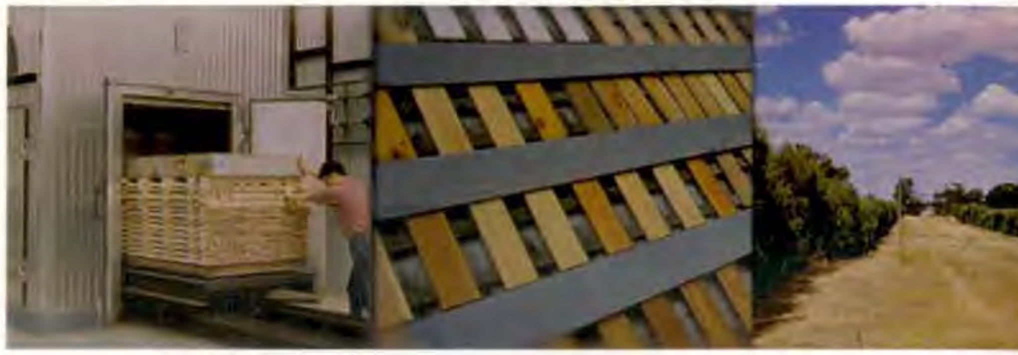

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'Shaping the Future'

A. Pollock

Victorian Private Forestry Council

This Forest Products Research Conference is the first of the 21st Century. Our proceedings start in a very different world, and the nature and expectations of all major forest stakeholders is shifting rapidly.

Forest products research until recently was conducted by a few major institutions, mostly government funded, to enhance values of traditional wood products harvested from public forests for processing by many in small isolated operations across Australia. Great work was undertaken on the variable inherent properties of native timbers, and of seeking the optimum characteristics of a few multipurpose plantations species, mostly exotic, for further value adding or value protection.

Much of this research was driven by the desire for pioneering knowledge or the basic understanding of the material formed by trees. And it has been quite successful. We have a viable and robust forest products industry, ranging from materials such as solid wood , reconstituted and fibre through to uses in high quality furniture, construction and printed packaging.

The future however is being shaped by fundamental shifts in the nature of the structure and aspirations of the owners and policy makers who see massed tree management as their domain, as well as the physical nature of the forests within the broader rural landscape.

The paper outlines likely changes in forest stewardship, the behavioural drivers determining the way forest products are perceived, and new policy frameworks set within a national context of maturing softwood plantations, reduced harvest of native hardwood forests, globalisation of commodity products and rising concerns for national safety.

Treatment of eucalypt heartwood using supercritical carbon dioxide as a carrier

A. Qader and L. Cookson

CSIRO Forestry and Forest Products, Clayton, Victoria

Introduction

Existing treatment methods do not give satisfactory penetration of preservatives into the heartwood of many hardwoods including eucalypts. The result is often a thin envelope treatment that termites might breach, allowing them access to an untreated core. As a consequence, we propose a more efficient method for treating wood with pyrethroids using supercritical fluids such as carbon dioxide as the carrier (Figure 1, also [1]).

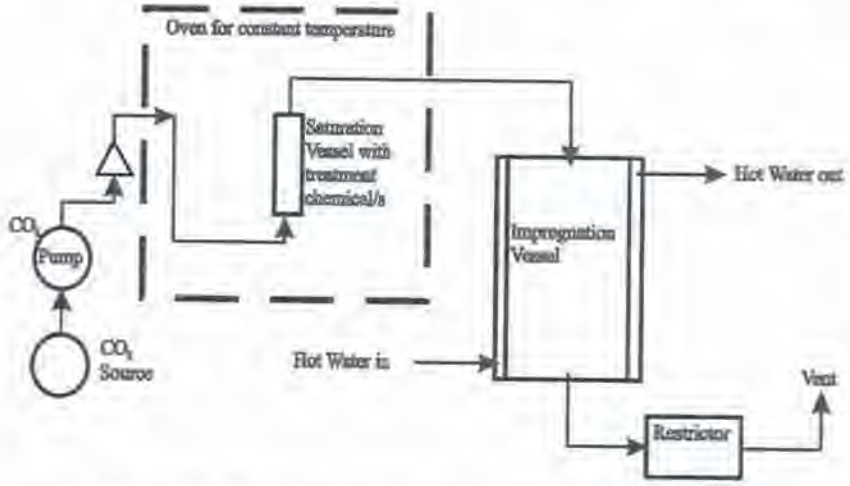

Figure 1: Schematic diagram of the experimental set up for treating timber using supercritical carbon dioxide (scCO2)

Broadleaved hardwoods produced some 1,322,000 cubic metres of timber in 1997-98 according to the Australian Forest Products Statistics (1999)[2]. With the greater emphasis in the Building Code of Australia on termite protection, a successful treatment method would improve the marketability of hardwoods for products such as flooring and framing.

In preliminary work with Eucalyptus oblique (messmate), heartwood blocks 200×35×35 mm were impregnated with permethrin dissolved in scCO2 at 200 bar pressure. After treatment, "In" and "Out" stakes, 200×10×10 mm were cut for analyses and trials (Figure 2). Two small blocks, 48×10×10 mm, were cut from the "In" and "Out" stakes for chemical analysis (A position). Two similar blocks were cut for termite bioassay (T position). Another stake 200×10×10 mm was allocated for strength testing. Untreated specimens, and specimens treated with LOSP using conventional vacuum pressure impregnation, were included for comparison.

