



# Strip Thinning High Density Pine Regeneration

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## ABSTRACT

FPIinnovations conducted a study of pre-commercial strip thinning treatments in a very high density, naturally regenerated (age class 1) lodgepole pine stand. Semi-mechanized treatments combined mechanized strip-mulching and motor-manual thinning. Both, semi-mechanized and fully mechanized treatments were less costly than conventional motor-manual thinning. Semi-mechanized treatments preserved enough trees to meet post-thinning density objectives. Fully mechanized treatments produced tree densities above provincial minimum stocking standard densities, but below target spacing densities. Even though sufficient trees were preserved, it is unclear whether fully mechanized treatments will be able to meet the long-term stocking objectives.

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## INTRODUCTION

Wildfires in the Kootenay region of British Columbia in 2003 and ideal germination conditions in 2004 resulted in extremely dense stands of natural regeneration lodgepole pine. Canfor salvage logged some blocks in 2004. On the blocks where salvage logging was done, the densely regenerated stands will need thinning to meet legislative stocking obligations and maintain stand productivity. Canfor is obligated to complete pre-commercial thinning on an estimated 1300 ha of salvage-harvested blocks within the next 6 years.

### Rationale and approach

Motor-manual treatments (using a brush saw) are expensive and not suitable at very high stand densities. Semi-mechanized strip cutting can lower costs and still provide a treatment quality similar to a labour intensive fully motor-manual operation (Ryans 1995; St-Amour 2000, 2004, 2006, and 2007). Thus, to investigate the semi-mechanized option, in the fall of 2013, FPIInnovations helped Canfor conduct a semi-mechanized pre-commercial thinning operation on fire-salvaged high-density pine blocks in the Plumbob Fire area near Cranbrook, B.C. A Fecon FTX 140 mid-sized non-articulated mulcher (Figure 1) was used for the mechanized strip-cutting treatments. The trial consisted of conducting mulching treatments with 50% removal (1.9 m retention strips), 66% removal (0.9 m retention strips), and 75% removal (double-pass cross-hatch pattern). Motor-manual thinning was studied by itself and in combination with the 50% removal mulching treatments on flat and steep ground.



**Figure 1. Fecon FTX 140 mulcher**



## OBJECTIVES

The objective of this study was to provide information for assessing the viability and cost-effectiveness of including mechanized thinning in the overall strategy for thinning very high-density pine stands. This study was implemented to:

- calculate the cost (\$/ha) and productivity (ha/h) of mechanized mulching with a mid-size machine (FTX 140 Fecon) on flat ground and steep ground
  - flat ground (0–20% slope): two mechanized treatments and one semi-mechanized treatment
  - moderately steep to steep ground (25–40% slope): one semi-mechanized treatment
- compare the cost and productivity of manual thinning with and without strip mulching treatments.

## METHODS

### Pre-treatment surveys

Pre-treatment surveys measured site conditions, stand density, species composition, and tree heights using four 2-m<sup>2</sup>, fixed-area plots per hectare. The first plot was randomly selected, and the other plots were established on a 50 m grid pattern from the first plot. Line intersect sampling was used to calculate slash volume on the ground. Slash volume was then used to assess the impact of slash on mulcher productivity on flat and steep ground.

### Post-treatment surveys

Post-treatment surveys were completed in all of the motor-manual, semi-mechanized, and fully mechanized treatments. Fixed-area plots were used to tally potential crop trees meeting requirements of species, height, form, and 2 m minimum inter-tree spacing (B.C. Ministry of Forests, Lands and Natural Resource Operations, 2012).

### Mulcher productivities

Net productivity and gross productivity were calculated:

- Net mulcher productivity (ha/h) was calculated as a product of machine working speed and the width of the cut strip, and the machine utilization (%). Machine utilization was determined as the ratio of productive machine hours (PMH)(mulching time) to total scheduled time that included non-productive machine hours such as delays.
- Gross mulcher productivity (ha/h) was calculated by including the areas of both treated strips and untreated retention strips.

