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**Using a small-log portable sawmill to reduce fuel reduction treatment cost on small parcels**

Michael J. De Lasaux  
UC Cooperative Extension - Plumas & Sierra Counties  
208 Fairgrounds Road, Quincy, CA 95971  
Telephone: 530.283.6125, Fax: 530.283.6088  
[mjdelasaux@ucdavis.edu](mailto:mjdelasaux@ucdavis.edu)

Raffaele Spinelli  
CNR - Timber and Tree Institute  
Via Madonna del Piano, Pal. F - I-50019 Sesto Fiorentino (FI) - Italy  
Telephone: +39 055 5225641, Fax: +39 055 5225643  
[spinelli@ivalsa.cnr.it](mailto:spinelli@ivalsa.cnr.it)

John R. Shelly  
Richmond Field Station - University of California  
Bldg 478, 1301 South 46th Street - Richmond, CA 94804  
Telephone: 510 231-9414, Fax: 510 215 4299  
[john.shelly@nature.berkeley.edu](mailto:john.shelly@nature.berkeley.edu)

Bruce R. Hartsough  
Biological and Agricultural Engineering - University of California  
One Shields Avenue, Davis, CA 95616  
Telephone: 530 752 0103, Fax: 530 752 2640  
[brhartsough@ucdavis.edu](mailto:brhartsough@ucdavis.edu)

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## Using a small-log portable sawmill to reduce fuel reduction treatment cost on small parcels

**Abstract:** An Economizer portable small-log processor was used to mill trees between 6 inches and 10 inches dbh that were removed as part of a demonstration of fuel reduction thinning in the wildland-urban interface. Time and motion studies were conducted at 4 of the 8 demonstration sites. Over 70 hours of productive milling time was observed during the study. Lumber recovery from small logs averaged 50 percent for lumber and 67 percent for cants.

### Introduction

The goal of the study was to test an alternative approach to fuel treatment that may respond to the needs of small-parcel owners. The tested system included a mobile small-log sawmill that could produce cants and boards of variable size, according to the needs and specifications of each property owner. The small-tree harvesting was performed by a small skid-steer that is well suited to small parcels and in dense forest conditions (De Lasaux et al, in review, Windell and Bradshaw 2000) rather than a standard mix of logging equipment. The compact and very mobile skid-steer had four attachments: for felling trees, processing them into logs, skidding the logs and masticating residues (De Lasaux et al, in review).

Previous studies have highlighted the potential of portable sawmills in adding value to products obtained from small parcels (Stewart 1999). However, obtaining good productivity with small logs is very difficult, because of the time required to handle one log is excessively long when compared to the quantity of lumber produced. Most portable sawmills are built around a band saw and require several passes to process one log. The result is a low-production operation, which has difficulty competing with a stationary small-log mill, despite the savings in transportation cost. Small-log portable sawmills with higher productivity are needed to complement traditional mills when the latter are not capable of processing small diameter timber profitably (Mackes and Lynch, 2000). The Economizer<sup>1</sup> wood processor (Figure 1), a portable mill built by the Canadian firm, Micromill Systems Ltd. was selected for the demonstration project. This trailer-mounted mill can be towed by a large pickup truck, allowing for frequent relocation with minimum downtime; this is crucial when dealing with small parcels. The Economizer is specially designed to handle small logs, such as those obtained from fuel reduction operations. The Economizer is a chip-n-saw mill that processes each log fed into the mill in a single pass: the log is first squared by the chipping-head assembly and then cut into boards by gang arbor ripsaws (Table 1). Chip-n-saw mills of this type are particularly effective with small logs (Darr and Fahey 1973, Vickers 1998). The study focused on quantifying the reliability, the productivity and the yield of the mobile sawmill under variable conditions, in order to provide directions on its most effective use.

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**Figure 1. Economizer wood processor**

**Table 1 – Economizer description**

Power unit	160-Hp Perkins Diesel
Weight	12,000 lb
Trailer length	20 feet
Canter	4 chipping cutterheads
Splitter	Arbor saw
Log diameter range	3-10 inches
Max. log length	20 feet
Saw kerf	0.16 inch

### **The Demonstration**

The demonstration was conducted from March 28 to May 14, 2003 on four sites (Table 2) in northeastern California selected from a much larger pool inspected and characterized during the previous year. The selected four were considered representative of many of the small parcels of the Northern Sierra Nevada and Southern Cascades.