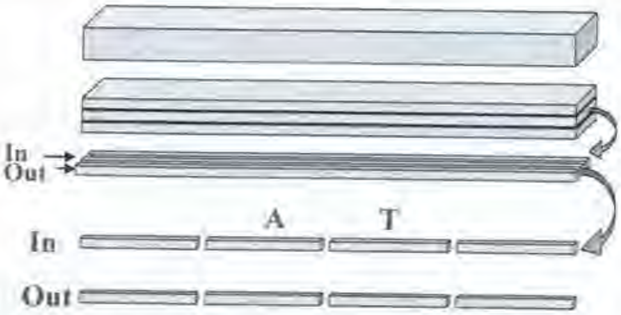

Figure 2: Cutting of specimens for various analyses

Results

Eucalyptus obliqua heartwood was successfully treated with permethrin using supercritical carbon dioxide as the solvent carrier. The specimen size used was 200×35×35 mm in accordance with the size of the pressure cylinder. Chemical analyses for permethrin using HPLC were conducted on the inner most parts of the treated samples. The mean permethrin retention obtained was 0.035% m/m oven dried wood, which is well above the required levels needed (0.02%) for H2 and H3 hazard classes. The Instron flexural tests conducted on samples cut from the blocks showed no deterioration of strength (MOR and MOE) compared to similar untreated samples or those treated by conventional vacuum-pressure impregnation. A termite bioassay using Mastotermes darwiniensis revealed that samples from treated wood were resistant to attack. Preliminary studies on blocks with sealed ends revealed some dimensional deformation due to the high pressure of supercritical fluid, indicating that the entrance of supercritical carbon dioxide is mainly through the end-grain, not the side-grain surfaces. However, the collapse can be prevented or controlled by altering process variables, such as pressure, temperature, rates of pressurisation and depressurisation etc.

Further trials are being conducted on boards up to one metre long in a larger pilot plant recently installed at CSIRO.

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Do we need the A in the CCA?

L.J. Cookson

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Introduction

Copper-chromium-arsenic (CCA) is the most widely used wood preservative in the world. Treatment plants using this preservative were first installed in Australia in the late 1950's, and since then, use has increased to about 8000 tonnes per year to produce some 800,000 m3 treated product. However, there are growing concerns about the use of CCA, resulting in restriction of use in neighbouring countries such as Indonesia and Japan, and current vigorous debate in the USA. Much of the concern is unfounded, as a number of studies have shown that CCA treated timber is safe to use with a few sensible precautions (Greaves 1997). Most attention focuses on arsenic, because the common inorganic forms are carcinogens and toxic to mammals. However, it should be noted that the arsenic (V) used in wood preservation is less toxic than trivalent arsenic, and once fixed in wood has further reacted into complex and immobilised forms. CCA plant guidelines (AS 2843.1: 2000) have addressed contamination risks from the treatment plant. However, disposal of CCA treated timber remains a problem. Accidental or misinformed disposal by fire can liberate arsine gas. Consequently, CCA-treated timber does not lend itself to simple industrial incineration due to arsenic content. The copper and chromium components collect predominantly in the ash.

This paper examines the need for arsenic, by comparing CCA with copper chromate (CC, but also often called acid copper chromate or ACC) and CCB (where boron leaches so is effectively copper chromate). Originally, arsenic was thought to be needed for insect control. However, the latest theory is that arsenic is more useful in controlling copper tolerant brown rotting fungi. CCA alternatives that lack chromium and arsenic are available in Australia (ACQ and Tanalith E). However, they are more expensive than CCA and have not yet gained widespread market share. Environmentally, they have the advantage over CC in also lacking chromium.

Discussion

Laboratory decay trials such as by Da Costa (1967) have shown that CC treated pine can be severely decayed by certain brown rot fungi. In comparison, the arsenic in CCA reduces brown rot. The same studies show that white rots are sensitive to CC. Morrell (1991) reviewed the impact of copper tolerant brown rot fungi and observed that the high degree of copper tolerance does not often translate into the field. In-ground decay trials of CC in Australia support this observation. Johnson and Thornton (1991a) described the 25 year inspection of a major preservative trial where CC in *P. radiata* performed as well as CCA (Tanalith C and Celcure A) in Sydney, and almost as well in Walpeup. In *Eucalyptus regnans* sapwood, CC was better than CCA at Sydney, and intermediate between the two CCAs at Walpeup. Furthermore, *P. radiata* stakes inspected at the PNG sites after 15.6 years (Tamblyn and Levy 1981) showed that CC and CCB were similar in performance to Tanalith C and Tanalith CA (high arsenic CCA), while Celcure A performed better than all. *P. radiata* stake tests in NZ (Hedley et al. 2000) showed CCB performing better than CCA after 20 years at three sites, but significantly worse at two sites where good soil drainage favoured brown rots. These preservatives were compared on a similar total active elements (TAE) basis, where the boron component of CCB had probably leached rapidly to leave a lower retention of 'CC'. Walters (1970) conducted a six-year trial of treated *P. radiata* in cooling towers, which provides a severe soft rot hazard (H5). He found that 'Acid copper chromate and CCB were as effective as the CCA preservatives'.