## Treatments

This study included the following mulcher treatments:

- Treatments 1 and 2 – Semi-mechanized
  - The mulcher cut 1.9 m wide strips and left 1.9 m wide retention strips, resulting in 50% removal. Treatment 1 was done on flat ground (0–20% slope) and Treatment 2 was done on steep ground (25–40% slope).
  - After mulching, motor-manual thinning was done in the retention strips.
- Treatment 3 – Fully mechanized; narrow strip
  - The mulcher cut 1.9 m wide strips and left narrow 0.9 m wide retention strips, resulting in 68% removal. This treatment was done on flat ground.
  - The purpose of leaving the narrow strips was to assess whether this treatment could retain sufficient crop trees and not require additional motor-manual thinning to meet the requirements for well-spaced stocking over the long term.
- Treatment 4 – Fully mechanized; cross-hatch pattern
  - The mulcher cut 1.9 m strips in a cross-hatch pattern, leaving square patches of untreated ground. This treatment was done on flat ground. The first pass cut successive parallel strips adjacent to each other, and the second pass cut parallel strips perpendicular to the first pass, resulting in 75% total removal.
  - The purpose of leaving the untreated patches was to assess the potential for this treatment to retain sufficient crop trees and not require additional motor-manual thinning to meet the requirements for well-spaced stocking over the long-term.

## Motor-manual thinning

Detailed timing of the motor-manual thinning determined their productive work time. The area thinned during each work day was measured and mapped with a Garmin 62sc GPS. Thinner productivity per person-hour was determined for the motor-manual only treatment (control) and for the combined mechanized/motor-manual (semi-mechanized) treatments on flat and steep ground.

## Treatment costs

Mulcher costs were calculated using FPInnovations' standard costing methodology that includes ownership and operating costs (Appendix 1). PMH was measured by detailed timing and applying a utilization rate for the mulcher. PMH, mulcher cost, and utilization rate were used to calculate treatment costs. The average cost for motor-manual only treatments in these high-density pine stands was provided by the licensee and for the purpose of this study was considered the standard benchmark treatment cost.

## RESULTS AND DISCUSSION

### Pre-treatment site and stand conditions

Pre-treatment site and stand conditions are presented in Table 1. Slopes ranged from 0 to 20% in the flat sites and from 25 to 40% in the steep sites. Pre-treatment tree densities ranged from 102 000 to 140 000 stems per hectare (sph), with an overall average for all treatment sites of 118 000 sph. Countable tree heights ranged from 1.2 to 2.3 m, with an average height of 1.3 m for all sites. The tree

species in the treatment area consisted of 94% pine, 4% larch, and 2% spruce. Slash volumes in the treatment areas ranged from 10 to 18 m<sup>3</sup>/ha.

## Post-treatment stand densities

The post-mulching densities of crop tree stands were generally lower than expected (Table 1) because the actual percent removal was higher than expected. This may be because additional turns and manoeuvring resulted in mulching additional ground beyond the planned mulched strips.

The targeted post-treatment *thinning* density was 4000–5000 stems per hectare (sph) and would normally require an inter-tree spacing of 1.4 to 1.6 m. The provincial *stocking standard* density is 1200 sph, which requires 2.9 m spacing. The motor-manual follow-up treatments were able to retain the target thinning density of 4000–5000 sph of crop trees (Table 1) with the trees left in the 1.9 m retention strips by reducing minimum inter-tree spacing distance to 1.0–1.5 m. The 0.9 m narrow-strip and cross-hatch treatment areas were not motor-manually thinned following mulching. The post-treatment densities of the narrow-strip sites were below the targeted 4000–5000 sph but above the provincial stocking standard density of 1200 sph (Table 1). However, since the post-treatment densities of crop trees in the narrow strip and cross-hatch treatments were relatively low, survival would need to be high in order to meet the long-term provincial stocking standard density of 1200 sph.

