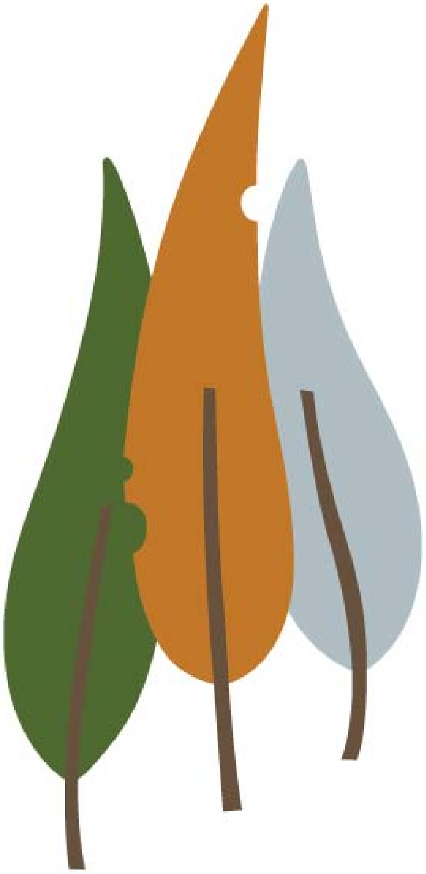
High-value wood resources

Technical Report 209

Processing plantation-grown *Eucalyptus globulus* and *E. nitens* for solid-wood products— Is it viable?

R Washusen

CRC for Forestry
Researching sustainable forest landscapes



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Processing plantation-grown *Eucalyptus globulus* and *E. nitens* for solid-wood products—Is it viable?

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Public report

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Preface

Preface

This report was prepared by Dr Russell Washusen at the request of the Cooperative Research Centre (CRC) for Forestry. It has been written for those familiar with the Australian eucalypt sawmilling industry. The review synthesises results from research trials that have examined the sawing and drying of plantation-grown sawlogs of *Eucalyptus globulus* and *E. nitens*, the two most widely planted eucalypt species in southern Australia.

The report considers a series of trials conducted by the CRC for Forestry under Dr Washusen's direction. It also covers other trials carried out by Dr Washusen's CSIRO team and other researchers external to the CRC's research program, most of these supported by Forest and Wood Products Australia (FWPA). It focuses on the processing of sawlogs from plantations that have been thinned and pruned. Most of the reports and papers that are reviewed here and listed as references can be downloaded from the CRC for Forestry[1] and FWPA[2] websites.

This report was presented and discussed at a CRC for Forestry science workshop 'Review of research progress and prospects for solid and engineered wood products from plantation-grown *E. nitens* and *E. globulus*', which was held in Hobart on 7–8 December 2010. The meeting was attended by 21 scientists and industry representatives involved in growing and processing plantation sawlogs. The report, and the publications which inform its conclusions, were circulated to participants prior to the workshop, and were discussed by the participants. There was general agreement that the review provides a good summary of the current state of knowledge of processing plantation-grown *E. nitens* and *E. globulus* sawlogs.

The conclusions drawn in this report cannot be applied to the sawing of logs from unthinned, unpruned plantations of these species. Experience has shown that such plantations will yield logs of small diameter, with wood quality dominated by the presence of knot-related defects. Only Tasmania has developed a significant area of sawlog plantations of these species, with thinning and pruning treatments applied to about 30 000 hectares of Tasmanian plantations. Commercial sawlog supplies from these plantations are forecast to develop over the next few years, with some 150 000 cubic metres of pruned sawlogs per annum predicted to be available from about 2020 onwards[3]. The successful processing of this new pruned plantation sawlog resource provides challenges and opportunities for Tasmanian processors.

The CRC gratefully acknowledges the assistance of a number of processing companies that made available their sawmills and drying facilities to conduct the research trials reviewed here.

Chris Harwood
Program Manager, 'High-value wood resources', CRC for Forestry, April 2011

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[1] http://www.crcforestry.com.au/publications/technical-reports/index.html

[2] http://fwpa.com.au/processing.aspx?s=2

[3] Forestry Tasmania (2007). Sustainable sawlog supply form Tasmania State Forest. Review No. 3. http://www.forestrytas.com.au/assets/0000/0113/SustSupply_RevNo3_100.pdf

Summary

This report reviews key research projects conducted in Australia that have examined product quality and wood behaviour during primary processing of pruned plantation-grown sawlogs of *Eucalyptus globulus* and *E. nitens*. Outcomes of applying conventional industry processing strategies used for native forest 'ash' eucalypts are examined, as well as results from a series of research projects designed to assess alternative but readily available strategies and equipment for processing plantation-grown sawlogs. The research suggests that most existing hardwood processors are poorly equipped to saw plantation-grown logs. Wood drying methods need to be altered to provide greater control over drying conditions, moisture content of boards throughout the drying process, and the effectiveness of steam reconditioning treatments. Such control, coupled with improvements in sawing accuracy and sawmill efficiency, should improve product recovery and quality and reduce processing costs.

Knowledge gaps and directions for future research and development in Australia are discussed. These primarily relate to the acceptability of closed internal checks in downstream manufacturing and the option of processing thin-section quarter-sawn boards of *E. nitens* in which internal checking and surface checking can be virtually eliminated.

In the longer term it will be possible to reduce levels of internal checking of *E. nitens* through breeding, and to minimise drying and sawing defects due to tension wood in *E. globulus* through improved silviculture.

Introduction

Research in Australia assessing the potential for producing high-quality solid-wood products from temperate plantation-grown eucalypts can be divided into two phases. Based on research reports, these phases divide around the year 2002. The earlier research and industry experimentation is reported well by Nolan *et al.* (2005). However, this research was usually *ad hoc* and unsystematic, and often ignored market requirements when selecting product size and assessing product quality. This was partly because suitable plantation-grown resources were scarce and many experimental processing trials were restricted to a few trees. Moreover, this research was almost always conducted without the involvement of the processing industry which faced more immediate challenges from declining tree age, log diameter and log quality of the native forest resources it was processing. While this early research was vital for establishing monitoring procedures to understand wood behaviour, it was of such an exploratory nature that little weight could be placed on results from an industry/market perspective.

The lack of systematic trials using plantation-grown logs led to considerable scepticism regarding the potential of these logs. Stories of log and board splitting, board distortion, poor sawing accuracy and poor drying performance emerged. This probably contributed to the conclusion of de Fégely (2004), from an industry survey, that indicated little prospect for processing plantation-grown eucalypts.

After 2002, the availability of suitable logs gradually increased, and processing trials became more systematic and used larger numbers of logs. Importantly, many of the logs were obtained from early experimental silvicultural trials, and on rare occasions, genetic trials. The most important change was the engagement of both hardwood and softwood processors, which allowed application of a wide range of processing systems.

While this review focuses on *Eucalyptus globulus* and *E. nitens*, the outcome of these changes was the first serious evaluation of logs of a number of eucalypt species from plantations located across southern Australia. In the past eight years the processing performance and product quality of *E. globulus* and *E. nitens* and species such as *E. dunnii, E. saligna, E. cladocalyx, E. viminalis* and *Corymbia maculata* (and other spotted gum species) have been assessed. These trials processed logs from stands that were often managed specifically for sawlog production, in which pruning and/or thinning had been applied.

Above all, the involvement of numerous working sawmills has allowed examination of a range of sawmilling systems and sawing strategies, and to a smaller extent various wood drying methods. This has allowed evaluation of alternative processing strategies that may be applied to plantation-grown *E. nitens* and *E. globulus.*

From this series of projects, two schools of thought have emerged in industry and scientific circles: that plantation eucalypts *can* be processed successfully, and that they *can't*. While some of this divergence could be attributed to earlier reports, much has come about as a result of two studies conducted in Tasmanian sawmills, one reported by Innes *et al.* 2008 and the other by Washusen *et al.* (2007a, 2009a,) that produced, from plantation sawlogs, lower product recovery and quality than would be expected from Tasmanian native forest sources. Nolan (2009) cited both of these studies as evidence that plantation and young native forest regrowth sawlogs were not viable to process in Tasmania. But is this really true, and what will happen if alternative processing strategies are adopted? This report reviews these two processing experiments and other important studies conducted in a variety of sawmills across Australia to reveal as complete a picture as possible of the potential to process plantation-grown *E. nitens* and *E. globulus* for the production of solid-wood products.

Assumptions of reader knowledge

This report, except for passing references, will assume reader knowledge of (i) branch-related defects and the effect of pruning on product quality, and (ii) the theoretical longitudinal peripheral growth stress distribution within eucalypt trees and logs.

Branches and pruning

The FWPRDC report by Nolan *et al*. (2005) is a reasonable summary of the wood quality issues found in past research. Clearly, defects associated with branches are a major constraint to production of conventional products, and pruning is the best way of overcoming these defects.

Sawmilling and growth stresses

Longitudinal peripheral growth stresses and sawmilling of eucalypts are inexorably linked. Much information has been published in scientific papers and textbooks over the past 50 to 70 years. These sources explain stress distribution and the consequences of the strains that develop with stress release during sawing.

