. On open clearcuts in Finland, damage from winter dessication and frost was reduced for planted seedlings that had been provided with artificial shade (Lundmark & Hällgren 1987). In New Brunswick, McInnis & Roberts (1995) found slash did not provide much shade in the summer, but slash did restrict airflow at ground level. A study done in Michigan (Heiligmann & Schneider, 1975) found that for black walnut trees grown from seeds in semi-permeable wind barriers, the associated wind velocities were reduced by 67% and radiation by 18%, and seedling growth was greatly improved. Farnden (1994) recommends that potential strategies to address winter dessication in the Engelmann spruce subalpine fir (ESSF) zone in north central British Columbia could include "planting seedlings on the leeward side of stumps, logs, or other obstacles". Proe & Dutch (1994) found that harvesting residues can improve microsite conditions under some conditions by providing shelter and reducing wind speeds around seedlings on exposed upland sites. The presence of debris can reduce soil temperatures during the growing season. Landäusser (2009) found slash had a negative impact on the growth of natural seedlings, but not on the growth of planted seedlings. Johansson et al. (2006) found slash was associated with higher soil moisture and reduced competition, and a consequent increase in growth in Norway spruce. In a study in North Canterbury, New Zealand, Platt & Wardle (1995) believed the problem of winter desiccation could be addressed mainly by reducing the area of the harvest openings (coupe size) and retaining harvesting slash to protect developing seedlings. In an earlier study in New Zealand, in the exposed environment following a fire, Thomson & Prior (1958) found light slash provided the optimum conditions for survival and development of young naturally regenerated radiata pine.

OBJECTIVES

In the summer of 2015 FPInnovations examined the practice of returning roadside processing debris (carry-back treatments) to a cutover in the Alberta Foothills for the purposes of:

1. Evaluating the effect on achieving a target density of plantable spots, with and without chain-drag scarification treatments, and
2. Evaluating the productivities and costs associated with using debris-return techniques on moderate-to-steep slopes.

SITE DESCRIPTION

The study site is located 45 km northwest of Sundre, Alberta in the Upper Foothills sub region of the Boreal forest. The trial block has a southwest aspect. The elevation is approximately 1500 m and slopes range from 20 to 45%.

The soils were shallow and had high shale content. The stand was predominantly (96%) lodgepole pine (*Pinus contorta*) with a small component (<5%) of spruce (*Picea glauca*). The average net merchantable volume was 189 m^3/ha or 0.21 m^3/tree.

METHODS

Debris microsite treatments

The treatments employed different machine combinations to move roadside processing debris back into the harvested area (Figure 1). Grapple skidders and crawler-tractors carried and/or pushed back the debris to the cutover. A separate crawler-tractor was used for chain-drag scarification. Treatment unit boundaries were mapped with a Garmin 62sc GPS and the treated areas were calculated.

Figure 1. Forestry equipment used in the trial.
(a) Tigercat 635 six-wheeled grapple skidder. (b) Tigercat 630 grapple skidder. (c) John Deere 2154-D processor with a Waratah head. (d) Caterpillar D-9H crawler-tractor with a brush blade.
(e) Caterpillar D-9H crawler-tractor with “shark-fin” chains attached to cable winch.

The treatments can be summarized as follows:

- Treatment 1 – Two grapple skidders returned roadside processing debris to the harvested area. Debris was carried downhill on slopes ranging from 30 to 45% and spread evenly over the ground. No scarification occurred.
- Treatment 2 – Two grapple skidders returned roadside processing debris to the harvested area. Debris was carried uphill and spread evenly over a moderate slope ranging from 15 to 30%. The site was then mechanically scarified by a D9 crawler-tractor pulling chain drags.
- Treatment 3 – The D9 crawler-tractor equipped with chain drags mechanically scarified the site before a second D9 crawler-tractor equipped with a brush blade pushed windrowed roadside processing debris uphill and spread it evenly over the scarified area. Slope ranged from 10 to 20%.
- Treatment 4 – A D9 crawler-tractor with brush blade pushed roadside processing debris uphill and spread it evenly over moderate slopes (20 to 30%) within the harvested area. This treatment area was then mechanically scarified by the D9 crawler-tractor pulling chain drags.
- Treatment 5 – An integrated system was deployed. A single skidder supplied stems to a single processor at roadside and returned debris, as it was produced by the processor, uphill to the harvested area. When the skidder was not providing stems to the processor or returning the freshly produced debris, it carried stockpiled roadside processing debris back to the cutover. Slope ranged from 10 to 30%.
- Treatment 6 (for cost comparison) – A standard harvesting treatment where the skidder skids and decks stems for the processor, but no debris is returned to the cutover. The debris is instead piled for burning once harvesting is completed.

