

In-Forest Debarking of *Pinus radiata* to Improve Supply Chain Efficiency

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by

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Executive Summary

Benchmarking of bark loss from current harvesting systems, debarking feasibility trials, a review of the advantages and disadvantages of in-forest debarking and construction of an economic model, were carried out over an 18 month period in Australia and New Zealand.

In-forest debarking was shown to be an economically viable alternative to debarking further along the forest to customer supply chain.

Breakeven costs for a debarker head that could be fitted to an excavator base were calculated.

Introduction

Bark is a low value product that adds cost from forest to customer. Eliminating it early in the supply chain was expected to improve the forest grower's profitability.

This project explored the potential benefits of in-forest debarking of *Pinus radiata*. The objectives of the project were to:

- quantify the potential costs and benefits of in-forest debarking of *Pinus radiata*, and
- identify the potential for modifying mechanised harvester / processor heads, and the maximum capital costs that could be paid for these modifications.



Figure 1. In-forest debarking.

The project involved:

- seasonal bark loss benchmarking trials
- seasonal relative drying rate trials
- debarker feasibility and productivity trials
- a safety review
- systems analyses extending from pre-harvest through to mill or port
- economic analyses

Primary funding for the project was provided by a grant from the New Zealand Forest Growers Levy Trust.

How Much Bark is on a Standing Tree?

Over-bark and under-bark diameter measurements recorded from over 1000 disks taken from fixed heights in 150 trees were used to estimate bark volume percentages. The mature trees were from a single seed source and had been planted at 17 sites throughout New Zealand. Bark volume percentages were converted to bark weight percentages using data from 390 trees from the central North Island of New Zealand.

The study¹ confirmed earlier research that bark accounts for 12 to 13% of over-bark volume and 7 to 8% of over-bark green weight for mature radiata pine boles prior to felling and log handling. It also showed that bark volume percent varied

- with location in a stem, decreasing exponentially from the base of the stem [~22%] to the merchantable limit [~8%]
- with tree size (small trees [17%] accounting for about 7% more overbark volume than large trees [9%])
- with site (a small decrease in bark volume with mean average temperature decrease was noted; equivalent to about one quarter of one percent of over-bark volume per degree decrease in mean average temperature).

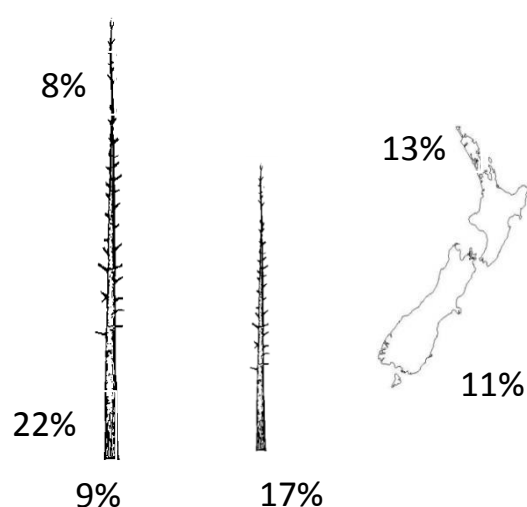


Figure 2. Bark, as a percentage of overbark volume in standing trees, varies with height in a tree, with tree size, and with site conditions.

¹ Murphy, G. and Cown, D. 2015. Within tree, between tree and geospatial variation in estimated *Pinus radiata* bark volume and weight in New Zealand. New Zealand Journal of Forestry Science Vol. 45. DOI: 10.1186/s40490-015-0048-5

Benchmarking Bark Loss

Based on current harvest volumes about 1.5 million cubic metres (m³) of bark is present on harvested radiata pine trees prior to felling in Australia and about 3.0 million m³ is present in New Zealand. A significant portion of this bark is lost during handling as logs progress along the supply chain.

Over 4000 stems and logs in eleven studies² were measured in Australia and New Zealand using digital photos and a line intercept method to determine the amount of bark removed during normal operations. Figure 3 shows a builder's tape of known length (circled in white on top of the trailer bed) which was used to obtain an approximate length for each log in the image. The black dashed lines on the photograph are examples of transects used to assess the presence or absence of bark using the line intercept method.