**Table 1. Pre- and post-treatment densities**

| Treatment                            | Pre-treatment<br>(total sph) | Post-<br>mulching<br>(total sph) | Post motor-manual<br>(crop tree sph) |
|--------------------------------------|------------------------------|----------------------------------|--------------------------------------|
| Motor-manual thinning (control)      | 103 750                      | <i>n.a.</i>                      | 4 800                                |
| Treatment 1 flat (~50% removal)      | 125 250                      | 24 840                           | 5 000                                |
| Treatment 2 steep (~50% removal)     | 101 750                      | 41 120                           | 4 500                                |
| Treatment 3 flat (~68% removal)      | 95 000                       | 7 021                            | 1 705 <sup>2</sup>                   |
| Treatment 4 (2 passes, ~75% removal) | 83 776                       | 21 238                           | 1 475 <sup>2</sup>                   |

<sup>1</sup>sph = stems per hectare

<sup>2</sup>The narrow-strip and cross-hatch treatments were not motor-manually spaced, but “countable” trees of acceptable height, species, and spacing, etc. (B.C. MFLNRO, 2012) were counted as crop trees.

## Mulcher working speeds

Working travel speeds ranged from 16 to 25 m/min, with an average working speed of 20 m/min for all treatments (Table 2). The highest working speed was obtained on the steep ground (35–40% slope), with travel speeds of 25 m/min uphill and 24 m/min downhill. This minor difference in travel speed indicates that slope steepness alone did not significantly affect working speed. In fact, the lowest working speed was recorded on the flat ground, with an average of 16 m/min. The flat site had more slash, and this likely caused the slowdown. The Fecon FTX-140 mulcher is a mid-sized machine, and during the study it was observed to reduce its working speed when encountering heavy slash and large stumps (Figure 2). Its fastest average working speed was recorded when the slash volume was lowest, and the slowest when the slash volume was highest (Table 2). The higher working speed on the



second pass during the cross-hatch treatment was due in part to the mulcher travelling over sections already mulched during the first pass. Also, the cross-hatch treatment site included a large section of smooth, flat ground with little slash and with much smaller and more widely spaced trees. This allowed the mulcher to maintain a relatively high working speed over that section of the block, resulting in a high overall average working speed of 23 m/min.



Figure 2. The mulcher tilting as it encountered a large stump.

Table 2. Working speeds and slash volumes

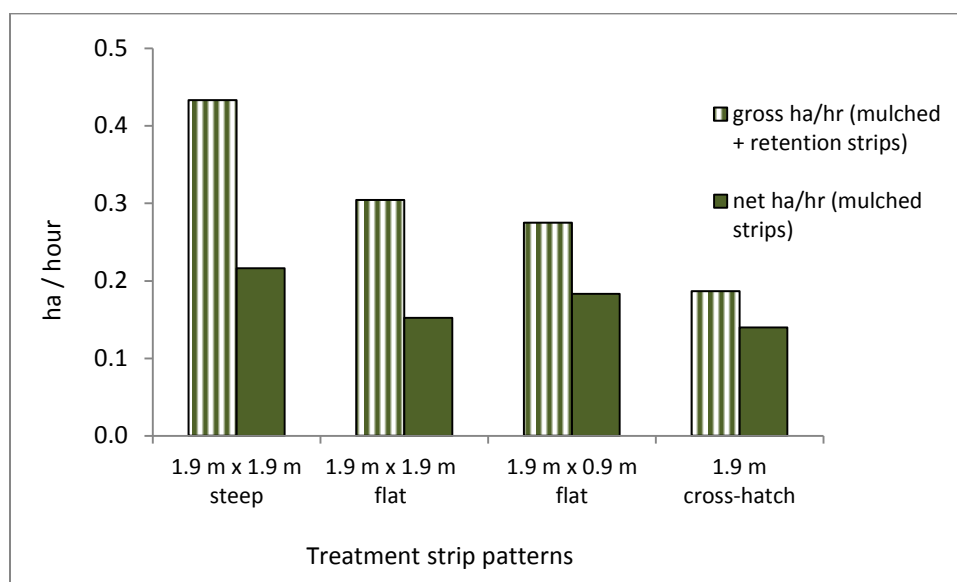
|                                              | Working speed (m/min) | Slash (m <sup>3</sup> /ha) |
|----------------------------------------------|-----------------------|----------------------------|
| Treatment 1: 1.9 m x 1.9 m flat              | 16                    | 18                         |
| Treatment 2: 1.9 m x 1.9 m steep             | 24                    | 11                         |
| Treatment 3: 1.9 m x 0.9 m flat              | 19                    | 10                         |
| Treatment 4 (first pass): 1.9 m cross-hatch  | 19                    | 12                         |
| Treatment 4 (second pass): 1.9 m cross-hatch | 23                    | 12                         |
| Average                                      | 20                    | –                          |