These results for decay suggest that CC is as effective as CCA when compared on a similar TAE basis, except in soils favouring brown rot. This qualifier may only apply to softwoods, which are predisposed to brown rot. Johnson and Thornton (1991b) showed that hardwoods are much more vulnerable to soft and white rot than brown rot, and these are the fungi that can be controlled with CC.

We have not compared these preservatives in the laboratory against termites. Nevertheless, after 30 years at Walpeup, CC treated *P. sylvestris* stakes performed similarly to CCA against termites (mean ratings 7.3 and 7.4 respectively on a scale of 8-0 where 8 is sound), although CC had suffered slightly more brown rot (mean ratings 5.0 and 6.3 respectively, Thornton and Johnson unpubl). Kalnins and Erickson (1986) recommend CC in beehives as effective and safer than CCA.

One of the most severe exposure conditions for wood is marine exposure (H6), where the main hazard is from marine borers, and some soft rot activity. After 25 years in the sea at Sydney and Kwinana (near Perth), CC treated *P. radiata* and *E. macrorhyncha* specimens were as good or better than Tanalith C and Celcure A when treated to 27 kg/m^3 formulation retentions (Barnacle and Cookson 1995). In a 17 year old trial in Sydney Harbour, *P. sylvestris* and *Alstonia scholaris* treated with CCA or CCB performed similarly (unpublished data), even though boron had leached.

In summary, the use of copper chromate in Australia is supported by several long-term trials. Research should determine which soils favour brown rots, as these could limit use in softwoods. More information against decay fungi in the above-ground (H3) hazard is also desirable.

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Performance of treated hardwood fences after five years

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Sawn hardwoods are difficult to protect with preservatives because they usually contain high proportions of refractory heartwood. Hardwood paling fences are generally untreated and of relatively low natural durability. The objective of this study was to investigate the performance of hardwood fencing timbers when treated with preservatives against decay, while at the same time producing an aesthetically pleasing coloured commodity. While treatments that would meet Australian Standard 1604 were not expected, it was thought that significant benefits might apply, especially to the thinly cut palings (which are often cut from the outer parts of the saw log, hence having a high content of sapwood). As a thin treatment envelope was expected, the study also investigated the problem of, and how to avoid, cutting timbers after treatment.

The timbers (posts, rails, palings, plinths) to be treated were *Eucalyptus regnans* and *E. obliqua*. They were treated unseasoned or only partially seasoned with PEC (pigment emulsified creosote, a brown pigment was used) or PROCCA (an emulsion of oil plus copper chromium arsenic) (Cookson et al., 1996). Model fences were constructed and compared to the performance of an untreated fence made from a combination of *E. regnans* and *E. obliqua* rails, plinths and palings with *E. camaldulensis* posts. Fence post stub trials were also installed in the AFS (decay) at Clayton and the field at Walpeup (decay and termites). The various trials were inspected after five years exposure.

Results

Model fences were assessed visually and the occurrence of biodegradation noted. The key findings were:

- Various components of the untreated model fence were decayed. Generally, decay was present in sections of timbers that were in close contact with other components, for example where a paling was fixed to a rail. The untreated E. obliqua plinth was heavily decayed where it was in ground contact and is now unserviceable.
- The above-ground components of the treated model fences were in very good condition, with no decay found. Slight decay due to soft rotting fungi was detected in the sections of plinths in ground contact.
- There was still good colouration to the fences (green or brown) after five years, although the brown PEC-treated fences were uneven in colour.
- Untreated *E. regnans* posts exposed in the AFS are heavily decayed and heavily attacked by termites at Walpeup. Untreated *E. obliqua* posts are still serviceable but have lost a considerable percentage of their cross-section to decay and termites.
- Against decay, untreated *E. camaldulensis* posts have performed better than most preservative-treated posts. Against termites, there is slight damage to *E. camaldulensis* posts, whereas, very few treated posts show signs of termite activity at all.

- The rate of decay was greatest in posts exposed in the AFS. Here, the mean decay ratings for PEC-treated posts were generally higher than for PROCCA-treated posts.
- Posts docked after treatment, thus removing the treated end grain, and exposed with the docked end in the soil were heavily decayed.
- Galvanised nails were in good condition in all fences, steel nails were also in good condition in PEC-treated fences but were corroded in both the untreated and PROCCA-treated fences, making them very difficult to dislodge from the rail during inspection.

Results from the five-year inspection of posts exposed at Walpeup, Clayton and in the AFS at Clayton are presented in Table 1. Ratings are based on a scale from 8-0 where 8 corresponds to no damage and 0 is destroyed. The decay hazard is moderate at Clayton and high in the AFS. Two ratings are given to posts at Walpeup where there is a moderate termite and decay hazard.

Table 1: Mean ratings (and mean depths of decay) for posts exposed in-ground 8 = sound.