All stands resulted from natural regeneration after logging or fire. Mixed-conifer stands were the most common, with various proportions of Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), ponderosa pine (*Pinus ponderosa*) and incense cedar (*Calocedrus decurrens*). SIE1, in Sierra county, was essentially pure ponderosa, with an occasional incense cedar.

The average area treated per site was 2.9 acres, yielding an average of 186 trees and 644 ft<sup>3</sup> of logs that could be milled. Not all logs were converted into lumber, however. The landowners often set aside part of the harvest for specialty products needed on the property, such as round poles or firewood. On average, 225 ft<sup>3</sup> of lumber was produced per site.

The work was conducted in the following sequence: after the trees were harvested and the logs skidded to and stacked at a landing, the mill was moved to the site and set up. In a couple of locations the logs were pre-sorted by the harvest contractor otherwise the logs were sorted by those doing the milling. Following sorting sawmilling began, and generally lasted a few hours. Lumber was stacked, stickered and banded. Finally, the sawmill was dismantled and loaded, and

**Table 2 – Description of the Demonstration Sites**

Site	NEV1	NEV2	SHA3	SIE1
Nearest Community	San Juan Ridge	Nevada City	Shingletown	Loyalton
County	Nevada	Nevada	Shasta	Sierra
Area, ac	3.8	3.4	2.6	1.8
Species	Mixed conifer	Mixed conifer	Mixed conifer	Ponderosa
Harvested trees	185	106	118	336
Dbh, in., mean (range)	6.5 (4-11)	6.4 (4-11)	6.8 (4-11)	5.9 (4-11)
Height, ft, mean (range)	47.9 (23.9-78.8)	45.1(31.2-80.3)	37 (23.6-67.9)	32.4(24.4-54.0)
Total harvest (ft <sup>3</sup> )	838	493	403	841
Number of logs milled	188	271	41	387
Lumber yield (ft <sup>3</sup> )	218	197	154	333
Lumber Value (\$)	\$1,809	\$1,579	\$670	\$1,783
Assortment	Boards	Boards	Cants	Boards

the operation moved to a new site. The equipment associated with the milling operation included the Economizer mill, a small skid-steer loader, a trailer for the skid-steer loader, a heavy pickup truck to alternatively tow the Economizer and the trailer with the skid-steer, and a light pickup truck for general use. The work was conducted by two operators, who assisted each other while sorting with the skid-steer loader and then positioned themselves respectively at the log in-feed and lumber out-feed when sawing. Both operators had considerable skill and experience, having worked with the machine for four years.

### Materials and methods

The research consisted of a time-motion study to quantify the productivity of the Economizer mill. All lumber produced during the test was tallied by dimension. In addition, 84 percent of the logs milled were numerically coded and described by recording species, total length, small end diameter inside bark (SEDIB) and large end diameter inside bark (LEDIB). Data were recorded on a Husky Hunter running the Siwork 3 time-study software (Kofman 1986). Each record contained the time for processing one log, the serial number of the log and the type (cants or boards), number and sizes of lumber produced. Process time was divided into elements, described in Table 3. Detailed time and motion studies of this type allow relating machine performance to job characteristics, that can be useful when trying to predict operational productivity under variable conditions (Bergstrand 1991). Delays were also recorded, providing the basis for an assessment of the reliability of the machinery as well as the efficiency of the system.

Recovery was estimated by comparing the volume of the lumber obtained from each individual log with its original volume. Comparison at the individual log level allowed checking all the variables that can affect lumber recovery, such as species, log size and board size choice. The diameter at breast height (dbh) and total height of the trees that yields log(s) was recorded in advance, so that tree utilization could also be estimated. Overall, the sample contained 446 trees.

**Table 3 – Description of time elements**

<b>Time element</b>	<b>Description</b>
Charge	The skidsteer loader picks up the logs from the deck and loads them on the log chain. Ends when the sawmill is started again and the log chain starts moving.
Load	Logs are pushed by the log chain into the singulator, which kicks one log onto the infeed rail. The log is pushed forward on the rail and into the sawmill. Ends when the first two feed wheels engage the log. May include a stop to check log diameter.
Adjust	The loading routine is interrupted to change the settings of the chipping heads, generally in a few seconds by using buttons on the control panel. Ends when loading is resumed.
Mill	The log is being milled. Begins when the first two feed wheels engage the log and ends when they engage another log or when the lumber has exited the saw tunnel.
Stack	The lumber is stacked and stickered. This is only a residual time, since one of the two operators is just stacking most of the time, and this element gets recorded only when the stacker lags behind and the other operator interrupts milling to assist.