Figure 3. Bunk load of *Pinus radiata* logs in Western Australia.

A little over 40% of bark was removed, on average, during harvesting and transportation in Australia. On average, bark loss was

² Murphy G, and Acuna, M. 2016. Effect of Harvesting Season, System and Equipment on In-forest *Pinus radiata* Bark Removal in Australia and New Zealand. International Journal of Forest Engineering. DOI: 10.1080/14942119.2016.1253269

somewhat higher, at 65%, for all harvesting systems in New Zealand.

Among other things, we have been able to show that bark removal is greater:

- in spring than winter (74% vs 56% for NZ) or autumn (47% vs 34% for Australia)
- with tree-length systems than cut-to-length systems (72% vs 42%)
- with mechanised processing than manual processing systems (69% vs 49%).



Figure 4. Less bark is lost during felling and extraction with cut-to-length harvester/forwarder systems than with tree length systems.

The greatest portion of bark removal occurs during felling and extraction (58%) with tree-length operations, with a small proportion occurring during delimbing and bucking (22%).

There was limited and weak evidence that bark removal may differ with location on pine stems; possibly being less on the upper portion of the stem.

Finally, we were able to show that the number of knives on a processor head can affect bark removal, although we would recommend that

further research be carried out on this topic, since the results ran counter to expectations.

Drying Rates

Five log drying trials, to determine the effect of the presence of bark on drying rates, were carried out in Australia and New Zealand. Fresh wood is about 50% water by weight. If truck payloads are weight limited, reducing the amount of water in a log increases the volume that can be carried. This should lead to fewer trips to carry a given volume and lower transport costs.

All Australian data and all New Zealand data from the five log drying trials were analysed using StatGraphics statistical software. The Australian data and the New Zealand drying data were analysed separately. “Bark On” and “Bark Off” models were developed for each site. The dependent variable for both sets of models was Weight Loss (kg). Independent variables included in the models were Initial Weight (kg), Bark On (%), and Season.

Average drying rates for a 10 day drying period in Australia were much higher (11%) than average drying rates in New Zealand (3%). This result was climate related; temperatures were higher and rainfall lower in Australia. Drying rates were related to log size, season and presence of bark as well as country.

Drying rates were higher with bark off than bark on. Figure 5 provides examples for both Australia and New Zealand based on regression models and a log size of 265 kg. The average initial weight of logs in both Australia and New Zealand was about 265 kg.

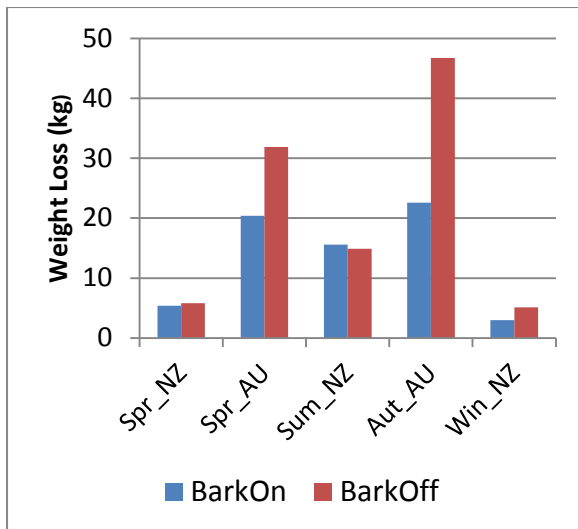


Figure 5. Weight loss for Bark Off vs Bark On Logs for a 10-day period in Australia and New Zealand for a log with an initial log weight of 265 kg. Bark Off and Bark On weight losses are based on 0% and 100% of bark on respectively.

Drying rates increased with log size in terms of weight (kg) but decreased in terms of percent of the initial weight of the log. Drying rates were also greatest in summer in New Zealand and autumn in Australia; no drying trial was carried out in summer in Australia.

Debarking Feasibility

Two sets of debarking feasibility trials were completed in New Zealand and Australia.