Timber species	Treatment	AFS decay rating (decay mm)	Clayton decay rating (decay mm)	Walpeup decay rating (decay mm)	Walpeup termite rating
E. regnans	Untreated	1.2 (31.4)	–	5.2 (10.0)	1.2
	PEC, plain	5.8 (7.6)	–	8.0 (0)	8.0
	PEC, incised	6.2 (4.8)	7.3 (1.5)	7.8 (0.6)	8.0
	PEC, slotted	5.0 (8.8)	7.0 (2.0)	8.0 (0)	8.0
	PROCCA, plain	4.0 (13.2)	7.3 (2.3)	7.0 (3.0)	7.8
	PROCCA, incised	5.2 (9.4)	6.0 (5.3)	7.6 (1.0)	8.0
	PROCCA, slotted	5.6 (6.8)	6.75 (2.8)	7.0 (2.6)	7.8
E. obliqua	Untreated	5.4 (7.6)	–	6.2 (5.2)	5.2
	PEC, plain	6.8 (3.2)	–	7.8 (0.6)	8.0
	PEC, incised	5.6 (7.6)	6.5 (5.0)	8.0 (0)	8.0
	PEC, slotted	7.0 (2.0)	7.0 (1.3)	7.6 (1.2)	8.0
	PROCCA, plain	6.0 (6.0)	7.0 (2.3)	7.0 (3.0)	8.0
	PROCCA, incised	4.8 (11.8)	7.0 (2.0)	7.2 (2.4)	7.8
	PROCCA, slotted	4.0 (14.2)	6.3 (4.5)	7.0 (2.8)	8.0
E. camaldulensis	Untreated	6.4 (3.2)	7.0 (2.0)	7.6 (1.2)	7.0

This trial has demonstrated that low durability hardwoods used for above-ground fencing components (rails, palings and plinths) can be successfully treated to extend the service life and maintain appearance. Based on mean decay ratings after five year's exposure in the AFS, sawn treated timbers of *E. regnans* and *E. obliqua* appear to be unsuitable for long-term performance as posts.

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Acknowledgements

We would like to thank Mr Boris Iskra and the Timber Promotion Council of Victoria for their continued support and advice to this project.

Timber Mooring Pile Study after Nine Years Service

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Introduction

This trial was established in 1991 through the coordinated effort of the Queensland Port Authorities, Department of Transport and Forest Research Institute, Koppers Timber Preservation and CSIRO. It was set up in response to the conflicting performance results being experienced with treated timber in the sea where some treatments failed within five years while a few examples of others provided long service lives (Barnacle et al., 1986). This trial is unique, even by world standards, in that actual mooring piles rather than small specimens are compared. The mooring piles in trial are untreated turpentine (*Syncarpia glomulifera*) with bark on, PEC (pigment emulsified creosote) treated spotted gum (*Corymbia maculata*), CCA (copper chromium arsenic) treated spotted gum and slash pine (*Pinus elliottii*), and double treated (CCA+PEC) spotted gum, slash pine and blackbutt (*Eucalyptus pilularis*). Forty mooring piles were installed at each of three ports, and the latest inspection is after nine years exposure. Piles at Bundaberg and Cairns were inspected for marine borer attack in the tidal zone, with additional observations using underwater video. Full length inspection of the piles at Townsville occurred after they were pulled from the water. Most of the piles at Townsville have since been reinstated as fender piles.

Results

Results for the nine year inspection are provided in the table, and the key findings are:

- Marine borer attack was most severe at Townsville, and least at Bundaberg.
- E. pilularis and C. maculata piles treated with CCA and PEC (double treated) performed best, with no attack at Cairns and Bundaberg. At Townsville, nine of the 12 piles had light attack from Sphaeroma and Martesia.
- All PEC treated C. maculata and double treated P. elliottii piles at Townsville were attacked, but only lightly. Minor attack also occurred at Cairns, while at Bundaberg only one of the double treated P. elliottii piles was damaged by marine borers.
- CCA treated P. elliottii piles had most severe attack at Cairns and Townsville due to Sphaeroma in the tidal zone. Most piles had moderate Sphaeroma attack in the tidal zone, while in one pile at Cairns attack was heavier. Similar piles at Bundaberg were unattacked due to the apparent absence of Sphaeroma.
- CCA treated C. maculata piles mostly were in better condition than CCA treated P. elliottii, however, their condition was more variable. Some piles have moderate-heavy teredinid attack, which is of concern, because of the rapid rate at which these borers can destroy timber piles once established.
- All treated piles performed better than untreated turpentine piles.
- Teredinids were not found in any pile containing PEC.

The piles were given a performance rating on a scale from 0-4, where 4 is unattacked and 0 is destroyed. A score of 3.5 means light attack, 3 or 2.5 moderate or moderate-heavy attack, and 2 means heavy attack and corresponds to the time when remedial action (such as placement of physical barriers) would be advised.

Table 1: Mean rating at each test site after nine years' exposure. L, S, T, M stands for Limnoria, Sphaeroma, teredinid and Martesia attack respectively.

Timber pile	Bundaberg	Townsville	Cairns
C. maculata CCA+PEC	4.0	3.7S, 3.7M	4.0
E. pilularis CCA+PEC	4.0	3.8S, 3.7M	4.0
P. elliottii CCA+PEC	3.9M	3.5S, 3.5M	3.5S
P. elliottii CCA	4.0	2.8S, 3.5M	2.7S, 3.9T
C. maculata CCA	3.8M, 3.9T	3.3S, 3.1M, 3.3T	3.4S, 3.8M, 3.3T
C. maculata PEC	4.0	3.5S, 3.5M	3.5S, 3.9M
S. glomulifera. Nil Treatment: Sapwood portion of piles	2.2M, 2.5T, 3.8L	0S, 0M	0.9S, 1.0M, 3.3T
Heartwood portion of *S. glomulifera* piles	3.3M	2.2S, 2.3M, 3.8T	2.9S, 3.0M,

This trial has revealed some pile types as inadequate for Queensland conditions. To make reliable distinctions between the other best four piling types (double treated *C. maculata*, double treated *E. pilularis,* double treated *P. elliottii*, and PEC treated *C. maculata*), continued monitoring is required. The results obtained will help develop H6 marine specifications located in Australian Standard 1604 Part 1. The piles are also being used as part of a long term study on the environmental fate of wood preservatives in the sea (Cookson et al., 1996).