## Results

### a) Time

The total activity time recorded for the Economizer during the study amounted to 71.4 hours, excluding meal time – i.e. more than nine 8-hour workdays (Table 4). This figure includes productive work, moving, set up, dismantle and maintenance.

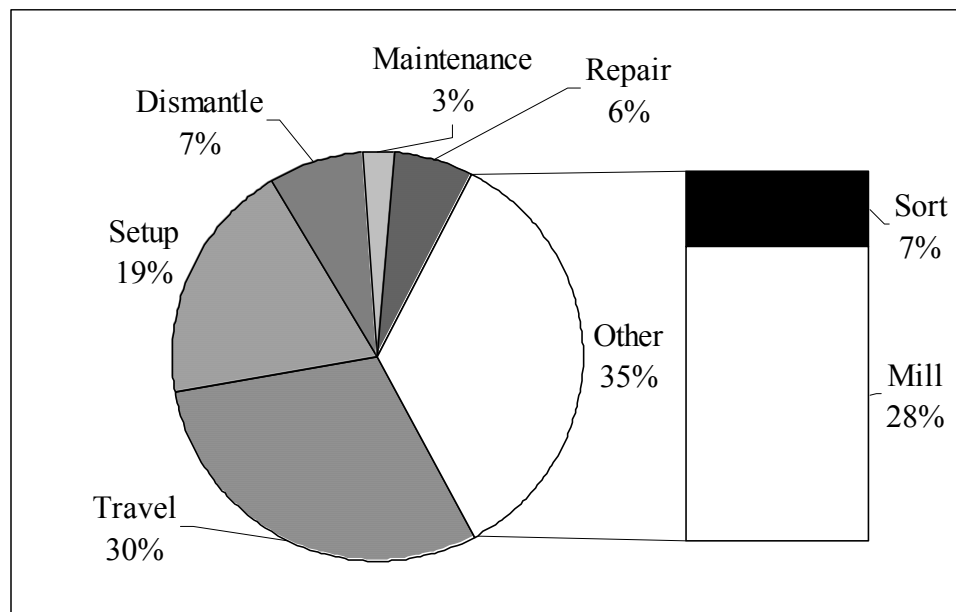
**Table 4 – Time consumption (hours) by activity and site**

Activity	NEV1	NEV2	SHA3	SIE1	All sites
Travel	8.0	4.2	-	9.3	21.5
Setup	5.7	1.7	1.8	3.3	12.4
Sort	4.7	0.4	-	-	5.1
Mill	4.3	5.3	2.7	7.4	19.6
Dismantle	1.0	1.1	1.7	1.1	4.9
Maintenance	3.7	0.6	-	1.9	6.1
Total time	27.3	13.2	6.1	24.50	71.1

The average total time required to process logs at a single parcel was 18 hours, but there were wide differences between sites, due to travel distance, amount of lumber milled and the ease of access to the landing.

Figure 1 shows the distribution of total time according to the activity performed. Productive work (sorting and milling) constituted a little more than one-third of the total time expenditure, due to the very small amount of wood available at each site. Travel time accounted for almost

**Figure 1 – Activity breakdown**



one-third of the total time expenditure, due to the relatively long distances between sites which averaged 57 miles and because each relocation required three one-way trips: the first to move the Economizer, the second to return to the previous site and the third to move the skid-steer to the new site. Faster moving could be realized by upsizing the second truck so that it could tow the trailer with the skid-steer: this would reduce moving time by about two-thirds.

Set up and dismantle were quick: they took 4.2 hours per site, but still represented 25% of the total time expenditure, due to the relatively short duration of the work conducted on each set up. There were large differences between sites: set up and dismantle time averaged 6.3 hours at the two sites with the most difficult access (NEV1, SIE1) and was only 3.1 hours on the other two, where easily accessible landings were available.

A similar grouping could be made for sorting time: at NEV2 and SIE1 the wood had been sorted beforehand using the ASV skid-steer and grapple, while at NEV1 and SHA2 the logs were sorted by the mill crew with the Case loader.

Maintenance time mostly involved the truck, which suffered a couple of breakdowns, including a flat tire. The mill itself demonstrated excellent reliability during the study.