The report by de Fégely (2004) indicated that the major perceived constraint to processing plantation-grown eucalypts was growth stresses. Growth stresses can pose difficulties during processing, potentially resulting in poor sawing accuracy, board distortion and end-splitting. Industry involvement, however, has provided opportunities to conduct trials not only in conventional sawmills, but also in the most modern hardwood mills in Australia, and to test modern softwood mills incorporating chippers that profile cants prior to or at the same time as sawing. The results of these experiments will be discussed in general terms, noting board behavioural characteristics related to growth stress release, and the efficiencies of processing. As will be shown, the latter will potentially have a significant impact on sawmilling costs (and hence profitability) and ultimately plantation value.

Sawmilling

Although sawmilling and wood drying are inexorably linked, this report treats them separately, both to simplify the issues as much as possible and because certain wood behavioural characteristics are associated with only one or the other of these processing stages.

Several trials with plantation-grown eucalypts (*Eucalyptus nitens* and *E. globulus*) have reported varying outcomes mostly due to differences in the drying performance (Washusen *et al.* 2004, 2007a, 2007b, 2009a, 2009b, Innes *et al.* 2008, Blakemore *et al.* 2010a, 2010b). This will be discussed in greater detail later. However, some differences are due to sawing strategies and equipment.

Conventional reciprocating-carriage single-saw log break-down systems

Conventional single-saw systems usually include a single bandsaw or circular saw that breaks down the log into manageable units for resawing. In smaller and older conventional mills, the resaw also has a single saw.

Single-saw systems have developed over many years to process native forest resources and are well suited to the highly variable quality of native forest logs where grade-sawing is required to maximise product quality. This variability includes a large range in diameter and level of internal defect.

The 'economics of processing' project

Some have made much of the FWPRDC report 'PN04.3007 Determining the economics of processing plantation eucalypts for solid timber production' (Innes *et al.* 2008). The conclusions drawn in this report are negative, but it is worth examining in detail.

The authors recognised that the sample of logs secured for all processing trials were not what was intended during project development. The logs had a very large diameter range with the majority less than 40 cm small end diameter (SED) and down to 25 cm SED. In the Tasmanian mills either an industry-standard quarter-sawing strategy or a 'through-and-through' sawing pattern was applied on the majority of logs (Figure 1). Both produce predominantly quarter-sawn wood.

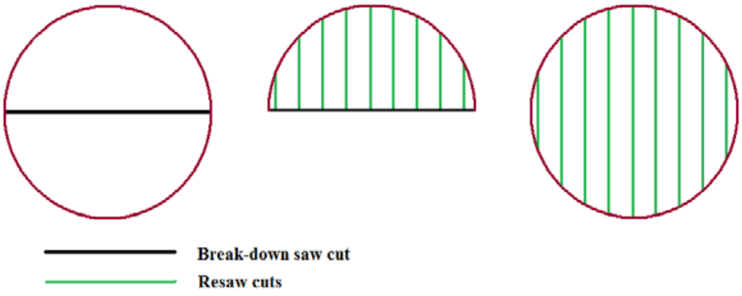

Figure 1. Quarter-sawing strategy (left and centre) and 'through-and-through' strategy (right) applied in Tasmanian mills in FWPA PN04.3007 (Innes *et al.* 2008) on 25–35 cm SED logs

It is well known that quarter-sawing strategies require large logs. For example, de Fégely (2004) indicated that quarter-sawing is impossible with native forest regrowth logs of less than 40 cm SED. This is somewhat overstated, but mostly true. The major reason for this conclusion is that growth-stress release has a major adverse effect on board distortion and end-splitting. Quarter-sawing also produces narrow boards and lower recovery (Washusen *et al.* 2004, 2007a, 2009a).

The cutting geometry indicated in Figure 1 will produce boards with a range of growth ring orientations. Some boards are back-sawn, some quarter-sawn and some mixed, which will contribute to different drying stress development and ultimately affect internal and surface checking and distortion (Blakemore and Northway 2009). In some cases boards will have growth ring orientation that varies along the board length, particularly in logs where the pith is not centred, and especially as the log diameter declines. This will complicate the internal drying stresses within the board, leading to even greater difficulties during drying.

With the sawing strategies in Figure 1, it is very probable that excessive variation in product thickness or width resulted from flitch and/or slab deflection as a result of growth-stress release. However, this was not measured. Boards undersized in width would have implications for downstream processing and could have contributed significantly to the undersizing reported during moulding of *E. globulus* boards (Innes *et al.* 2008), which led to the negative conclusions of Nolan (2009).

Another possible cause for undersizing in final products is the selection of incorrect green sizes that do not allow for shrinkage which may be greater than shrinkage of native forest material. However, the shrinkage rate was also not reported.

Given a combination of poor sizing accuracy, higher than expected shrinkage and spring (no matter how slight), skip in final products will be inevitable during machining to produce flooring. This could all stem from the selection of incorrect sawing strategies and could be easily remedied by simple modifications to the strategies.

Another point that should be noted from this report is that, in grading the final flooring products, boards shorter than 1.8 m were rejected. This may be standard practice in Tasmanian mills but it is not the case in other parts of Australia where random-length flooring is produced. Innes *et al.* (2008) also concluded that if plantation-grown material was to be processed, changes would need to be made to grading standard interpretation and more liberal allowances made for spring. This would also bring the Tasmanian industry into closer alignment with processors in New South Wales and Western Australia.

This report is lacking in the detail critical to understand some of the issues raised above. However, in its defence, the project was set up to see if native forest ‘ash’ processors could process plantation eucalypt material with their existing processing strategies. It is unfortunate that a suitable sample of plantation sawlogs could not be found. Despite this significant limitation, the outcome of the project was quite clear. Existing operations in Tasmania are incapable of processing such small-diameter short-length logs with their normal processing strategies. This was clearly the most important conclusion drawn by Innes *et al.* (2008).

The CRC for Forestry processing trial on E. nitens *from Goulds Country*

The CRC for Forestry trial accessed pruned sawlogs from 22-year-old *E. nitens* trees grown at a range of stocking densities (100, 200, 300, 400 and ≈700 stems ha^{-1}), following thinning and pruning treatments imposed at age 6 years. The plantation was one of the first operational Forestry Tasmania plantations of *E. nitens* located at Goulds Country, north-east Tasmania.

As indicated above, it is well understood that quarter-sawing is a poor sawing strategy for small diameter eucalypts. A general rule of thumb in native forest mills is that when logs are smaller than about 40 cm diameter then back-sawing strategies should be applied. The Goulds Country *E. nitens* processing trial, in another Tasmanian sawmill (Washusen et al. 2007a, 2009a), recognised this and used a strategy in which all of the smaller logs were back-sawn and the larger logs were quarter-sawn. The quarter-sawing strategy was similar to that shown on the left in Figure 1. The back-sawing strategy used a single saw and log rotation to produce the pattern similar to Figure 2.

This project produced differences in product recovery (Figure 3) with higher recovery from the smaller back-sawn logs. However, it also demonstrated the problem of sawing accuracy (with both sawing strategies) in mills designed to process very large diameter, long-length logs from native forests. This is because the mill was unable to overcome the problem of log and/or flitch deflection as the sawing progressed. The result is boards generally thicker mid-length than at the ends. Similar problems occur in board width. Figure 4 shows some of the thickness variation data produced in back-sawn boards (Washusen *et al.* 2007a).

Washusen et al. (2009a) found in a further analysis of this project that the standard deviation for thickness from more than 1700 measurements was 0.83 and 0.84 mm for quarter-sawing and back-sawing respectively. In comparison the guaranteed standard deviation from modern sawmill manufacturers are around 0.5 mm and may be much less in practice (Westermark, Viesto Oy, Finland).

With the green target thickness of 27.5–28.0 mm, a standard deviation of 0.83–0.84 mm and thickness shrinkage of 5–6% which equates to about 1.5 mm, some 20% of the board length was below 25 mm before dressing. This had a significant effect on both product recovery and quality.

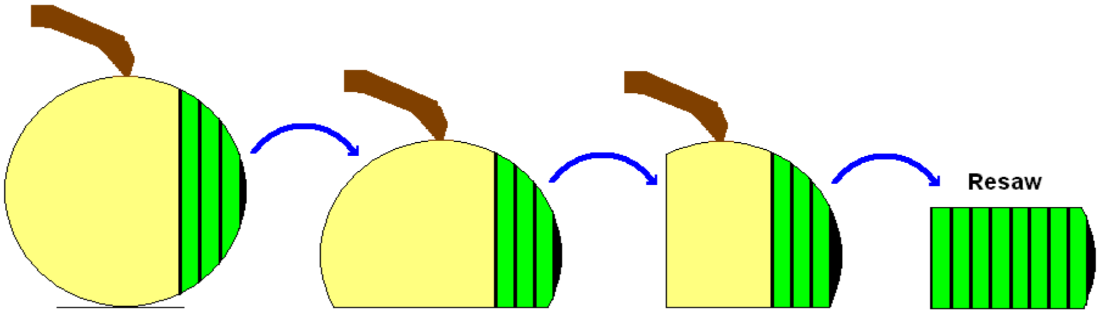

Figure 2. A back-sawing strategy similar to that applied in the CRC for Forestry Goulds Country *E. nitens* processing trial on logs smaller than 38 cm SED (Washusen *et al.* 2009a)