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Acknowledgements

We appreciate the assistance of the Queensland Department of Transport and the respective Port Authorities during inspections.

LOSP treatment of I-beams and their evaluation against termites

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Composite timbers represent an increasing proportion of structural materials used in buildings. To maximise performance in service as structural elements within buildings in Australia these materials should be protected from termite attack. Wood composites, including timber I-beams, are often difficult to treat with preservatives due to the impermeable nature of the glue bonds and the amount of heartwood present. Accordingly, satisfying the current treatment specifications outlined for solid wood in Australian Standard 1604.1-2000[1] is often difficult. New standards are currently being developed for the preservative treatment of wood composites; however, more information on the performance of treated wood composites is required.

This work evaluated the capability of a light organic solvent preservative (LOSP) treatment containing permethrin to penetrate the OSB webbing and LVL flanges of Douglas-fir I-beams at retentions suitable for Hazard Class H2 (inside, above-ground) of AS 1604.1-2000. In addition, the ability of the preservative treatment to protect I-beams against two species of subterranean termites was evaluated in the field.

Treatment and chemical analysis

Twenty I-beam samples, one metre long, were supplied by Tilling Timber Pty. Ltd. Ten of the I-beams were treated with an LOSP, containing permethrin at 0.52 kg/200 L (0.34% m/m). The remainder were left untreated for use as untreated controls in the termite field trial.

After treatment and air-drying, all I-beams were docked to leave a 200 mm central biscuit. The central biscuit was then cut into two pieces. A 120 mm piece was put aside for the above-ground termite field trial, while the remaining 80 mm piece was available for chemical analysis. A random selection of five of the ten 80 mm pieces of treated I-beam was further cut. The LVL flanges were cut from the webbing and each piece sectioned according to the sampling diagram in Figure 1. Six samples, numbered as indicated, were cut from each of the five I-beams.

The screened samples were then analysed for permethrin using a methanol extraction technique where the extract was analysed using HPLC (Qader 2000[2]).

Australian Standard 1604.1-2000 specifies a minimum permethrin retention of 0.020 % m/m (mass of preservative per the oven-dried mass of treated wood) in the penetrated zone for Hazard Class H2 (inside, above-ground). With the exception of only one sample, all were above the retention requirement for H2. As expected, the retentions in the LVL flanges and OSB webbing decreased markedly as the sampling point depth from the treated surface increased. However, the mean permethrin retentions still met the requirement of H2 despite this reduction. The OSB webbing appears to be easier to penetrate than the LVL flanges, as higher permethrin retentions were detected in these samples.

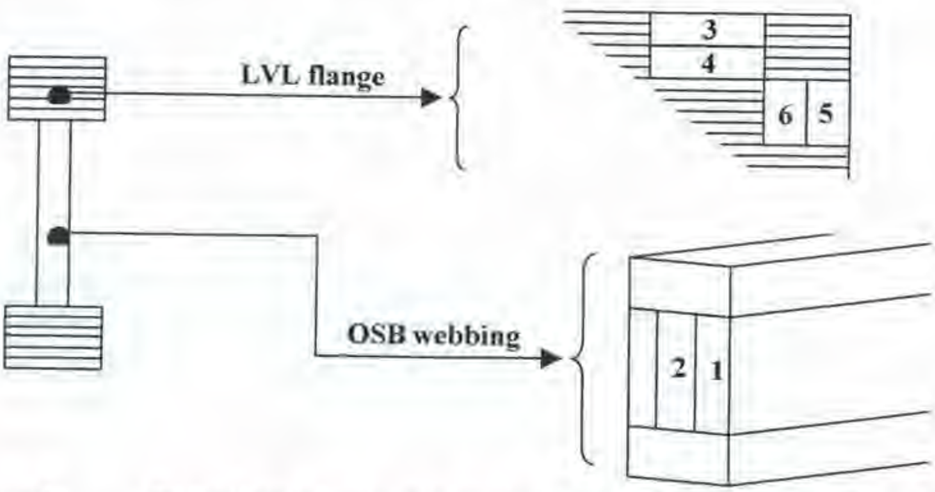

Figure 1: Sampling diagram of treated I-beam for permethrin analysis

Above ground termite trial

The freshly docked ends of the 120 mm long specimens cut from near the centre of both treated and untreated I-beams were sealed with hot melt glue and aluminium flashing, to prevent the entry of termites via surfaces exposed after treatment. The 20 specimens were then dried in vacuum ovens at 40°C and −95 kPa for five days to remove any residual solvent and volatiles.