Debris and microsite survey

The purpose of returning debris to the harvested area is to create structure that provides planted and natural seedlings with protection from exposure to the sun and wind.

The target minimum depth for well-spaced debris structures was 15 cm—i.e., similar to the average height of a planted seedling (Pl 411, 1+0) scheduled to be planted on the study block. Line transect surveys were conducted to calculate the volume and height distribution of the debris before and after treatment. Two perpendicular 20-m line transects were measured off each of the plot centres established on a 40x40-m grid pattern in all treatments. Fixed-area circular plots (3.99-m radius) were established at the end points of the transects to determine the type and density of acceptable microsites. Two classes of acceptable microsites were identified (Figure 2); microsites with debris structure ≥15 cm in height, and microsites with obstacles such as stumps or logs ≥15 cm in height. A minimum inter-tree distance of 1.5 m was used to count well-spaced microsites.

Figure 2. (a) Debris microsite. (b) Obstacle microsite (stump).

Productivity and costs

Detailed timing studies were conducted to determine the productivity of each machine in the five treatments. A total of 22 crawler-tractor cycles, 121 skidder cycles, and 1050 processor cycles were evaluated. Machine productivity was calculated using the productive machine hours (PMH) and the merchantable volume of wood that had generated the debris which was subsequently returned to the harvested area. Treatment costs were calculated using machine productivity and the hourly machine rates provided by the licensee. Treatment costs were compared to a standard harvesting treatment (Treatment 6) where no debris is returned to the cutover and is instead piled for burning once harvesting is completed. Costs for the standard harvesting treatment were calculated using data from a concurrent FPInnovations harvesting study (Byrne, 2016).

RESULTS

Debris volume and microsite density

The pre- and post-harvest debris volumes for each treatment unit are presented in Figure 3. Before the debris was returned to the cutover, the volume and heights of debris (≥1 cm in diameter) was similar for all treatment units; average volume was 61.5 m^3/ha. As expected, the debris volumes increased considerably after the debris-return treatments. The average height of the debris clumps also increased after the treatment, from 7.2 cm to 22.8 cm.

Before the treatment, the average density of microsites for all treatment units was 741 debris microsites/ha and 500 obstacle microsites/ha. After treatment, the average density of microsites in the treatment areas was 2284 debris microsites/ha and 120 obstacle microsites/ha (Figure 4).

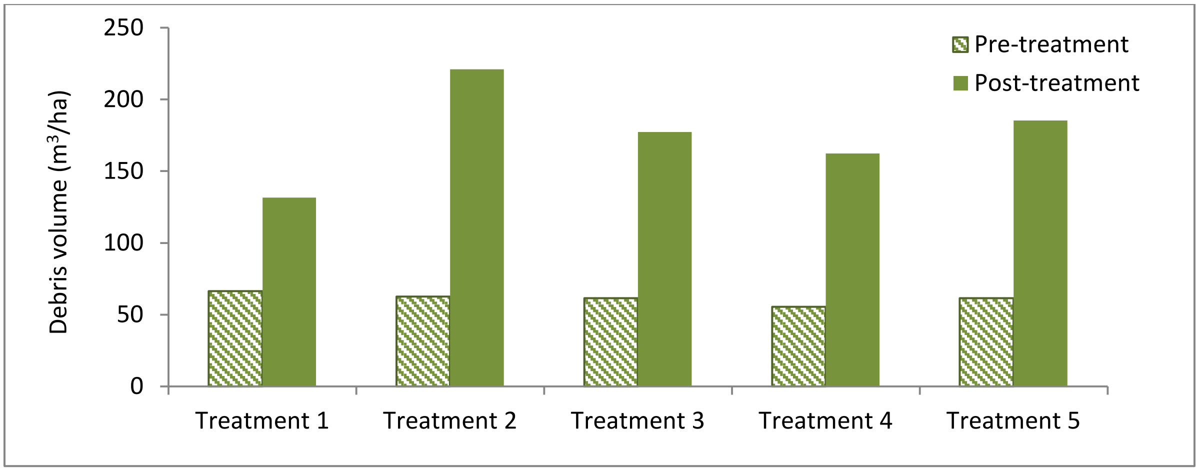

Figure 3. Debris volume on the cutover, before and after debris-return treatments.