The New Zealand debarking feasibility trial was carried out in spring (August) in a radiata pine stand about 15 km to the south of Rotorua. A 22 inch SATCO eucalypt debarking head on a Caterpillar excavator base was being used by Phelan Logging Ltd to delimb and shovel log stems. The eucalypt debarking head was too small for many of the logs being handled and did a poor job of removing bark from the stems that were too big. A significant amount of the bark was removed from the smaller stems but possibly no more than would have been removed by a conventional processing head for radiata pine. The logging contractor, Gene Phelan, and the machine operator both

thought that a conventional processor head would have done a better job of removing radiata pine bark. They believed that the amount of bark removed with the eucalypt debarking head was more a function of how many times a stem was handled (particularly with using the debarker to assist with shovel logging) than the type of head being used.

The Australian debarking feasibility trial was carried out in spring in Western Australia. The sponsor for the trial was interested in retaining, rather than removing, as much bark as possible. Eight treatments were carried out; four with a standard Waratah processor head along with various combinations of roller and knife pressures, and four with modified rollers (Moipu feed rollers, Figure 6) along with various combinations of roller and knife pressures. The greatest bark retention was obtained with the standard Waratah rollers and pressures. Reducing the roller and knife pressures for both the standard rollers and the adapted rollers resulted in lower bark retention.



Figure 6: Moipu Feed Rollers

A separate study was carried out by Forme Consulting Group Ltd in 2015 and funded by STIMBR to determine if using a processor head

might provide a competitive alternative to methyl bromide fumigation. Modifications to machines trialled by processor head manufactures that engaged in the trials were mainly limited by them to altering the feed rollers used and modifying knife and arm pressures. The study found that a modified processor head could be competitive with methyl bromide fumigation, however there were some limitations. Further development work by manufacturers was recommended.

Southstar Equipment Ltd are currently developed a debarking head for softwood species. It was not available for trialling before this project was terminated in December 2016.

Phytosanitary Requirements

China is the only country that will accept debarking as an alternative to chemical treatment of logs to control insect risk, etc.

New Zealand biosecurity rules for log export require that bark amounts to no more than 2% on a batch of logs and 5% on a single log where logs are not fumigated. There is no standard method to assess this, however. The inspection organization is responsible for developing a method which the New Zealand Ministry for Primary Industries can accept or reject.

Forme's 2015 report to STIMBR indicated that in-forest debarking to phytosanitary standards could be achieved for some log grades but could take up to five times the number of passes of the processor head to do so. Smaller head logs, and rougher logs may not be debarked to minimum phytosanitary requirements.

Logs that have been through a ring debarker, on or off port, can and do fail inspection. Bark can still be found around branches, fluting area, in forks, etc.

Visits to close to 20 Central North Island logging crews indicated that many mechanized processing operators make a point of removing as much bark as possible from the bottom portion of the stem. This may take several passes of this portion of the stem. It is done to improve the accuracy of under-bark diameter measurements on the logs for optimal bucking and log volume determination reasons, rather than for phytosanitary reasons.

Safety Implications

Coefficient of friction (COF) is a measure of the relative force required to slide one body across another. Static COF relates to two bodies that are initially at rest. Dynamic COF relates to two bodies in motion relative to each other. Static COF would be important for logs stacked in a log yard or on a landing. Dynamic COF would be important for logs resting on a braking truck or in the grab of a moving log loader.

Dynamic COF tends to be a half to two-thirds that of static COF. Dry logs with the bark removed have static and dynamic COF's that are two-thirds to three quarters that of dry logs with the bark on. Wet logs with the bark removed have static and dynamic COF's that are about half that of dry logs with the bark removed. Wet debarked logs will have a dynamic COF that is less than half that of dry logs with the bark on.

It is expected that there would be negligible impact on the production of log handling once initial training and minor equipment modifications were addressed to overcome lower frictional forces of debarked logs. Because a certain percentage of bark free logs would already exist in the supply chain it is expected that storage locations on landings and at mills are already designed to provide firm, level and stable storage surfaces that will easily accommodate the debarked logs with

very minor reductions in stack height. Peak storage capacity could perhaps be reduced by a few percent in some cases.