Specimens were exposed to two species of subterranean termites, *Coptotermes acinaciformis* and *Mastotermes darwiniensis* in a field trial emulating H2 exposure conditions. The trial utilised a 20 L steel drum containing one treated and one untreated I-beam specimen. Susceptible timber substrate was then placed around and on top of the test specimens to attract termites into the drum as well as maintain their presence for the duration of the trial. After 15 weeks the termites had consumed all available susceptible substrate and retreated from the drum. Both treated and untreated I-beam test specimens were then cleaned and assessed visually for signs of damage due to termite attack.

All treated I-beam specimens exposed to *C. acinaciformis* in the above-ground field trial were unattacked. Four of the five untreated control specimens were substantially attacked with more than 80% wood consumption. The fifth specimen was attacked to a lesser extent due to the presence of predatory ants within the drum.

Four of the five treated I-beams suffered superficial attack when exposed to the more voracious *M. darwiniensis* in the field. The corresponding untreated control specimens were substantially attacked. The fifth treated specimen was more heavily attacked with approximately 20% consumption of the flanges and some minor attack in the webbing. Its untreated counterpart was totally consumed.

The results have shown that I-beams made from Douglas-fir can be successfully protected from termite attack by LOSP treatment with permethrin.

Acknowledgement

We wish to thank Craig Kay of Tilling Timber Pty. Ltd. for supporting this work.

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Reconstituted wood products - adding value to the resource

G.A. Sanderson

Ausply Pty Ltd, Wagga Wagga

The development of Reconstituted Wood Products culminating in modern Engineered Wood Products is traced with particular reference to the influences of factors such as the decreasing availability of old growth forest, the development of adhesives and the purely economic aspects, both in manufacturing as well as the aspects of changing on site construction methods.

The extraordinary growth of those products is discussed in the light of the rapid way in which large section solid sawn timber has given way to LVL and I-beams once successful specifier/user education was implemented.

The performance and cost of long fibre composites like LVL is compared with short element products like Tim strand.

The potential for New Composite Wood Products as structural elements for the construction industry is developed having regard to predicted resource availability, required performance criteria and developing manufacturing techniques.

The use of plantation eucalypts in Oriented Strandboard

G. Freischmidt

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Introduction

Australia is moving towards the use of new raw material sources for re-constituted wood-based composites. Future wood resources are likely to be dominated by plantation grown hardwoods, particularly eucalypts. These will typically be fast-grown and young at harvest (less than 10 years of age). Whilst they could be chipped for use as a feedstock for paper production, there are other approaches to utilising such resources which could add value. The manufacture of re-constituted wood-based panels such as oriented strandboard (OSB) is one option.

OSB evolved in North America from a need to make use of small diameter 'weed trees', primarily aspen, which were being cleared to make way for land development in the 1960s. The first product developed was 'waferboard', which proved to be highly successful as a low cost cladding material. By the early 1980s the production process had been developed to facilitate the manufacture of panels with wood 'strands' oriented in cross-directional layers, similar to the arrangement of successive veneers in plywood. Today over 18 million m3 of OSB is produced annually in North America in 60 mills, with around 70% being used in residential construction. Other uses include: packing crates, pallets, furniture, shelving, construction barriers and the webbing component of I-joists.

OSB represents one form of reconstituted wood product in which Australia is well placed to export to South-East Asia and Japan. The region is expanding its use of wood-based panel products and some countries are in need of low cost housing and low cost building materials. The growth in demand for OSB in the Asia-Pacific region is projected to be 25% in the decade 1998-20081, albeit from a low base. This paper looks at some of the commercial background and technical issues in producing OSB from young plantation eucalypts.

Eucalypt OSB

The CSIRO Forest Products Laboratory has been assessing a wide range of eucalypt species as raw materials for OSB. Results have been promising. Optimum flaking conditions for different species of varying densities have been found using a pilot-scale flaker. Log conditioning prior to flaking was found to give the best results in terms of strand flatness and minimisation of fines production. Examples of flakes produced from (a) green logs at room temperature and (b) conditioned logs with core temperatures of 70°C are shown in Figure 1.

(a) (b)

Figure 1: Examples of flakes produced from (a) green logs at room temperature and (b) logs conditioned at 70°C. White bar scale = 10 cm.

Panel fabrication and testing

OSB flakes were resinated with liquid phenolic resin at an 8% loading. Panels were made by randomly laying-up flakes in a perform box (45×45 cm) followed by hot pressing between Teflon film and aluminium caul plates for 300 seconds at 200°C. The target panel thickness was 12 mm. The mechanical and physical properties of OSB from selected eucalypt species are shown in Table 1 and compared to Canadian Standard 0437[2].

Table 1: Mechanical and physical properties of OSB from selected eucalypt species.

Species	Whole Panel Density (kg/m^3)	MOE (GPa)	MOR (MPa)	Thickness Swell (%)	Internal Bond Strength (kPa)
E. viminalis	733 (7)	4.04 (0.69)	25.68 (5.03)	20.0 (1.4)	406 (123*)
E. nitens	787 (3)	4.44 (0.79)	28.30 (6.19)	14.6 (2.8)	646 (131)
E. kartzoffiana	759 (8)	4.93 (0.35)	29.76 (3.03)	12.5 (2)	671 (187)
E. macarthurii	771 (1)	5.11 (0.31)	32.34 (6.66)	17.2 (3.5)	575 (162)
Canadian Standard – 0437	-	3.10	17.00	15.00	345

*standard deviation

The flexural strength, stiffness and internal bond strength of eucalypt OSB met the requirements of the Canadian Standard. However, further work is needed to reduce the high thickness swell of some panels. Resin selection and pressing schedules have been identified as requiring more detailed study to meet improved performance levels.