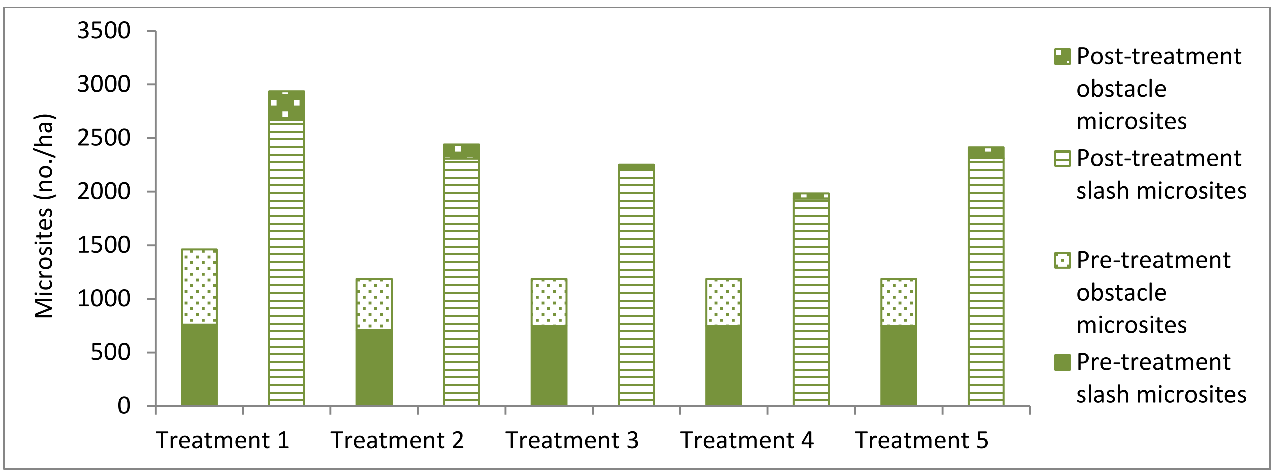

Figure 4. Density of microsites on the cutover, before and after debris-return treatments.

Treatment productivity and cost

Machine productivities (m^3/PMH) and treatment costs ($\$/m^3$) are presented in Table 1. The cost to return processing debris from the roadside to the cutover was $\$0.73/m^3$ for the grapple skidders working downhill in Treatment 1. The combined cost for returning debris with scarification was $1.14 in both Treatments 2 and 3, while the combined cost in Treatment 4 was higher at $2.17 because the crawler had more difficulty pushing a large, older, tangled debris pile than pushing fresh, loose, roadside-processing debris. There was no additional skidding cost for returning debris during the integrated system (Treatment 5) because the skidder carried debris to the cutover on the return trip to pick up trees.

In Table 1 the cost of the integrated system (Treatment 5) with debris returned is compared to the standard harvesting system (Treatment 6) without debris return and with burning and fill planting (Figure 5). These are then compared to a third option of standard harvesting with debris return but without burning and fill planting.