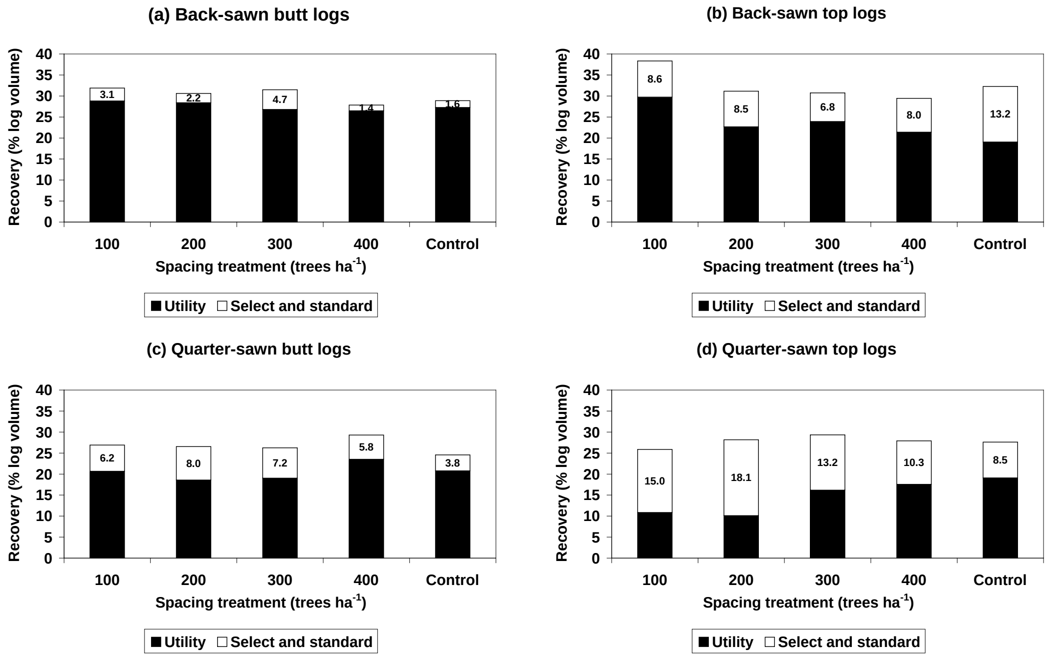

Figure 3. Comparison of recoveries from back-sawing and quarter-sawing strategies applied to logs from the same plantation. For quarter-sawing, logs had a minimum small-end diameter (SED) of 38 cm, and for back-sawing 25 cm SED (Washusen *et al.* 2007a)

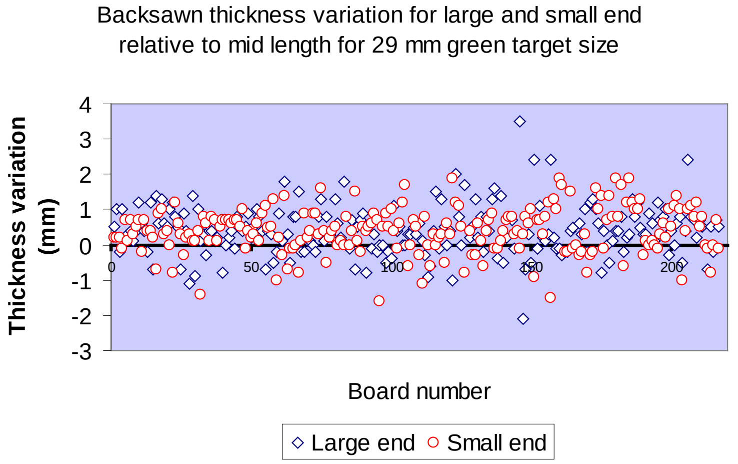

Figure 4. Thickness variation in back-sawn boards from the CRC for Forestry Goulds Country *E. nitens* processing experiments (Washusen *et al.* 2007a)

It is also important to note that during sawing the sawyers applied face cutting with the break-down saw to limit the thickness variation to that shown in Figure 4. To a small extent this face cutting would have also contributed to a lower recovery had it not been necessary and it slowed the sawing process considerably. Another important result from the Goulds Country trial was that, for logs of equivalent size, there was no appreciable effect of thinning treatment on processing performance. Sets of back-sawn and quarter-sawn logs were matched for size across the five thinning treatments. This suggested that commercial pulpwood thinnings could be obtained from *E. nitens* plantations without compromising processing performance of the final sawlog crop.

Single-saw log break-down systems with line-bars

The addition of a line-bar to single-saw log break-down systems, coupled with multi-saws in downstream processing, will help reduce the thickness and width variation with both back-sawing and quarter-sawing strategies applied on appropriate-sized logs. This is because the saw has a reference (the line-bar). Correctly used, the line-bar can eliminate the need for face cutting and should improve sawing accuracy in the hands of a well-trained operator.

There are very few research trials in which line-bar carriage single-saw systems have been used correctly to process *E. nitens* and *E. globulus*. The only known recent report is the study reported byWashusen *et al.* (2006) which used a quarter-sawing strategy on a line-bar carriage with multi-saws for downstream processing. The logs processed were pruned 17-year-old *E. nitens* from the Otways in Victoria and *E. nitens* logs of equivalent diameter and grade from 1939 regrowth natural forests from the Central Highlands of Victoria. The aim of this research was to quantify differences between plantations and natural regrowth. Log diameter and product value per log are plotted for each log in Figure 5. In terms of sawing accuracy, the results were good and undersized product rare. However, using the wood-grading strategies and market values developed by Black Forest Timbers in Central Victoria, lower product value was found for the plantation-grown logs (Figure 5). In this case wood-moth infestation was the primary reason for differences, and graders found no evidence of differences in processing performance between the two samples of logs. No other study has yet been conducted in which direct comparisons can be made with native forest eucalypts because of the difficulties in matching samples and then subjecting logs and boards to identical processing and product evaluation methods.

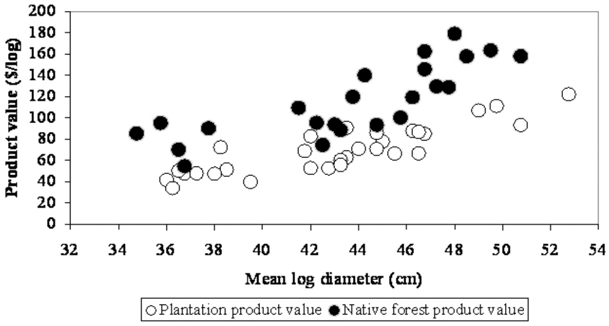

Figure 5. Comparison of product value of 17-year-old pruned *E. nitens* and 1939 native forest regrowth *E. nitens* (66 years old) matched on log grade and diameter (from Washusen *et al.* 2006). All logs were Victorian B-grade. Wood-moth holes and associated decay and stain were the primary wood quality differences between plantation and regrowth sources

The efficiency of conventional single-saw log break-down systems

One of the inevitable failings of single-saw log break-down systems is their slow material throughput due the requirement to pass logs backwards and forwards through saws. Where single-saw systems employ large-diameter circular saws, the saw kerf (the width of the saw cut) may also exceed 6 mm. Allowances for oversizing can also be large in mills wanting to avoid undersized products, for example some ash processors select a 31 mm green target thickness to produce nominal 25 mm dried boards (Washusen *et al.* 2006). While this is acceptable for native forest logs, single-saw log break-down systems become comparatively inefficient with plantation-grown logs (as diameter reduces, and with it log length), leading to unacceptably high processing costs.

Reciprocating carriage and overhead end-dogging twin-saw log break-down systems

An important option for improving sawmill efficiency is to use twin-saw log break-down and multi-saw resaws. Twin-saw systems apply sawing strategies that, when coupled with appropriate log rotation, produce cutting patterns that release growth stresses more symmetrically around the log than is possible with single saws.

A few hardwood mills in Australia have employed twin-saw log break-down systems with chipper-reducers that operate ahead of twin bandsaws. With the first pass through the saw, four cuts are made (Figure 6). This dramatically improves performance over conventional single-saw systems.

Figure 6. The McKee twin bandsaw at Auswest Timbers, Pemberton, equipped with chipper reducers (in this photograph hidden ahead of the saws) that effectively make four cuts on the initial pass. This photograph was taken during a trial back-sawing pruned 22-year-old plantation-grown *E. globulus* and shows the sawing immediately after the first turn-down

Twin-saw systems have been used to process *E. globulus* with a quarter-sawing strategy in Victoria and Western Australia (Washusen *et al.* 2004) and with back-sawing strategies in two Western Australian studies (Washusen *et al.* 2004, 2009b).

Quarter-sawing E. globulus *with twin saws*

The quarter-sawing study reported by Washusen *et al.* (2004) had a large element of experimentation and so is less relevant to this discussion than the back-sawing. Two different methods of quarter-sawing were tested:

1. In Victoria, logs were split with one of the twin-saws and then each half was put through the twin-saws again to produce three accurately sawn flitches for resawing.
2. In Western Australia, where the twin saw was equipped with a chipper reducer, the method applied in Victoria was not possible. In this case back-sawn flitches were sawn accurately in thickness and then diverted to a resawing line, turned down and sawn to produce quarter-sawn boards on a resaw (i.e. the original thickness becoming the width of the quarter-sawn board). This meant that spring could not be removed

> during resawing, as is normally done in mills set up for quarter-sawing. This ultimately left minor spring in some boards, although this level of spring was acceptable for the flooring that was ultimately produced.