Figure 7. Rear guards of log trailers may be required to prevent loss of debarked logs.

The greatest potential for impact would be in the transportation of the logs. Most of the literature that recognises debarked logs as a different commodity for transportation refers to eucalypt logs. If we assume debarked radiata pine logs are similar to debarked eucalypt logs then safe transport may require

the addition of a rear load guard in addition to the regular load securing (Figure 7). These guards will add up to 1000 kg in weight to the trailer. The resulting increase in tare weight would increase the cost of transport between 5% and 7%. If an extra tie-down on each bunk of wood were used – as specified in the NZ Log Transport Safety Council Industry Standards (2012) for debarked logs – the impact would be less; assuming an extra 5 minutes per trip to deal with the extra tie-downs the impact on the transport cost would be less than 2%.

Economic Analysis

Two models were developed within Excel spreadsheets that allowed quantification of the costs and benefits of in-forest debarking. One model was volume-based, the other model was weight-based. The models were populated with data from the benchmarking and drying trials, relevant published data, industry reports, and information supplied by industry personnel. The models span from forest establishment through to delivery of logs to mills or shipside (Figure 8).

Species	P. radiata	Total Revenue	No In-Forest Debarking	In-Forest Debarking	Delta%
Input Volume (m3 ub)	100,000		\$ 13,386,044	\$ 13,185,925	-1.49%
Wood Weight Initial (incl bark)	101,931	Harvesting Costs	\$ 2,451,852	\$ 2,835,767	15.66%
Number of days drying	5	Transport Costs	\$ 1,710,000	\$ 1,715,985	0.35%
Season (S_ummer, A_utumnn,	S	Mill Yard Costs	\$ 555,750	\$ 182,115	-67.23%
W_inter, SP_ring)		Port Costs	\$ 748,000	\$ 582,511	-22.12%
Location	NZ	Waste handling costs	\$ 39,331	\$ -	-100.00%
Wood Weight Final (NIFD)	94,752	Other Costs	\$ 309,615	\$ 334,462	8.02%
Wood Weight Final (IFD)	92,340	Extra Shipping Costs	\$ 268,889	\$ -	-100.00%
Harvesting System (GB, C, SW)	GB	Net Revenue	\$ 7,302,607	\$ 7,535,086	3.18%
Export % of total	55	Change in Net Rev.			3.18%
China % of Export	65				
Fumigation Port	Y				
Extra Port Visit Required	Y				

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Summary

Wood and Bark Data

Harvesting Economics

Transport Economics

Mill

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Figure 8. Summary page from the In-Forest Debarking Economic Model

The models were used to assess the economic viability of in-forest debarking for two sets of base case conditions; one set for Australia and one set for New Zealand. The main difference between the two sets of conditions was that log exports were not included for Australia. Sensitivity of economic viability to a range of key variables was undertaken for both sets of conditions.

For the New Zealand base case conditions, there is a 2.3% gain in net revenue as a result of in-forest debarking. This is equivalent to \$1.65 per m³. The results were sensitive to:

- Use of cut-to-length harvesting systems
- Number of drying days (in Spring and Summer only)
- The proportion of volume that is exported
- Whether a ship has to visit a second port to pick up fumigated logs for above deck cargo
- The assumed cost for a separate in-forest debarking machine
- Mill debarking costs
- The utilisation of bark generated at ports
- Daily shipping costs.
- Sapstain losses
- Contamination losses

For the Australian base case conditions, there is a 9.5% gain in net revenue as a result of in-forest debarking. This is equivalent to \$4.25 per m³. Other than export related parameters the results were sensitive to the same variables.

Maximum capital costs for processor-debarker heads

The models were also used to determine the breakeven price for a processor head suitable for in-forest debarking. In-forest debarking costs were increased to the point where the benefits became neutral. A breakeven-price for a debarker head was then back-calculated based on standard costing procedures.

The breakeven price for New Zealand operations ranged between \$245,000 and \$480,000. For Australian operations, breakeven price ranged between \$475,000 and \$800,000. It should be noted that the economic viability of in-forest debarking and the breakeven prices were very sensitive to the assumed value loss caused by sapstain.

Acknowledgements

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