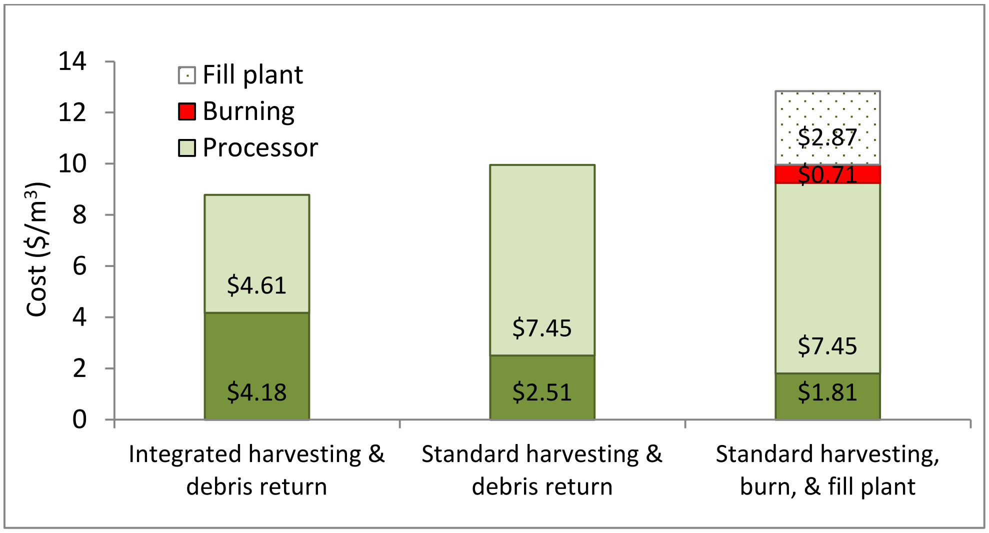

Figure 5. Cost comparison of integrated and standard harvesting systems.

DISCUSSION

The debris-return treatments created more than double the well-spaced pre-treatment microsites than if no debris had been returned to the cutover, thereby increasing the potential opportunities for natural regeneration and/or planted seedlings.

It is important to note the chain drag treatments provided exposed mineral soil on the scarified ground, whereas the skidder debris-return treatments did not. This could impact the potential for natural regeneration to be successful, but should not affect tree-planter productivity.

The licensee required a minimum density of 1000 stems/ha and had a target density of 1600 stems/ha. The debris return treatments provided an average of 2284 microsites/ha. Future monitoring will be required to determine the density of debris microsites that become occupied with natural regeneration and whether these microsites actually contribute to an increase in survival of natural and/or planted seedlings.

The returned debris created many additional debris microsites, but some obstacle microsites were lost if they no longer met the minimum spacing requirement from the newly created debris microsites or if the obstacles were simply covered by deep debris. Obstacles such as stumps or logs may provide a better microsite than a debris microsite because of their long-term structural and nutrient supply properties. Nevertheless, a debris microsite will have more protection from exposure than open ground without any debris nearby.

Table 1. Productivity, by treatment

Treatment	Equipment	Work cycle	Work direction	Slope (%)	Time (PMH)	Merch. volume (m^3)	Productivity (m^3/PMH)	Cost ($\$/m^3$) [1]
1	2 skidders	Carry back & spread debris. No scarification.	Downhill	30 to 45	1.2	234	195.0	0.73
		Total						**0.73**
2	2 skidders	Carry back & spread debris.	Uphill	15 to 30	2.5	554	221.6	0.64
	1 crawler-tractor	Chain-drag scarification.	Uphill		0.4	177	442.5	0.50
		Total						**1.14**
3	1 crawler-tractor	Chain-drag scarification.	Uphill	10 to 20	0.4	381	952.5	0.23
	1 crawler-tractor	Push & spread debris.	Uphill		1.6	381	238.1	0.93
		Total						**1.16**
4	1 crawler-tractor	Push & spread debris.	Uphill	20 to 30	1.1	163	148.2	1.49
	1 crawler-tractor	Chain-drag scarification.	Uphill		0.5	163	326.0	0.68
		Total						**2.17**
5	1 skidder	**Integrated system:** Carry back & spread fresh & stockpiled debris during harvesting.	Uphill	10 to 30	5.3	180	33.9	**4.18**
6	1 skidder	**Standard system:** [2]						
		Skid & deck stems.						1.81
		Fill plant cost. [3]						2.87
		Pile & burn cost. [4]						0.71
		Total						**5.39**

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[1] *Machine costs are based on hourly machine rates of $142 and $222 for the skidder and crawler tractor respectively.*

[2] *Standard system costs are based on the FPInnovations' study done by Byrne (2016).*

[3] *Estimated fill plant cost ($\$/m^3$) based on $575/ha/200 m^3/ha).*

[4] *The cost of burning in 2016 (Baxter 2010 = $0.60) = $0.71 adjusted for 2016.*