Results of both of these projects indicated that *E. globulus* could be sawn and dried effectively. However, minor spring was noted as being present in some boards at the conclusion of drying in both projects.

Back-sawing E. globulus *with twin saws*

Washusen *et al.* (2004) conducted back-sawing at the Auswest Timbers mill in Pemberton, Western Australia, on 22-year-old pruned plantation-grown *E. globulus* logs. Standard sawing strategies for *E. diversicolor* native forest regrowth were applied. The wood was dried by the West Australian Forest Products Commission using standard drying methods for native forest *E. calophylla* (marri).

The high recoveries of select and standard grade boards reported are likely to be at least partly due to the sawing accuracy of the twin bandsaw and chipper reducer. The result was largely unexpected as back-sawing with unthinned and unpruned logs in the past had produced very low recoveries of standard grade and better (Washusen *et al.* 2000). To determine if the improved recovery was repeatable, a second project was conducted using logs from a 17-year-old thinned and pruned provenance trial (Washusen *et al.* 2009b).

FWPA-PRC114-0708 West Australian clearwood eucalypt project

The West Australian clearwood eucalypt project reported by Washusen *et al.* (2009b) was conducted using the small log line at Whittakers Timber Products (Figure 7). This is the newest dedicated hardwood mill in Australia. With the adoption of computerised optimisation of sawing, this mill has taken the use of twin-saws and multi-saw resaws to contemporary levels. The process involves scanning log dimensions, selecting the sawing strategy that will produce the best recovery and using the computer to control the sawing process. This mill also has a log-turn-down device that eliminates the need to release the log during log-turn-down, potentially speeding up the sawing process.

One limitation of these systems is that many have strict maximum log diameter requirements of about 45 cm SED. For plantations where log diameter can quickly exceed this limit, this may not be ideal. In this project with 17-year-old *E. viminalis*, *E. globulus* and *E. saligna*, some logs had to be rejected at harvest because they exceeded this diameter limit.

Figure 7. The system at Whittakers Timber Products processing 17-year-old pruned plantation-grown *E. saligna*. Left: sawing on the twin bandsaw; (centre) the hydraulic turn-down device in operation; (right) scanning of the central cant prior to sawing on the multi-saw

The recovery of boards was lower than reported by Washusen *et al.* (2004). This was primarily because the 100 mm x 108 mm centre cant and boards below standard grade were tallied as chip.

Sawing accuracy was assessed directly on boards as a ratio of undersized board length to the total length of boards produced. In the 16 samples of logs, this ratio expressed as a percentage ranged from 0% to 5.2%. The worst result was for *E. saligna*. For the three provenances of *E. globulus* the range was 0.4% to 3.2%. The poorer performance of *E. saligna* was attributed to log end-splitting during sawing, which was the major reason for undersizing in all provenances.

Figure 8 shows an example of the log end-splitting observed that contributed to undersized product. This is due to changes in the growth-stress balance. Here a 17-year-old *E. saligna* log has had four slabs removed during log break-down without turning the log down. This has produced a cant that is undimensioned in width (the rounded surface of the log remains). This cant is 105 mm thick and about 250 mm wide. The treatment of this log was a departure from the normal recommendation to turn eucalypt logs after chip, boards or slabs have been removed equal to about 33% of the log diameter. In this case more than 60% of the diameter was removed. This is technically a failure in the computer software that can be overcome with reprogramming. However, this problem has been observed in other trials and on other species (Washusen *et al. 2004*; Washusen 2009a) where the sawyer has had greater control of the sawing process. It appears to be very easy to mistakenly remove too many slabs before turning the log down. As log diameter declines this issue becomes increasingly important, but care with log segregation and selection of conservative sawing strategies will overcome this difficulty.

Changes in the growth-stress balance within logs also have subtle effects that may not be as noticeable as log end-splitting. During the trial on plantation *E. dunnii* described by Harwood *et al.* (2005), splitting ahead of the saws was observed during resawing of centre cants. This probably was the result of a similar phenomenon, the cant being too thin relative to its width.

Splitting ahead of saws is probably the least recognised problem associated with growth-stress release. In the numerous trials conducted by CSIRO this issue has emerged frequently.

As log diameter declines, problems of stress imbalances leading to both end-splitting and splitting ahead of the saw remain to be effectively addressed in mills using either conventional single-saw systems or more contemporary multi-saw systems.

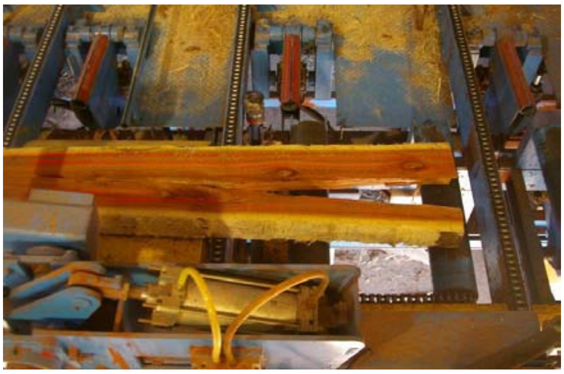

Figure 8. Log end-splitting in 17-year-old *E. saligna*, the consequence of sawing to produce a cant that is too thin relative to the log diameter

Linear-flow multi-saw systems

The main issues identified above as limiting sawmilling efficiency and potentially limiting product value as a consequence of the sawing process in conventional single-saw and twin-saw systems are:

- sawing accuracy of single-saw systems
- large saw kerf, particularly from large-diameter circular saws
- log end-splitting and cant end-splitting
- splitting ahead of the saw
- the requirement to rotate logs during sawing
- the reciprocation of logs through break-down saws, and in the more conventional systems the reciprocation of logs, flitches and slabs through resaws.

Other problems associated with growth-stress release relate to board deflection, either as spring in quarter-sawn boards or bow in back-sawn boards. In general, this has not hampered the sawing process as the sawing methods themselves are designed to reduce the extent of this deflection, or to eliminate it during resawing. The choice of log length has a major bearing on problems of deflection. In the trials described above, sawlog length was always conservative (only 2.7 m to 3.3 m) with the aim of reducing deflection to manageable levels and limiting recovery loss in the resawing process.

So what happens if we apply even more symmetrical cutting patterns than those possible with twin-saw log break-down systems, and adopt a linear flow of wood as opposed to a reciprocating flow?

Close-coupled saws and chippers

Linear-flow sawing systems are usually associated with softwood mills where longitudinal growth stresses are not a constraint to sawmilling. However, a number of trials have now been conducted with linear sawing systems with *E. globulus* and *E. nitens* and a few other species from northern New South Wales. FEA Ltd in Tasmania has processed small-diameter *E. nitens* for structural products on a commercial scale, using a HewSaw R200. Recent trials have also been conducted using the HewSaw R250 at the Carter Holt Harvey mill in Gippsland (formerly NF McDonnell & Sons) (Figure 9). These two sawing systems apply chippers to remove wood from around the log to produce a profiled cant simultaneously with or just ahead of small-diameter circular saws (Figure 10). This strategy eliminates the problem of growth-stress imbalance identified above by removing wood simultaneously from around the log.

The HewSaw R250 and R200 complete the sawing in a single operation and without reciprocating the log. This creates some obvious disadvantages that will be discussed below.

The HewSaw R200 and R250 have log diameter ranges of 14–25 cm and 14–34 cm SED respectively, and so are suited to resources of different age or size. At conservative feed rates into the saws, total log volume input is around 120 000 m^3 of logs per year in a single shift. This is a much greater volume than can be processed by any hardwood sawmill where trials have been conducted.

The potential ramifications of high throughput are that, if a suitable resource were available, the cost of sawmilling could fall dramatically, improving the profitability of growing and processing plantation eucalypt sawlogs.

Figure 9. The HewSaw R250 at the Carter Holt Harvey Mill in Gippsland

Figure 10. Diagrammatic representation of the internal arrangement of chippers and saws in the HewSaw R250 (source: www.hewsaw.com)

To understand how effective these systems are at processing logs with high and variable growth stresses, research has been conducted with the HewSaw R250 (Washusen *et al.* 2007b) on logs from 17-year-old unthinned *E. nitens* plantations. Log lengths were up to 5 m—much longer than in any other trial to date in more conventional systems.

The characteristic related to growth-stress release of greatest importance was bow in boards near the log periphery. Photographs of the range in bow observed during the trial are shown in Figure 11. These photographs were taken immediately at the conclusion of sawing on the HewSaw R250. Figure 12 plots longitudinal growth strain displacement (LGS, a measure of peripheral longitudinal growth stress) measured on standing trees and maximum bow for each log. Bow of this extent was of little consequence to board handling or stacking, and would be eliminated during drying.