**Mulcher productivity**

**Lowest-productivity treatment.** As expected, the cross-hatch treatment had the lowest overall gross productivity (Figure 3) because some of the mulcher’s work time during the second pass was spent travelling over previously treated ground.

**Highest-productivity treatment.** The 1.9 m x 1.9 m treatment on steep ground had the highest net and gross productivity (Figure 3). The steep slopes of 35–40% did not seem to affect working travel speeds. However, another factor is that the stand density and slash loads were generally lower on the steep site than on the flat sites. It is expected that higher slash loads on steep slopes would reduce working travel speed for this small non-articulated mulcher, especially during uphill travel.

**Productivity with narrow retention strips.** The treatment with the narrow (0.9 m) retention strip had less slash and a higher working speed than the treatment with the wider (1.9 m) retention strip (Table 2), and it yielded a higher *net* productivity (Figure 3). Improved visibility during this treatment enabled the operator to travel faster while cutting successive strips. However, the narrowness of the retention strips yielded a relatively low *gross* productivity because a higher proportion of the total area was mulched.



**Figure 3. Net and gross productivity for mulcher treatments.**

**How visibility affected productivity and consistency.** Taller trees on the flat ground reduced visibility for this medium-sized mulcher, and the mulcher did not have a precise GPS tracking system. The poor lateral visibility reduced its working speed and made it difficult for the operator to maintain a consistent width of retention strips. Conversely, visibility was much better on the steep ground, allowing the operator to manoeuvre more effectively through the terrain and obstacles (rocks, stumps, and slash). Mulching on the steep ground resulted in a faster working speed and a more consistent width of retention strips.

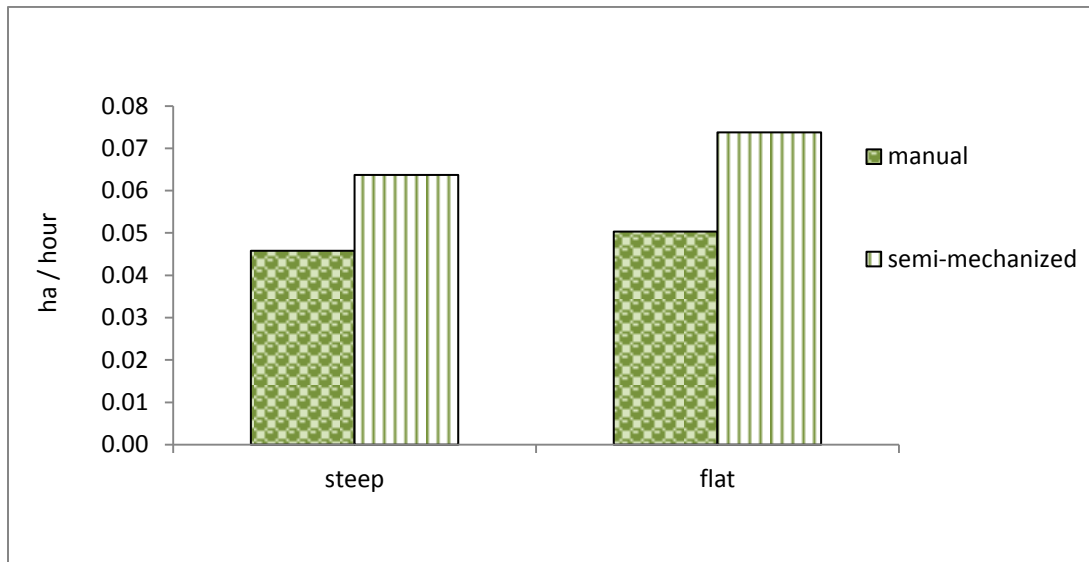
**Damage to edge trees.** The mulcher cut an average width of 1.9 m, but the edges of the mulcher head were unguarded and resulted in some damage to edge trees (Figure 4). On average, there was one damaged tree every 0.6 m along the edge of the strip cuts and every 0.3 m along the cross-hatch cuts. This was particularly critical for the narrow strip treatment, where 26–46% of the crop trees in the retention strips were damaged, and for the cross-hatch treatment, where all four sides of the retention patch experienced damage losses. It is important to note, all damaged trees were edge trees that have the most exposure to light and presumably an increased potential for successful long-term release. Installing protective guard rails on the edges of the mulcher head would likely reduce tree damage and increase the stocking potential of the retention strips (St. Amour, 2006).