Recorded data help demonstrate the potential of the Economizer sawmill: it proved reliable, could be set up and dismantled in a few hours and, once it was running, produced 45 ft<sup>3</sup> of lumber per scheduled hour.

Cycle time data for milling were analyzed statistically to obtain meaningful relationships between time and independent variables. The equations obtained are all significant at the 0.0001 level (Table 5).

No meaningful relationship was found between log deck charge time and any of the tested independent variables, this was not unexpected since charging was not cyclic.

**Table 5 - Prediction models for time consumption in milling**

Time Element, cmin/cycle (1 log)	Regression	R <sup>2</sup>
Charge	3.8	-
Load	7.71 + 4.00 * Log Vol, ft <sup>3</sup>	0.032
Adjust	21.92 cmin per adjustment, which occurs once: every 7.7 logs if good sorting/low variability every 2.9 logs if mediocre sorting/high variability	-
Mill	6.04 + 12.81 * Log Vol, ft <sup>3</sup> + 2.13 * Log length, ft	0.530
Stack	- 0.445 + 1.87 * Lumber Vol, ft <sup>3</sup>	0.012

The time for loading had a weak but significant correlation with log volume, whereas that for adjusting the mill settings could not be related to any of the measured independent variables. The time for adjusting the spacing of the chip heads is approximately constant; what actually changes is the frequency of adjustments: this depends on the variability within the batch of logs to be processed and therefore the precision of sorting. Therefore, data were organized by site and grouped according to the estimated sorting quality achieved on each site. Finally, two different adjustment frequencies were calculated and adopted into the model.

As expected, the milling time is strongly correlated to log volume and length. Stacking time also increases with the amount of lumber to be stacked: the weak correlation is caused by the fact that the recorded stacking time was a residual time only: one of the two operators was stacking most of the time, and the stacking element by our definition only involved time when the other operator had to interrupt milling and assist.

These equations provide net work time, excluding productive delays which averaged 13 percent of the total work time. Net productivity can be transformed into gross productivity using a 0.87 factor.

*b) Lumber recovery from logs*

Lumber recovery averaged 50 percent for lumber and 67 percent for cants. Summary data are shown in Table 6.

**Table 6 – Log and lumber recovery data by species, mean (range)**

Species	Logs	Recovery %	Log length ft	SEDIB in.	Taper in/ft
All	909	51.1 (16.9-100.6)	9.9 (6.2-14.7)	4.5 (2-9)	0.118 (-0.146; 0.460)
Cedar	73	49.8 (28.3-90.3)	9.5 (6.9-14.4)	4.2 (2-8)	0.148 (-0.146; 0.345)
Douglas-fir	185	59.4 (16.9-100.6)	12.0 (6.6-14.7)	4.9 (2-9)	0.083 (-0.079; 0.336)
White fir	25	71.2 (41.6-100.6)	11.2 (8.4-12.8)	4.9 (3-7)	0.103(0.000; 0.189)
Ponderosa pine	624	47.8 (20.4-93.8)	9.2 (6.3-13.0)	4.5 (2-9)	0.125 (-0.117; 0.376)

Regression analysis resulted in the following relationship; all independent variables are significant at the 0.0001 level:

$$Rr \% = 82.57 - 43.79 BV - 10.72 * Tp * L + 8.48 * Tp * L * BD + 10.76 * BD * Tk$$