In Eastern Canada, Desrochers (1996) found a 150-kW crawler-tractor returning delimber debris from the roadside had an estimated productivity of 0.2 ha/h. In the Sundre trial, a 346-kW crawler-tractor achieved a productivity of 0.8 to 1.2 ha/h (productivity was converted from merchantable volume to compare with the Desrochers trial). The productivity and costs of the different treatments generally depended on the specific machines that were used, but were also affected by the combination and sequence of the machine phases used during the treatment. The grapple-skidders were not very effective at carrying debris up steep slopes (i.e., >35%), especially when travelling uphill over debris that had been returned to the harvested area. However, when moving downhill, the skidders were able to push and carry the debris effectively on the steep slope and provide a good distribution of debris microsites. On moderate slopes, the skidder was able to return debris to the cutover for a slightly lower cost than the crawler-tractor.

The integrated system (Treatment 5) was the most costly treatment in the trial because most of the skidder time (70%) was spent returning previously stockpiled slash. This could be reduced by adding a second processor. The standard harvesting method (Treatment 6) involved a separate phase for the skidder to build the deck of trees, followed by another in which the processor processing trees at roadside. If the skidder does not return debris to the cutover, the additional costs to pile and burn the debris and any costs for fill planting need to be included.

The trial results indicated the productivity of the processor was slightly higher in the integrated treatment than for the standard harvesting method where skidders built the decks (Table 1). This likely occurred because it was easier for the processor to pull out individual pieces from a small, loose, bundle of trees than to pull them from a large, stacked deck of stems.

The integrated system had an average skid distance of 124 m with an average cycle time of 6.5 min, and the skidder carried an average of 19 stems/load (piece size was 0.3 m^3/stem). The relatively short skid distances and large number of stems per load meant the skidder would have had enough time to provide an adequate supply of stems to two processors. This would reduce the cost ($/$m^3$) of the treatment. The cost of the standard harvesting system was higher than the integrated system because the skidder included an additional phase for decking stems, because the productivity of the processor is lower when working on large decks than with small skidder loads, and because there are additional costs for burning debris and possibly fill planting.

Integrated harvesting may be a preferred system when conditions are suitable. More details are listed in the Appendix.

Using a debris burning cost of $0.71/$m^3$ (Baxter, 2010), this trial found the cost of skidders returning roadside processing debris to the cutover (without scarification) was comparable at $0.70/$m^3$. Returning debris to the cutover may be a preferred treatment because burning carries a risk of a potentially costly fire escape. Furthermore, if enough seedlings experience mortality, there could also be additional fill-planting costs of $2.87/$m^3$ to meet stand density objectives.

SUMMARY

In 2015 FPInnovations studied the cost and effectiveness of debris-return techniques and the impact of debris return on site preparation, in terms of achieving a desired density of plantable spots with and without chain-drag scarification. Six treatments were examined, on slopes ranging from 10 to 45%, at a harvesting site in the Alberta Foothills.

- All of the debris-return treatments, including the steep-slope treatment, provided over 2000 debris microsites/ha.
- The productivity of the D9 crawler-tractor for debris return was higher for the treatments that returned windrowed processor debris than for the treatment that pushed debris which had been previously piled for the purpose of burning. Pushing large "burn piles" is more difficult than pushing the smaller, loosely piled windrow of roadside processing debris found in Treatment 3. Debris should not be piled if it is going to be returned to the cutover.
- In the integrated system, there was essentially no additional cost for returning debris because the skidder was able to carry debris back on its return trips to the cutover. Also, the productivity of the processor was higher when it worked with small skidder loads of stems than when it worked with the large deck of stems in the standard harvesting treatment.
- The cost of the integrated system may be reduced by using two processors per skidder as long as there are no lengthy, unplanned delays.
- The cost of returning roadside processing debris to the cutover by the grapple skidders and crawler-tractor was similar to the cost of burning the debris. However, with public concerns related to smoke from the burning of piles and the potential for costly fire escapes, returning debris to the harvested area may be a better option. The debris also provides a long-term source of nutrients to the harvested area, and is a cost-effective treatment if it succeeds in reducing seedling mortality and minimizing the need for fill planting.
- These sites require monitoring over the next few years to determine how many of the debris microsites provided by the treatments become occupied by natural regeneration.
- The debris microsites will need to be evaluated for their impact on the regeneration, growth, and survival of both natural regeneration and planted seedlings in their first few years of growth.