Acknowledgements

The financial support of JVAP, NHT and CALM is gratefully acknowledged as are the contributions from S. Terrill, A. Pereira, M. Reilly and P.J. Collins from CSIRO Forestry and Forest Products.

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Degradation of wood dyes on exposure to ultra-violet light

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There is a great market potential for dyed eucalypt veneers in decorative wood products such as furniture, joinery and architectural products. However, the stability of the colour and resistance to fading of these veneers to UV light has not been researched.

The resistance of the dyed veneers to UV light was evaluated on both raw and coated veneers in order to determine the degree of UV resistance of various lacquers and to compare their performance.

This study aimed to:

- determine whether there is an association between UV light exposure and discolouration/fading of dyed veneer products,
- compare the UV resistance of typical furniture coatings
- determine the protective effect of the coating that allows minimum colour change.

The test material used for the evaluation consisted of MDF panels laminated with dyed Tasmanian Oak veneers, quarter cut, with two different colours of dyes. Precatalysed, acid-catalysed and polyurethane lacquer were selected as typical protective finishes.

The samples were exposed to both natural and artificial UV light. The samples exposed to the natural UV light were placed in greenhouse conditions. The samples exposed to an artificial UV light were placed in a chamber with the UV fluorescent lamps to accelerate any discolouration/fading process. The exposure apparatus was constructed according to AS/NZS 1580.483 – 1994[1].

The samples were examined every two weeks for three months using a Microflash Spectrophotometer, a dual-beam spectral measuring portable instrument with CHROMA-QC software for data analysis.

Visual examination of tested samples revealed significant colour changes in the dyed veneers exposed to both natural and artificial UV light. The changes were already visible after two first weeks of UV exposure. The intensity of the colour changes increased during the subsequent testing.

It was observed that the samples of veneers dyed with dark brown dye (Dye 2) suffered more severe colour changes than the veneers dyed with the light brown dye (Dye 1). Both coated and uncoated samples showed signs of the colour changes.

It was observed that the changes in the samples exposed to sunlight were most severe in uncoated samples followed by the samples coated with precatalysed lacquer, acid-catalysed lacquer and polyurethane lacquer. This result was obtained on the veneer samples dyed with both types of dyes.

The colour changes in the samples exposed to artificial UV light were more severe than in the samples exposed to natural light. However, it appeared that the changes in coated and uncoated samples were different from the samples exposed to sunlight. The Dye 2 samples followed a similar sequence to the sunlight samples but the Dye 1 samples performed quite differently. The colour changes in these Dye 1 samples were more severe in coated samples than in the uncoated samples. The samples most affected by the colour changes were the ones coated with acid-catalysed lacquer, followed by precatalysed lacquer and polyurethane lacquer.

The results of the analysis of colour changes using the spectrophotometer confirmed the results of the visual observation. However, they provided quantified data. The samples of veneers dyed with light brown dye (Dye 1) exposed to both sunlight and UV light suffered more severe colour changes than the veneers dyed with the dark brown dye.

The high values of the total colour changes for both types of dyes indicate that even these widely used chemically based dyes will change their colour when exposed to natural sunlight. Therefore they should be used with understanding of this natural characteristics of artificial colouring of wood products. UV inhibiting lacquers may reduce this effect.

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Generating success by applying good science

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The timber products industry in Australia currently faces possibly its greatest challenge yet as it prepares to move from being a relatively complacent domestic industry to a highly competitive international industry.

The challenges that come with this transition reflect not only the changing domestic environment but also the more uncertain dynamics of the global market.

The future of the industry is highly dependent on a continued significant focus on research. It is important that the whole of the timber products industry contribute significantly to funding this research, but in doing so it must be capable of determining the focus and direction of such research.

Whilst the timber products industry in Australia is currently well supported by a number of centres of scientific excellence, there is still asignificant discrepancy between developing good science and transferring technology to the industry.

Portable sawmills and high-density timber

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Introduction

Following work by Washusen[1] and Stewart[2] there was questions raised about the timbers from the lower rainfall areas and the ability for the economical conversion into high value timber.

Portable saw mills were seen as a possible solution to overcome the viability of processing small volumes of timber. Some questions have been raised about the ability of a portable sawmill to produce accurately sized timber[2].

This project scientifically examined some of the factors that effects the sawing of timber and the use of portable mills using 4 high density hardwood species from Western Victoria

- *E. astringents* – Brown mallet
- *E. cladocalyx* – Sugar Gum
- *E. leucoxylon* – Yellow Gum
- *E occidentalis* – Swamp Yate

Portable circular saw mills

A Lucas Mill was used as a representative of the circular saw type of portable mills. These types of mill have the log placed on bearers on the ground and the saw blade and motor are on a frame which moves over the log. They have the ability to saw with the blade in the vertical orientation on the forward cut and then be swung to the horizontal orientation for the return cut.

The blades were 5-tooth with a carbide tip. Four different tip width (4.5, 5.0, 5.4 and 5.7 mm) blades were trailed in the various species.