$$R^2 = 0.183$$

Where: Rr % = Recovery rate %

BD = Board Variable, 1 if output is Boards, 0 if Cants

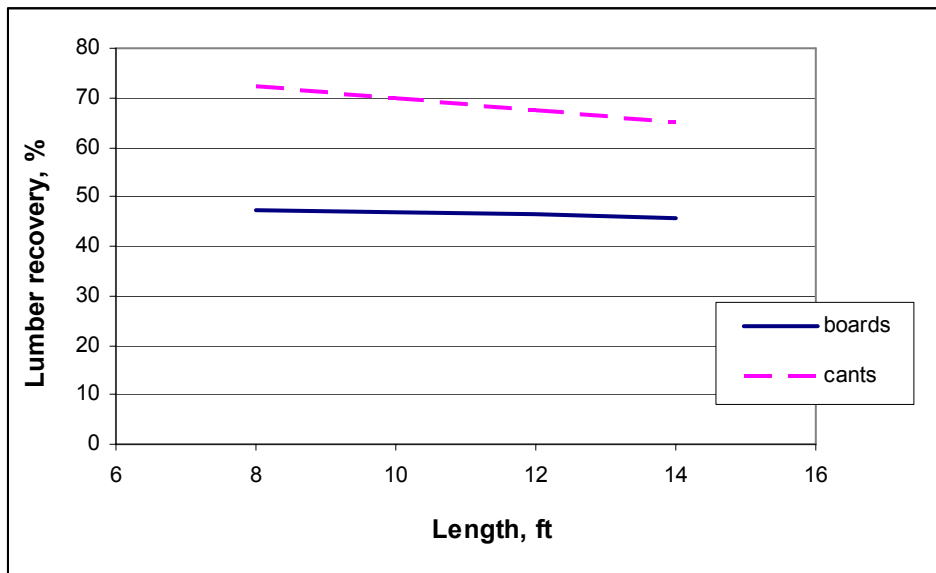
Tp = Taper, in./ft

L = Log length, ft

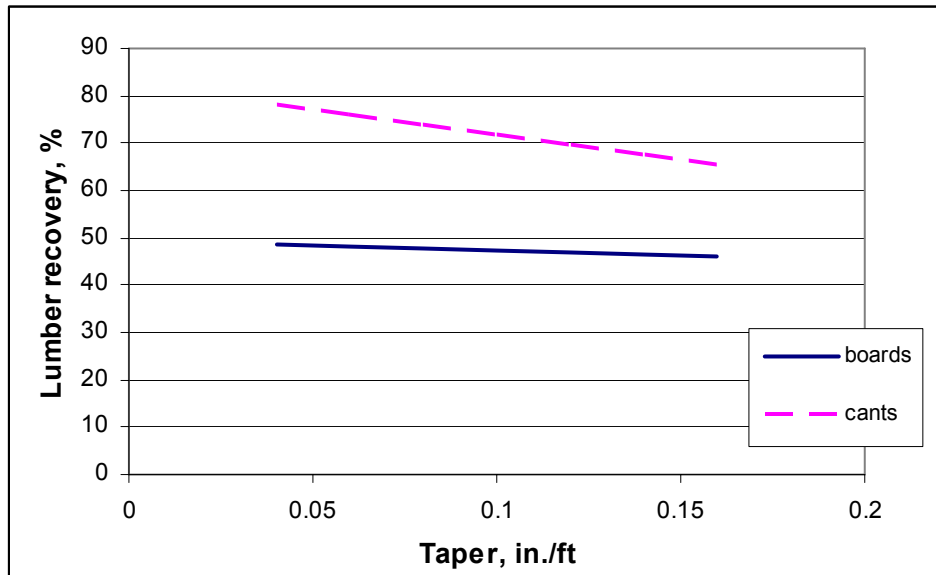
Tk = Assortment thickness, in.

This equation was used to calculate recovery as a function of length for the average taper (0.118 in./ft) and a board thickness of 1 inch (Figure 2), or as a function of taper for a 10 foot length and a board thickness of 1 inch (Figure 3). Both graphs show the difference between milling cants and boards, the former resulting in a much higher recovery rate. By combining this equation with the models used for predicting milling time, one can calculate the milling productivity of the Economizer. Figure 4 shows productivity as a function of SEDIB for 10 foot long logs, with average taper. For boards, a 1 inch thickness was assumed. The graph also highlights the higher productivity obtained when producing cants: this does not depend on a faster milling rate, but on a higher recovery rate. The time to mill a log of a given size is the same regardless of the product obtained, but the lumber output is higher when milling it into cants, hence the higher productivity.

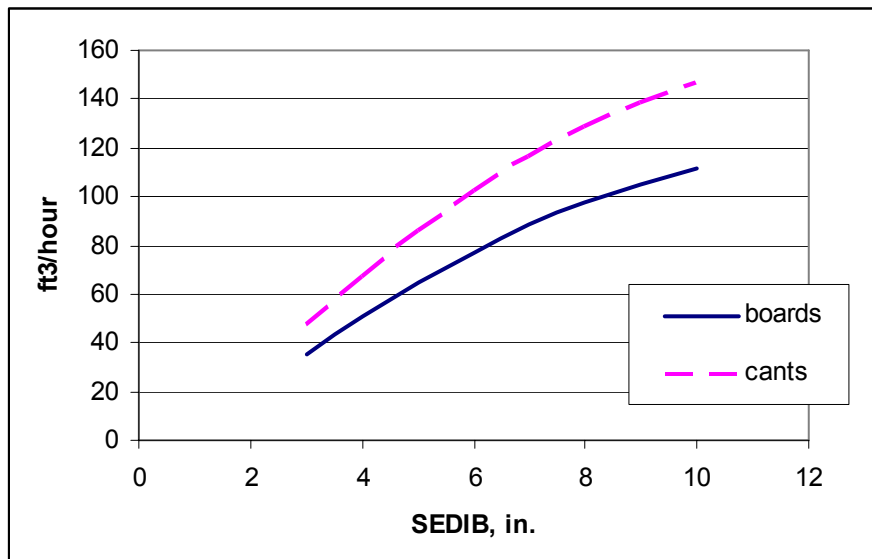
**Figure 2** – Lumber recovery as a function of log length and product type