**Figure 4. Mulcher-damaged tree.**

### Motor-manual thinning productivity

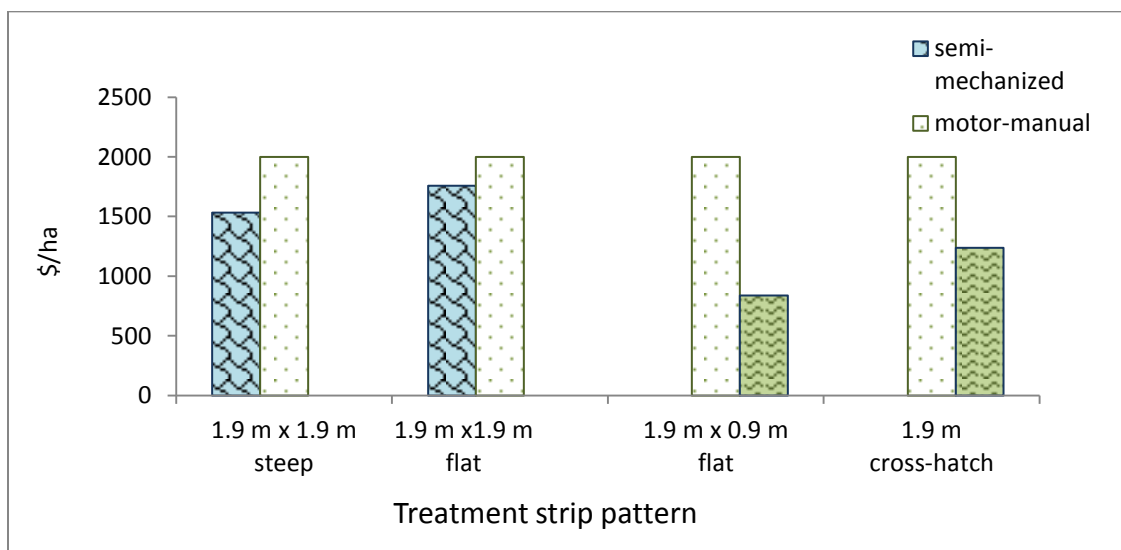
During the motor-manual only operation, individual thinner productivity averaged 0.050 ha/h on the flat ground and 0.046 ha/h on the steep ground. While thinning the retention strips during the semi-mechanized operation, thinners increased their productivity by 48% (to 0.074 ha/h) on the flat ground and by 39% (to 0.064 ha/h) on the steep ground (Figure 5). Because the thinners only need to work in the retention strips, a semi-mechanized operation in a 50% removal treatment will result in a gross productivity per person-hour (not including mulcher time) that is much higher than that of the motor-manual productivity.