Figure 11. The approximate range in board deflection for 17-year-old *E. nitens* logs observed in trials with the HewSaw R250

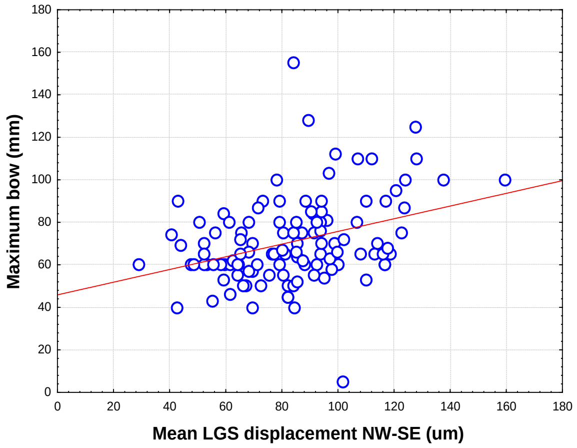

Figure 12. Plot of LGS displacement and the maximum bow recorded for each log

The advantage of being able to produce boards of this length is that product value is linked to board length (as well as to width and thickness). On current markets, if average board length is less than 3 m there is a discount of 10% on the current wholesale price, and for boards less than 1.8 m in length there is a discount of 50% (Ken Last, formerly FWPRDC, *pers. comm.*).

There is another less obvious advantage in sawing longer logs. Some log end-splitting resulting from harvesting and handling appears to be inevitable in eucalypts. Although worsening of the splitting can be prevented by the sawing process, if log end-splits show up in board ends they are docked, reducing recovery. In this trial in 17-year-old *E. nitens* with 5 m logs, log end-splitting accounted for a range of 1.2–2.9% loss in recovery for the six samples processed (Figure 13). This compares to 5% loss in the Goulds Country trial on 22-year-old *E. nitens* with 2.7 m logs (Washusen *et al.* 2007a). An assessment of log end-split severity indicated that the 17-year-old logs actually tended to have worse end-splitting than the 22-year-old logs. The reason for the difference in loss due to docking end-splits is that the end-split length was less, as a proportion of log length, in the 17-year-old logs. While the results were presented differently, this lower loss due to end-splitting in longer logs was repeated in a subsequent CRC for Forestry trial (Blakemore *et al.* 2010a). Docking of end-splits in this trial would have accounted for approximately 2% loss in recovery, the same as the mid range recorded by Washusen *et al.* (2007b).

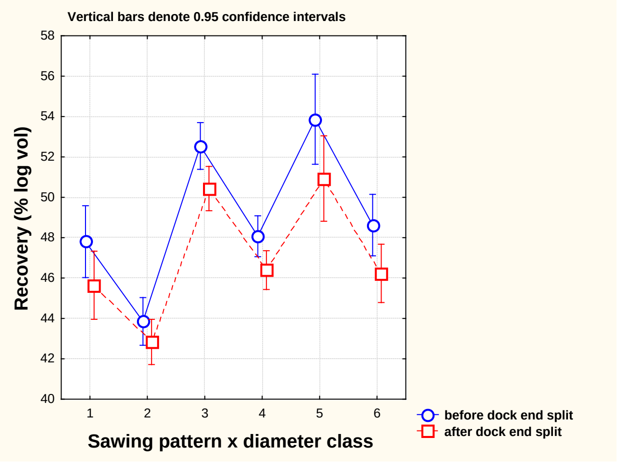

Figure 13. Plot showing loss due in green volume recovery due to end-splits for three different sawing patterns on a HewSaw R250 and two diameter classes for each sawing pattern (Washusen *et al.* 2007b)

There is one disadvantage with the sawing pattern employed by these close-coupled machines: many boards containing the pith are produced. As log diameter declines the percentage of board length affected increases. This is because the sawing pattern produces boards through the centre of the logs (Figures 10 and 11) which commonly have drying defects associated with the pith.

The potential to apply sawing lines to eucalypt processing

To address the problem of drying wood with the pith included, one option would be to saw around the pith and segregate the boards containing the pith from the drying process. This can be achieved by separating out the various processing components into separate machines. Sawing lines configured in this way are common and they retain the superior stress release attributes of the close-coupled machines.

An example of one such machine is the HewSaw SL 250 PLUS Trio. The cutting pattern of this sawing line is shown in Figure 14. The three main components are the cant chipping, cant sawing/edging and rip-sawing machines. If required, the thickness of the final cant can be varied to avoid the problems of end-splitting and the narrower centre boards diverted from drying. The mills can also process logs from 2.4–6.0 m length and from 10 cm SED to 40 cm SED and 50 cm LED. Line speed is 60–150 m/min (Washusen 2009b). The range of acceptable length gives greater flexibility for controlling board deflection and the larger diameter range makes it more flexible for processing eucalypts.

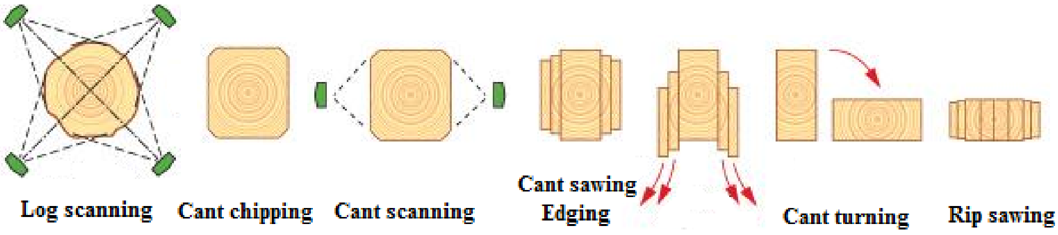

Figure 14. The sawing pattern of the HewSaw SL 250 PLUS trio showing the role of the separate components

The implications of high speed and linear flow

The implications of moving from conventional reciprocating carriage or overhead end-dogging systems to a linear sawmill either equipped with a close-coupled machine or sawing line is best demonstrated through modelling. CSIROMILL modules (Washusen 2009b) are available that represent the Whittakers MEM Tally Twin and Cobra Multi-mate resaw system, a HewSaw R250 and a HewSaw SL 250 PLUS trio. The estimated log intake per year for a two-shift operation and modelled sawing costs on a comparative basis are given in Table 1.

Table 1. Modelled sawing costs (from CSIROMILL) for given log intake ranges for three sawing systems

Processing system	Annual log intake for 2 shifts (cubic metres)	Modelled sawing costs based on 2007 prices and 15 year mill life ($ per cubic metre intake)
MEM Tally Twin and resaw*	36 000–45 000	$55–$65
HewSaw R250**	200 000–260 000	$18–$22
Hewsaw SL 250 PLUS Trio***	260 000–320 000	$15–$20

* Source of costs and log throughput: Whittakers Timber Products (WA), Auswest Timbers (WA), Black Forest Timbers (Vic.)

** Source of costs and log throughput: NF McDonnell & Sons (SA), Carter Holt Harvey (Vic.), D&R Henderson (Vic.), Forest Enterprises Australia (Tas.)

*** Source of costs and log throughput: NF McDonnell & Sons (SA), Carter Holt Harvey (Vic), D&R Henderson (Vic.), Viesto (Finland), Forest Enterprises Australia (Tas.)

As indicated in Table 1 the sawing costs can be reduced substantially over conventional reciprocating sawing systems by applying close-coupled linear systems—the sawing line providing even greater cost reductions. There are also very large differences in log intake ranges. In Australia it will be very difficult to find a supply of 260 000–320 000 m^3 of eucalypt sawlogs required for a sawing line in the foreseeable future. However, there are some softwood mills with suitable sawing systems that have capacity to take on a suitable hardwood resource if it were available as part of their feedstock. Given the large differences in sawing costs, the softwood mills would have a competitive advantage over conventional hardwood processors.

Of course this is only relevant for logs smaller than 45 cm diameter for the twin bandsaw, and 40 cm SED for the linear sawmills. Except for the HewSaw R250 (and for the HewSaw R200 which has similar sawing costs) which has a ‘through-and-through’ sawing pattern from which quarter-sawn boards can be derived, these mills normally only produce back-sawn wood.

High-speed quarter-sawing

It not known whether these linear mills can be adapted to quarter-saw. Experimentation with the HewSaw R250 (Blakemore *et al.* 2010a) which attempted to produce flitches for resawing quarter-sawn boards in an off-line pallet mill indicated that spring was excessive. This experiment used logs of 3.6 m length and 32 cm SED, and produced 75 mm thick flitches for resawing at the top and bottom of the cant. This is a very radical cutting pattern, given the length and diameter of the logs and it is not surprising that it produced excessive spring, averaging 30–50 mm. However, on this mill no other option could be tested because, for this mill, 3.6 m is the minimum length and 32 cm the maximum SED.

As indicated earlier the HewSaw SL 250 PLUS trio sawmill can process logs up to 40 cm SED and down to 2.4 m log length. Given the results of the quarter-sawing experiments on similar-sized *E. globulus* logs with the McKee twin bandsaw at Auswest Timbers (Washusen *et al.* 2004 cited above) ,where flitch deflection was minor, it may be possible to produce similar-sized flitches for downstream quarter-sawing with acceptable distortion on the HewSaw SL 250 trio. It may be worthwhile testing this possibility in future, particularly if back-sawn *E. nitens* develops too much drying defect for high-value markets.

The impact of tension wood on sawing

As a general rule, tension wood was scarce in all of the projects reported above. The only project where the level of tension wood occurrence was unstated was in Innes *et al.* (2008), and the only occasion where it was positively identified was in Washusen *et al.* (2004). In the latter study, damaging levels of tension wood, in the form of unrecovered collapse, were found in boards from 6% of the *E. globulus* logs. This led to recovery 3.9% lower, on average, than for logs free of tension wood and of the same diameter range. Had the tension wood been present at the log periphery when sawing was conducted it would have also contributed to excessive distortion; however, in this study the tension wood was overgrown with normal wood.