REFERENCES

Baxter, G. (2010). *Costs and benefits of seven post-harvest debris treatments in Alberta's forests* (Advantage Report, Vol 11, No. 24). Vancouver, B.C.: FPInnovations, FERIC.

Byrne, K. (2016). *Comparison of harvesting system costs on variable slopes in the Alberta foothills* (Technical Report TR-26). Vancouver, B.C.: FPInnovations.

Desrochers, L. (1996). *Treatment of roadside delimbing areas* (Technical Note TN-248). Pointe-Claire, Quebec: FERIC.

Farnden, C. (1994). *Forest regeneration in the ESSF zone of North-Central British Columbia* (Information Report BC-X-351). Victoria, B.C.: Natural Resources Canada, Canadian Forest Service.

Heiligmann, R., & Schneider, G. (1975). Black walnut seedling growth in wind protected microenvironments. *Forest Science* 21(3):293–297.

Jacobs, D., & Steinbeck, K. (2001). Tree shelters improve the survival and growth of planted Engelmann spruce seedlings in southwestern Colorado. *Western Journal of Applied Forestry* 16(3):114–120.

Johansson, K., Orlander, G., & Nilsson, U. (2006). Effects of mulching and insecticides on establishment and growth of Norway spruce. *Canadian Journal of Forest Research* 36(10):2377–2385.

Klappstein G., Banhardt L., & Greenway G. (2005). Appendix 9B: Porcupine Hills harvesting and silviculture strategies. In *C5 Forest Management Plan 2006–2026*. Edmonton, Alberta: Forest Management Branch, Alberta Sustainable Resource Development.

Laundäusser, S. (2009). Impact of slash removal, drag scarification, and mounding on lodgepole pine cone distribution and seedling regeneration after cut-to-length harvesting on high elevation sites. *Forestry Ecology and Management* 258(1):43–49.

Lundmark T. & Hällgren J. E. (1987). Effects of frost on shaded and exposed spruce and pine seedlings planted in the field. *Canadian Journal of Forest Research* 17(10):1197–1201.

McInnis, B., & Roberts, M. (1995). Seedling microenvironment in full-tree and tree-length logging slash. *Canadian Journal of Forest Research* 25(1):128–136.

Platt, I., & Wardle, J. (1995). Winter desiccation of seedlings in a managed NZ black beech (*Nothofagus solandri*) forest — and its potential solution. *New Zealand Journal of Forestry* 39(4):38.

Proe, M. F., & Dutch, J. (1994). Impact of whole-tree harvesting on second-rotation growth of Sitka spruce: the first 10 years. *Forestry Ecology and Management* 66(1–3):39–54.

Rittich, C. (2016). *Energy intensity profile of a steep slope harvest in the Rocky Mountain Foothills of Alberta* (Technical Report TR-11). Vancouver, B.C.: FPInnovations.

Spittlehouse, D. & Stathers, R. (1990). *Seedling microclimate* (Land Management Report No. 65). Victoria, B.C.: Research Branch, British Columbia Ministry of Forests.

Thomson, A., & Prior, K. (1958). Natural regeneration of P. radiata following the Balmoral forest fire. *New Zealand Journal of Forestry* 7(5):51–70.

APPENDIX - SUITABLE CONDITIONS FOR INTEGRATED SYSTEMS

An integrated harvesting system can be cost effective when conditions are suitable, but effectiveness is affected by production delays. If any of the equipment has a delay, overall productivity could decrease or stop completely and the financial advantage would be quickly lost. Separate-entry harvesting methods are simple and robust, and reduce the risk of unplanned delays or interruptions. Nevertheless, integrated systems can be effective in situations where:

- The roadside landing area is too small for large roadside decks.
- Processed logs are required immediately.
- Tree size is small enough to provide a sufficient number of stems to slow the productivity of the processor and allow longer cycle times for the skidder.
- Skid distances facilitate efficient timing of the skidding and processing.
- Adequate equipment is available including a spare skidder if necessary.
- The operators are experienced and work well together.
- Returning debris to the harvested area is an objective.

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