**Figure 5. Productivity of manual and semi-mechanical thinning**

## Treatment costs

The standard cost for motor-manual thinning in these dense pine stands is \$2000/ha<sup>1</sup>. The cost for the mulching treatment combined with the cost of motor-manual thinning in the retention strips comprises the total cost for the semi-mechanized operation (Appendix 2). The study results show that the cost of semi-mechanized treatment (blue columns) on both the steep and flat ground was lower than the standard cost of motor-manual only (white columns) (Figure 6). Costs for the fully mechanized treatments (green columns) for both the 0.9 m narrow treatment and the cross-hatch treatment were even lower than the semi-mechanized treatments because they do not include any costs for motor-manual thinning (Figure 6).



**Figure 6. Costs for all treatments** (the cost for motor-manual thinning is provided as a reference for the standard treatment cost).

<sup>1</sup> Personal communication with Nick McRae (Canfor), October 2013.

## CONCLUSIONS AND IMPLEMENTATION

### Conclusions

- The working speed of the mulcher was not affected by slope. However, the working speed declined when it encountered more slash and when taller trees reduced visibility. The two-pass cross-hatch pattern had the lowest productivity because it covered some of the same ground twice.
- Minimum inter-tree distance was reduced to achieve the target density in the semi-mechanized treatments.
- The motor-manual workers were more productive in the semi-mechanized treatments than in the fully motor-manual treatment, regardless of the slope.
- The cost for semi-mechanized thinning was lower than for the standard motor-manual only thinning. Even though the cost per hectare for the area thinned manually in the retention strips in the semi-mechanized operation was the same as for the motor-manual only thinning, the cost of the area treated by the machine was low enough to make the total combined cost of the semi-mechanized operation lower than the cost of the standard motor-manual only.

### Implementing the semi-mechanized treatments

- This study indicates that the semi-mechanized approach is a cost-effective, viable method for thinning high-density pine stands if mulcher costs per gross hectare are low enough to offset the costs of the follow-up motor-manual thinning, and if the density requirements for stands of crop trees can be met with the trees remaining in the retention strips. Inter-tree distances in the retention strips may need to be reduced to reach target densities.
- Minimizing tree damage is particularly important with the narrow-strip treatment (where a relatively low number of potential crop trees remain in the retention strips), and with the cross-hatch treatment (where all four sides of the retention patch suffered damage). Damage to trees during mulching could be reduced by installing guard plates on both sides of the mulcher head
- It is still unclear how effective a narrow-strip treatment is at producing a desirable target stand of trees that will be well spaced at harvest time. A narrow-strip treatment incorporating slightly wider retention strips will initially preserve a larger number of crop trees and may provide a greater potential for achieving long-term stocking objectives. Further research and monitoring is required to understand the potential for narrow-strip treatments to achieve long-term stocking objectives.