The effect of silviculture on tension wood occurrence

Tension wood produces extreme longitudinal peripheral growth stresses (e.g. Nicholson *et al.* 1972, Boyd 1977) and this will impact on sawn board behaviour. Tension wood also has abnormal shrinkage characteristics during drying. For these reasons trees with significant levels of tension wood will be very difficult to process in any sawmill and commercial viability will be compromised.

With *E. globulus,* tension wood is very common in unthinned conventional pulpwood stands at about harvest age (Washusen 2000), and this contributed to poor processing outcomes. There is some evidence that thinning early will reduce tension wood occurrence (Washusen 2002, Washusen *et al.* 2004) and that is presumed to be the main reason for the satisfactory processing results reported by Washusen *et al.* (2004).

The exact effects of silviculture on tension wood formation are still not completely understood. Washusen *et al.* (2005) found that levels of tension wood increased in *E. globulus* trees at Tostaree, Victoria, subsequent to a heavy thinning (corresponding to a commercial pulpwood thinning) at age 8 years. With fertiliser application following such thinning, tension wood levels did not increase, suggesting that rapid diameter growth response subsequent to thinning reduced tension wood formation.

The CRC for Forestry has an ongoing research project to clarify effects of site, genetics and silviculture on tension wood formation in *E. globulus.*

Wood drying

Wood drying of plantation-grown *Eucalytpus globulus* and *E. nitens* has been reasonably well researched and the different results found are another source of confusion among scientists and industry.

There is no doubt that high-quality timber can be produced from plantation logs of both species, and that it is different from native forest timber. An example of what is possible with plantation-grown *E. nitens* is shown in Figure 15. This furniture was produced among other decorative products from boards processed at Black Forest Timbers, Victoria; the sawing and drying of which was reported by Washusen *et al.* (2006).

In order to produce wood like this it must be dried without significant drying defects developing.

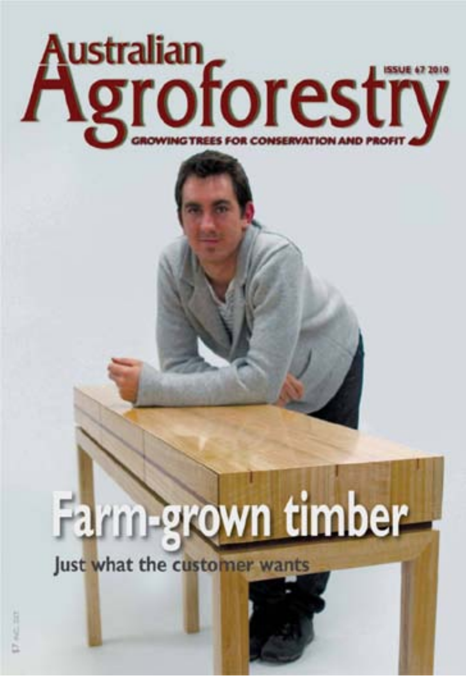

Figure 15. Furniture produced from 16-year-old *E. nitens* (source: *Agroforestry News*, Issue 67, 2010)

Effects of tension wood on drying performance

Damaging levels of tension wood can cause the most severe defects arising from the drying process. Tension wood differs anatomically from normal wood in a number of ways. The most striking difference is the presence of fibres where the S_2 layer has been highly modified in that lignin has not been deposited normally during cell formation (Figure 16). These tension wood fibres are very unstable during drying and the wood consequently has abnormally high transverse and longitudinal shrinkage. The transverse shrinkage appears similar to shrinkage resulting from cell collapse in normal wood; however, unlike normal wood, the shrinkage is unrecoverable during stream-reconditioning treatments. The defect in dried boards appears as high shrinkage (Figure 17), surface and internal checking and distortion in the form of spring, bow (that may not be present after sawing), cupping and twist. Where damaging levels of tension wood are common (such as in unthinned *E. globulus* pulpwood stands), it will be very difficult to viably process wood into solid-wood products.

While tension wood is very common in *E. globulus,* its occurrence in other species is not well understood. However, in contrast to the thinned and pruned *E. globulus* described by Washusen *et al.* (2004) in which tension wood was easily identified, during processing of *E. nitens* in all of the CRC for Forestry trials (Washusen *et al.* 2007a, 2009a, Blakemore *et al.* 2010a, 2010b) damaging levels of tension wood were uncommon and had little impact on recovery or product quality. This suggests that damaging levels of tension wood are less common in *E. nitens* than in *E. globulus*.

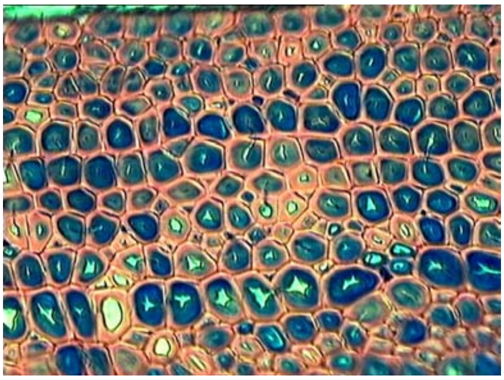

Figure 16. Transverse section of tension wood from plantation-grown *E. globulus* double stained with safranin (red; lignin stain) and alcian blue (blue; cellulose stain). The blue (dark) layers are unlignified (from Washusen 2000)

Figure 17. High shrinkage and cupping from damaging levels of tension wood in 22-year-old *E. globulus* (from Washusen *et al.* 2004)

Drying defect in normal wood (in the absence of tension wood)

There are two sources of drying degrade in normal wood that impact on the potential to produce high-quality final products like that in Figure 15. These are surface checking and internal checking. Blakemore and Northway (2009) provide the most recent review of mechanisms for both of these forms of drying degrade and the state of knowledge of their occurrence, particularly in the native forest resource in south-eastern Australia.

Both surface and internal checking are due to internal stresses that are generated by differential shrinkage during drying. This shrinkage is due to either: (i) normal shrinkage within the cell wall, which occurs below fibre saturation point, or (ii) collapse shrinkage in the early stages of drying, above the fibre saturation point (i.e. when cell lumens contain water).

Simplistically, normal shrinkage is responsible for surface checking in back-sawn boards where shrinkage across the board face and hence drying stresses are high, while collapse shrinkage is responsible for internal checking.

Check propensity of E. globulus *with standard industry drying methods*

E. globulus is susceptible to both internal and surface checking when tension wood is present. However, its collapse propensity is not well understood. Blakemore and Northway (2010) suggest that it is collapse-prone but do not indicate whether or not tension wood is implicated.

The best way of determining collapse propensity is to examine the occurrence and severity of internal checking. Innes *et al.* (2008) examined a sample of boards by cross-cutting 40 cm from the end of each board. They found that 87–92% of boards had no visible internal checks, while a further 8–11% received a subjective 'minimal check' rating. This suggested internal checking and collapse was a minor problem in these samples of *E. globulus*. Innes *et al.* (2008) did not report the grade of the boards that were assessed, or if the occurrence of surface checking was related to the presence of tension wood.

In the two studies on *E. globulus* reported by Washusen *et al.* (2004) and Washusen *et al.* (2009b), internal check assessment was only conducted as part of normal grading of boards by a visual inspection of board ends. Internal checks were absent or rare. Destructive internal check assessment by cross-cutting boards was not conducted either for back-sawn or quarter-sawn boards.

Results from these projects generally indicate that wood from well-managed *E. globulus* plantations in which thinning and pruning have been conducted is not prone to severe internal checking. However, in the absence of follow-up studies where a destructive internal check assessment is undertaken, the propensity for internal checking remains uncertain. This is a similar situation to the understanding of checking in the native forest ash eucalypt resource. While it is known that internal checking occurs, its extent is largely unquantified and the statement by Blakemore and Northway (2009) that 'internal checking propensity is likely to be worse in *E. globulus* than for the current ash regrowth' may not be correct.

Washusen *et al. (*2009b) did quantify surface checking severity on the graded face of each back-sawn board and expressed it as the ratio of board length with surface check to total board length. For the three southern Tasmanian provenances of *E. globulus* studied, the range was 2.0 to 5.0%, indicating that surface checking was a minor defect in this study.

The results generally support the findings of Washusen *et al.* (2004) that *E. globulus* sawlogs grown in thinned and pruned plantations can be back-sawn effectively and, if dried with care, little surface checking will occur. However, there remains a question about the suitability of the air-drying method employed and the lack of a steam-reconditioning treatment in the Washusen *et al.* (2009b) study. While a faster drying time may have produced more surface checking, it is also probable that a reconditioning treatment would have been beneficial in reducing visible checking, post reconditioning.

Check propensity of E. nitens *with standard industry drying methods*

Both Innes *et al.* (2008) and Washusen *et al.* (2007a, 2009a) have quantified internal check occurrence in plantation-grown *E. nitens* after application of industry standard drying practices. Washusen *et al.* (2007a, 2009a) also quantified surface check severity on both back-sawn and quarter-sawn boards.