**Figure 3** – Lumber recovery as a function of taper and product type



**Figure 4** – Milling productivity as a function of SEDIB and product type



*c) Lumber yield from trees*

The tree data were analyzed and relationships were developed to predict lumber yield as a function of tree characteristics (Tab. 7). The volume equations obtained from this study may be useful for planning fuel treatment operations. The table shows two equations for each tree species, the former being less precise but requiring only the basic data that can be recorded with a rapid stand cruise.

#### *d) Economics*

Machine operating costs have been calculated using Miyata's (1980) costing method. The primary assumptions are a depreciation period of 5 years, a salvage value of 30 percent of the initial price and a service life of 10,000 hours. The initial costs were estimated to be \$400,000 for the mill, \$30,000 for the skid-steer and \$40,000 for the truck. Assuming an operator wage of \$25 per hour, the cost of the whole operation was \$143 per scheduled hour. This figure does not include administrative and management costs and profit. For the average recorded productivity of 12 ft<sup>3</sup> of lumber per scheduled hour, the milling cost was \$12/ft<sup>3</sup>, including stacking and banding. This number is heavily burdened by the high incidence of moving time.

#### *e) Prediction model*

The relationships developed in this study were incorporated into a spreadsheet model to estimate productivity and cost as a function of log characteristics, moving distance and site conditions. The model may be useful tool for prospective users when evaluating the suitability of the system for their own needs. A copy of the spreadsheet model may be obtained by contacting the lead author.

### **Conclusions**

The Economizer is an efficient portable sawmill especially designed for handling small logs, such as those obtained from fuel reduction operations. It is reliable, can be set up and dismantled in a few hours and is very productive for a portable mill. After the logs have been sorted, the mill can process between 30 and 100 ft<sup>3</sup> of lumber per working hour, depending on log size and job type. *Recovery rate is high for a small portable plant, and exceeds that obtained with stationary chip-n-saw mills under similar small-log conditions (Fahey and Hunt 1972).*

Small parcels, however, present very difficult work conditions. The amount of wood processed on each of the demonstration sites was too limited for cost-effective operation. The Economizer is designed as a high-productivity industrial mill, which explains the relatively high investment cost. This potential cannot be fully exploited if the machine is running only one third of the time. The situation could be improved by pooling the wood obtained from small parcel fuel reduction treatments in satellite yards and processing it only when a large enough amount of wood has been accumulated. This would involve additional costs to load and transport logs to the yards, and to haul the milled lumber back to the originating sites if it is to be utilized by the owners.

Non-productive time can be significantly reduced by increasing the size of the second truck, so that re-location requires only one trip instead of three. Sorting should be done in advance, before the mill arrives on site and not when an \$80/hour machine sits idle.

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**Table 7 – Lumber yield for small trees from fuel reduction operations (dbh 4-11 in.)**

Species	Trees	Lumber yield, ft <sup>3</sup>	R <sup>2</sup>	Note
Ponderosa	273	$0.0043 * \text{dbh, in.}^{1.419} * H_{3\text{in.}, \text{ft}}^{1.010}$	.916	Boards only
Douglas Fir	98	$0.0106 * \text{dbh, in.}^{1.423} * H_{3\text{in.}, \text{ft}}^{.820}$	.777	Boards only
Cedar	34	$0.0087 * \text{dbh, in.}^{1.239} * H_{3\text{in.}, \text{ft}}^{.848}$	.853	Boards only*
White fir	17	$0.0183 * \text{dbh, in.}^{.509} * H_{3\text{in.}, \text{ft}}^{1.290}$	.892	Cants and Boards, but too few data points

Note: H<sub>3in.</sub> = Stem length to 3 in. top diameter