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## APPENDIX 1. COST ANALYSIS OF THE FECON TX-140 MULCHER

|                                      |         |                                |           |
|--------------------------------------|---------|--------------------------------|-----------|
| Scheduling - Mulching                |         | Fixed costs                    |           |
| Hours per day (h)                    | 8       | Annual capital costs           | \$32 092  |
| Days per week (d)                    | 5       | Yearly other costs             | \$7 600   |
| Weeks per year (w)                   | 35      | Yearly total                   | \$39 692  |
| Scheduled hours per year (h)         | 1 400   | Cost per PMH                   | \$35.00   |
|                                      |         | Cost per SMH                   | \$28.35   |
| Scheduling -Total                    |         | Variable costs                 |           |
| SMH <sup>1</sup> per year (h)        | 1 400   | Yearly total                   | \$57 761  |
| PMH <sup>2</sup> per year (h)        | 1 134   | Cost per PMH                   | \$50.94   |
| Estimated life of machine (y)        | 7       | Cost per SMH                   | \$41.26   |
| Estimated life of machine (SMH)      | 9 800   |                                |           |
| Estimated PMH during life (h)        | 7 938   |                                |           |
| Purchase price new (\$)              | 190 000 | Labour costs                   |           |
| Residual value (\$)                  | 19 000  | Yearly total                   | \$63 700  |
| Insurance (\$/year)                  | 7 600   | Cost per PMH                   | \$56.17   |
| Interest rate (%)                    | 6.25    | Cost per SMH                   | \$45.50   |
| Utilization rate (%)                 | 81      |                                |           |
| Lifetime repair cost (\$)            | 190 000 | Overhead costs <sup>3</sup>    |           |
| Fuel consumption (L/PMH)             | 20      | Yearly total                   | \$66 875  |
| Fuel cost (\$/L)                     | 1.25    | Cost per PMH                   | \$58.97   |
| Oil and lubricants (\$/PMH)          | 2.00    | Cost per SMH                   | \$47.77   |
| Operator wages (\$/SMH)              | 35      |                                |           |
| Fringe benefits (%)                  | 30      | Administration risk and profit |           |
| Administration, risk, and profit (%) | 15      | Yearly total                   | \$34 204  |
|                                      |         | Cost per PMH                   | \$30.16   |
|                                      |         | Cost per SMH                   | \$24.43   |
|                                      |         | <b>TOTAL COST</b>              |           |
|                                      |         | Yearly total                   | \$262 232 |
|                                      |         | Cost per PMH                   | \$231     |
|                                      |         | Cost per SMH                   | \$187     |

Note: All dollar amounts are in Canadian dollars.

<sup>1</sup>SMH = scheduled machine hours.

<sup>2</sup>PMH = productive machine hours.

<sup>3</sup> Overhead costs are estimated and do not include all actual costs.

## APPENDIX 2. TREATMENT PRODUCTIVITY AND COSTS

**Table A1. Mechanized treatment productivity**

| Treatment           | Utilization (%) | Mulched strips (net ha/h) | Mulched + retention strips (gross ha/h) |
|---------------------|-----------------|---------------------------|-----------------------------------------|
| 1.9 m x 1.9 m steep | 80.7            | 0.22                      | 0.43                                    |
| 1.9 m x 1.9 m flat  | 84.7            | 0.15                      | 0.30                                    |
| 1.9 m x 0.9 m flat  | 83.6            | 0.18                      | 0.28                                    |
| 1.9 m cross-hatch   | n/a             | 0.14                      | 0.19                                    |
| Average             | 81.4            | –                         | –                                       |

**Table A2. Semi-mechanized treatment costs**

| Treatment                             | Motor-manual only (\$/ha) <sup>1</sup> | Mulcher (\$/net ha) | Mulcher (\$/gross ha) | Mulcher+manual (\$/gross ha) |
|---------------------------------------|----------------------------------------|---------------------|-----------------------|------------------------------|
| Treatment 1 flat (50% removal)        | 2 000                                  | 1 518               | 759                   | 1 759                        |
| Treatment 2 steep (50% removal)       | 2 000                                  | 1 067               | 533                   | 1 533                        |
| Treatment 3 flat (68% removal)        | 2 000                                  | 1 260               | 840                   | 0                            |
| Treatment 4 cross-hatch (75% removal) | 2 000                                  | 1 651               | 1 239                 | 0                            |

<sup>1</sup>Motor-manual costs are provided for all treatments as a standard cost reference.

**Table A3. Motor-manual treatment productivity**

| Treatment                                | Productivity |            |                      |               |
|------------------------------------------|--------------|------------|----------------------|---------------|
|                                          | Total (min)  | Total (ha) | (ha/d <sup>1</sup> ) | (ha/person-h) |
| Motor-manual (steep)                     | 1 048        | 0.8        | 0.275                | 0.046         |
| Motor-manual (flat)                      | 834          | 0.7        | 0.302                | 0.050         |
| Motor-manual in retention strips (steep) | 1 002        | 1.1        | 0.382                | 0.064         |
| Motor-manual in retention strips (flat)  | 1 057        | 1.3        | 0.443                | 0.074         |

<sup>1</sup>One day (d) = 6 hours.



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