Innes *et al.* (2008) found, in an assessment of a subset of *E. nitens* boards cross-cut in the same way as their *E. globulus* study, that 56–65% of boards had no visible internal checks, a further 25–31% had a subjective 'minimal check' rating, and 6–17% had a subjective 'moderate to heavy check' rating. No information on surface checking was given.

Washusen *et al.* (2007a) found internal checks assessed at mid-length of a subsample of boards to be even more common than reported by Inness *et al.* (2008) and surface checks to be common on both back-sawn and quarter-sawn boards. Table 2 summarises the findings for upper and lower logs and for both sawing strategies. Upper log and lower log refer to the top log and butt log (each ≈ 2.7 m in length) from the pruned stem.

Table 2. Summary of the percentage of boards with internal and surface checks and mean number of internal checks per board in 22-year-old plantation-grown *E. nitens* (from Washusen *et al.* 2007a)

% of boards with surface checks	**Lower logs**	**Upper logs**
Back-sawn	69.5	45.4
Quarter-sawn	21.9	11.8
% of boards with internal checks	**Lower logs**	**Upper logs**
Back-sawn	73.3	34.3
Quarter-sawn	73.1	23.1
No. of internal checks per board	**Lower logs**	**Upper logs**
Back-sawn	7.58	1.99
Quarter-sawn	4.10	0.74

From the studies of Innes *et al.* (2008) and Washusen *et al.* (2007a, 2009a) it can be seen that internal and surface checking was very common in *E. nitens*. There were reductions in checking levels with increasing height up the stem, and quarter-sawn boards had less checking than back-sawn boards.

Little else can be made of these two projects because the monitoring procedures and recording equipment failed to produce adequate information on board moisture content, which is crucial for understanding drying behaviour. In addition, the CRC for Forestry project produced inadequate records of board handling procedures, ambient conditions during air-drying and conditions in the pre-dryer and kiln, preventing conclusive judgments about the adequacy or otherwise of the drying methods employed.

Check-propensity of E. nitens *using controlled drying methods*

While drying defect was anticipated, the inadequacies of the monitoring procedures in the two critical projects described above led the CRC for Forestry to undertake a series of further controlled experiments to understand the drying behaviour and check propensity of plantation-grown *E. nitens.* This research is described by Blakemore *et al.* (2010a, 2010b).

This follow-up research applied accurate sawing, controlled drying and careful monitoring of moisture content to test the effectiveness of commercially available drying treatments and experimental pre-treatments for plantation-grown *E. nitens*.

Above all else, the research aimed to apply a steam-reconditioning treatment at a mean moisture content of 15% in the wood in the drying stack. This is generally a higher moisture content than industry would use to steam-recondition ash eucalypt boards. At this higher moisture content, steam-reconditioning has been shown to maximise collapse recovery in a commercial setting (Blakemore & Langrish 2008, Blakemore & Northway 2009). In all, eight drying treatments were tested (Table 3).

Table 3. Source of logs, sawing orientation and drying and reconditioning treatments for CRC for Forestry research into drying plantation-grown *E. nitens*

Plantation	Sawing	Board green thickness (mm)	Drying treatment	Steam-recondition (MC %)
Goulds Country + Tumut	Back	28	1.Controlled air drying / kiln drying[1]	15% mean
Goulds Country + Tumut	Back	28	2. Industry propriety kiln drying[1]	Unknown
Goulds Country + Tumut	Back	28	3. Mild pre-drying schedule / kiln drying (Treat. 3)[1]	15% mean
Goulds Country + Tumut	Back	28	4. Microwave pre-treatment / Treat. 3[1]	15% mean
Goulds Country + Tumut	Back	20	5. As for treatment 3[1]	15% mean
Goulds Country + Tumut	Quarter	25 / 28	6. As for treatment 3[1]	15% mean
Goulds Country + Tumut	Quarter	25 / 28	7. Boron diffusion / Treatment 3[1]	15% mean
Lisle	Quarter	9	8. Mild pre-drying schedule / kiln drying[1, 2]	15% mean

Source: [1] Blakemore *et al.* (2010a): [2] Blakemore *et al.* (2010b)

Severity of surface checking was assessed on the dried boards on the best face following planing, assuming that end-splits were docked. Internal check severity was assessed by cross-cutting all boards to determine internal check number and aggregate cross-sectional area before and after reconditioning.

Generally, there was little difference between the drying methods evaluated in Table 3 except for thin-section (9 mm green) quarter-sawn boards which were virtually check-free. However, there was a general substantial improvement in drying performance relative to the earlier *E. nitens* trials that can be seen by comparing data with that was reported by Washusen *et al.* (2007a, 2009a) (Goulds 1). Figure 18a–18b gives the percentage of boards with surface and internal checking for back-sawing and quarter-sawing, with the data produced from the drying experiments listed in Table 3 combined where appropriate. The percentage of boards affected was greatly reduced in all of the drying experiments relative to Goulds 1, and the best results were for thin-section quarter-sawn boards.

Figure 18a–18b does not show how much improvement there was at the individual board level; it simply signifies the proportion of boards in which the defect was present. Figure 19 plots the surface check length to board surface area ratio for back-sawn boards from Washusen *et al.* (2007a) and Blakemore *et al.* (2010a). The comparison between the two projects is not exact, because; (i) the sets of boards did not match exactly, and; (ii) surface check assessment in Blakemore *et al.* (2010a) excluded 50 mm portions of boards which were docked when cutting wafers for the study of internal checks. However, this resulted in only a very small fraction of the board length being excluded from surface checking assessment. Therefore, a reasonable, although not exact, comparison of surface checking in the two studies can be made.

Figure 19 shows that the surface check severity was reduced substantially in the back-sawn boards. Together with fewer boards being affected, this suggests good potential to improve the wood quality and recoveries reported by Washusen *et al.* (2007a, 2009a). The factors contributing to the improvements are not known for certain, but a combination of correct oversizing of green boards through more accurate sawing, the steam-reconditioning treatment at a mean moisture content of 15%, the controlled conditions during air-drying and pre-drying and correct weighting of drying stacks all probably contributed to improvements. Comparison of internal checking before and after reconditioning demonstrated clearly that the majority of internal checks visible prior to reconditioning could be closed (Blakemore *et al* 2010a, 2010b) producing major reductions in the number of visible internal checks after reconditioning.

Blakemore and Northway (2009) raised the issue of the implications for closed and open internal checks in the FWPA review. With good drying practices, internal checks associated with normal wood can be closed as has been demonstrated in this CRC for Forestry work. It is unclear if closed checks are a problem during secondary processing. While some believe that closed internal checks lead to defective products, Blakemore and Northway indicated that there is no validated scientific evidence to support this assertion.

Ultimately, in the longer term, it will be possible to reduce levels of internal checking in *E. nitens* by breeding, as research has demonstrated that checking is under a substantial degree of genetic control (Blackburn *et al.* 2010).

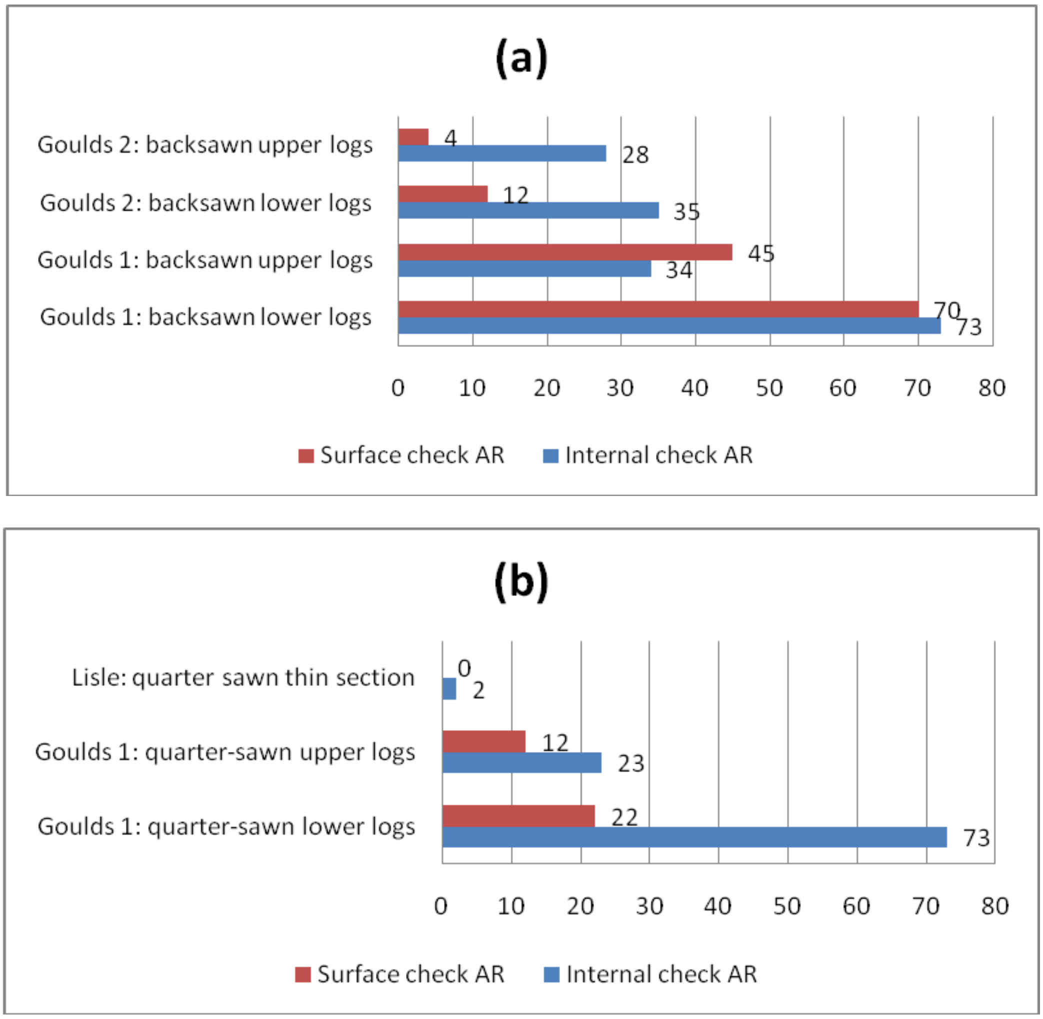

Figure 18a–b. Comparison of the percentage of *E. nitens* boards with internal and surface checking between studies: AR = after reconditioning; Goulds 1 = Washusen *et al.* (2007a); Goulds 2 = Blakemore *et al.* (2010a); Lisle = Blakemore *et al.* (2010b); Upper and lower log locations refer to the top log and butt log from the lower stem

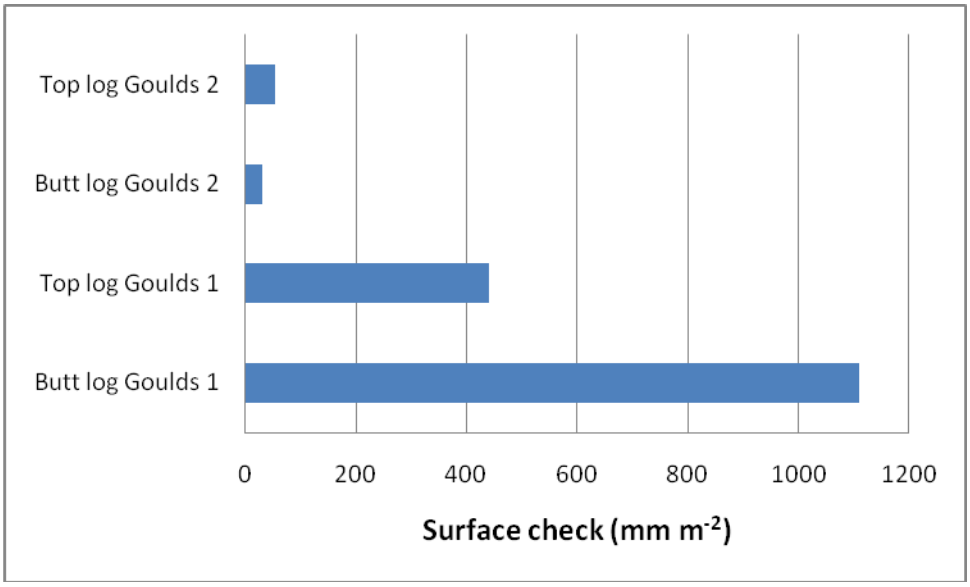

Figure 19. Comparison of surface check aggregate length to board surface area for back-sawn boards from Goulds 1 (Washusen *et al.* 2007a) and Goulds 2 (Blakemore *et al.* 2010a)

Recovery and drying defect comparisons with native forest eucalypts

Table 4 gives comparisons with existing native forest timber from recent FWPA studies examining differences in wood quality between thinned and unthinned native forest regrowth from across southern Australia. This work is summarised in Washusen *et al.* (2009c). The information of importance relates to surface check severity, total recovery and select plus standard grade recovery. Internal check assessment is not included in Table 4 because destructive analysis was not undertaken on the native forest regrowth boards.

The first processing study on plantation-grown *E. nitens* from Goulds Country (Washusen *et al.* 2007a) stands out in Table 4. Surface checking was worse than found in these comparable studies for a given sawing strategy. However, with the application of controlled drying and steam-reconditioning at mean 15% moisture content, this drying defect was bought into line with the native forest samples. Given that surface checking was the major grade-limiting defect found by industry graders (Washusen *et al.* 2007a), there is considerable scope to improve the recovery of select and standard grades for Foresty Tasmania's *E. nitens* clearwood plantations. The market acceptance of these grades will depend on closed internal checks and surface checks (particularly for back-sawn boards, in which they will be more prevalent) not hindering final product quality.

Table 4. Comparison of surface check severity, grade recovery and select plus standard grade recovery for native forest eucalypts and Forestry Tasmania *E. nitens*

Species	History	Sawing method	Surface check (mm m^{-2})	Recovery all grades (% log vol)	Recovery select & standard grade (% log vol)
E. fastigata	NSW regrowth unknown age[1]	Quarter	73	20.8[5]	3.8[5]
E. diversicolor	WA regrowth unknown age[1]	Back	51	28.2[6]	7.9[6]
E. regnans	Vic regrowth 1939[1]	Quarter	41	25.8[6]	3.7[6]
E. regnans	Tas regrowth 1934[1]	Quarter	13	30.8[6]	19.3[6]
E. seiberi	Vic regrowth unknown age & 1957[1]	Back	738	31.1[6]	0.0[6]
E. nitens	Tas Goulds 1 butt logs[2]	Quarter	120	26.9[6]	6.8[6]
E. nitens	Tas Goulds 1 top logs[2]	Quarter	80	27.9[6]	14.3[6]
E. nitens	Tas Goulds 1 butt logs[2]	Back	1110	29.8[6]	2.5[6]
E. nitens	Tas Goulds 1 top logs[2]	Back	440	31.2[6]	9.1[6]
E. nitens	Tas Goulds 2 butt logs[3]	Back	55	NA	NA
E. nitens	Tas Goulds 2 top logs[3]	Back	31	NA	NA
E. nitens	Tas Lisle[4]	Quarter / 9 mm	0	NA	NA

[1] Washusen *et al.* (2010c); [2] Washusen *et al.* 2007a; [3] Blakemore *et al.* (2010a); [4] Blakemore *et al.* (2010b); [5] Based on final flooring sizes; [6] Based on nominal dried dimensions

Basic wood properties

Wood properties (density, stiffness, hardness and shrinkage) of sawn boards from plantation-grown *E. globulus* and *E. nitens* are not covered in detail here Washusen *et al.* (2007a, 2009a) provide this information for 22-year-old *E. nitens* and Washusen *et al.* (2009b provide similar information for 18-year-old *E. globulus*. Many studies have shown that there are radial (pith-to-bark) trends in these wood properties. Typically, density and stiffness increase somewhat from pith to bark (i.e. in successive years of wood production as the tree grows), as do tangential and radial wood shrinkages. It is also known that wood properties are affected by genetic variation within species, site conditions and silviculture. Therefore, comparisons of wood properties of plantation-grown and native forest timber must always be placed in context: all such comparisons must be qualified by referring to the age of the wood samples, and the origin of the samples within the tree.

Conclusions

This report examines the product quality and wood behaviour during primary processing of thinned and pruned plantation-grown *Eucalytpus globulus* and *E. nitens* grown in regimes similar to those developed by Forestry Tasmania for its eucalypt plantation estate. The results of applying conventional industry processing strategies developed for native forest ash eucalypts are examined as well as results from a series of projects designed to assess alternative but readily available strategies and equipment to process logs from these sources.

It is clear that small-diameter eucalypts (less than 40 cm small end diameter) will make up a substantial volume of logs produced from plantations like those developed by Forestry Tasmania. This review has acknowledged this and examines suitable processing strategies for such small-diameter logs.

This review of research suggests that most existing processors are poorly equipped to saw plantation-grown logs that may have smaller diameter and shorter length than their current native forest sources. Also, wood drying methods need to be altered to provide greater control over drying conditions, with careful monitoring of moisture content of boards throughout the drying process to enable accurate scheduling of steam-reconditioning treatments. Such control, coupled with improvements in sawing accuracy, should improve product recovery and quality.

Research has also produced evidence that indicates that a steam-reconditioning treatment, conducted when board mean moisture content is at 15%, will close most internal checks, improving the visual appearance of boards. Further rigorous scientific research is needed to determine the implications of closed internal and surface checks on secondary processing and final product quality.

Processing thin-section quarter-sawn boards coupled with such steam-reconditioning treatments can eliminate almost all internal checks and completely eliminate surface checks in the collapse-prone *E. nitens*. Further work is needed to see how this may be applied in practice, and how final products will be produced. Existing sawmills are inadequate for this strategy and specialised mills equipped to quarter-saw boards thinner than 15 mm and possibly as thin as 9 mm would need to be developed for logs larger than 40 cm SED. Another area for assessment is the application of sawing lines to produce flitches suitable for resawing quarter-sawn boards. Some softwood mills already have systems that may be capable of this, if log length can be reduced and log diameter increased sufficiently to eliminate flitch deflection.

Importantly, research has produced evidence that linear sawmills could substantially reduce sawing costs, giving those processors a competitive advantage over more conventional hardwood sawmills and leading to higher plantation value.

In the longer term it will be possible to reduce levels of internal checking in *E. nitens* through breeding, and to reduce sawing and drying defects due to tension wood in *E. globulus* through silviculture.

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