Horizontal bandsaw mills

A Wood Mizer L15 and a Laidlaw Farmill were used for the evaluation of the Bandsaw type mills. Blade parameters were trialled to determine the configuration of hook, set and tension that would produce the straightest cut in *E. cladocalyx*.

Each of the 4 species was sawn with blades of 2 widths (32 and 50 mm) and of 3 different compositions (carbon steel, bimetal and carbide tipped) to determine which blades would saw the straightest.

Straightness of cut

The 5.0 and 5.7 mm wide blades produced significantly straighter cuts than the other width blades over all the species trialed.

The blade orientation was show to be significant when sawing in the different species. Cuts in the vertical orientation where straighter than those in the horizontal orientation (Table 1)

Table 1: Number of 150 mm cuts by Species and saw orientation that are within or out side the 1.5 mm deviation tolerance.

Species	Blade orientation	Less than 1.5 mm	Greater than 1.5 mm
Brown Mallet	Horizontal	14	10
	Vertical	23	1
Sugar Gum	Horizontal	12	12
	Vertical	24	0
Yellow Gum	Horizontal	10	14
	Vertical	23	1
Swamp Yate	Horizontal	16	8
	Vertical	23	1

The horizontal bandsaw when using the 32 mm bimetal, 50 mm bimetal and 32 mm carbide tip blades produced significantly straighter cuts than with the other 3 blades

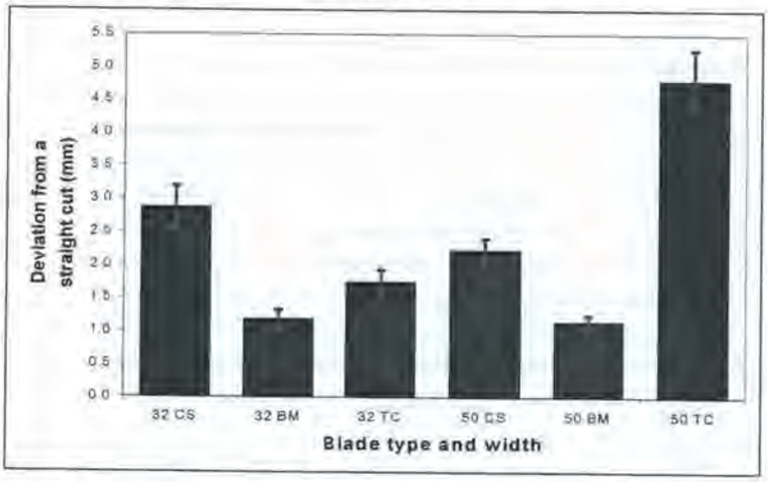

Figure 1: Mean deviation of all cuts by blade width and type. Bars are standard error.

Both type of portable mills have the ability to saw high density timber to equal or better than the Australian Standards require.

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Economics of portable sawmills

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Four types of portable sawmill and 1 relocatable mill (a total of about 40 mills altogether) were investigated for economic and operational performance. The cost of a mill was found to be strongly linearly related to the degree of automation in the mill. However, level of automation did not necessarily translate as closely into sawn productivity which was effected by other factors such as log quality and operator technique.

An economic model was developed for each of the 4 types of protable mill based on prices and costs applying to portable mill operations. The model examined the volume of softwood and hardwood timber required to break even on a portable milling investment. In each case, a smaller volume of hardwood was required. Sensitivity testing of 7 variables on the model showed that price received for sawn timber was the most important wheras distance to the market was least important. These results suggest there is a role for portable mills in handling small volumes of potentially high value timber and that remoteness from key markets is not critical.

The potential of four eucalypt species to produce high-value solid-wood products when grown in low rainfall regions of southern Australia

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Objective

To assist farm forestry growers select species for high-quality solid-wood production in lower rainfall areas by evaluating the potential of four species of plantation grown trees to produce high value solid-wood products.

Experimental detail

Field inspections of existing plantations in the 400-600 mm rainfall zone of the southern Murray-Darling Basin were conducted to establish the most appropriate species for the study. Growth and form were the main considerations. To examine the species potential for producing appearance grade timber, green product recoveries and drying performance were evaluated. Ten logs of each of 4 species were back-sawn to maximize the recovery of nominal 100 mm wide by 43 mm thick products for the drying performance study. A sawing strategy common to different sized logs was adopted. Comparisons were made with other product recovery studies conducted by CSIRO Forestry and Forest Products[1], which used similar sawing and product evaluation methods.

Results and discussion

The limited range of species and number of plantations with enough trees of sufficient size for sawlog assessment restricted the choice of species. The species selected for the sawing study were *Eucalyptus occidentalis*, *E. cladocalyx*, *E. astringens* and *E. leucoxylon*. In all the plantations inspected, low crown breaks limited the length of the logs that could be harvested from the trees to a 3 m butt log.

Using CSIRO developed appearance grading rules[2], the recovery of green appearance grade products (measured either as Appearance recovery – select grade and better, or Target recovery – cover grade and better) from the sampled trees was poor and highlights the difficulties of growing high-value sawlogs in this region.

Table 1: Appearance and sawn recoveries.

Species		Appearance Recovery	Target Recovery	Sawn Recovery
		(% of log volume)		
E. occidentalis (Swamp Yate)	42 y.o.	5.2	14.0	43.0
E. cladocalyx (Sugar Gum)	29 y.o.	1.0	18.1	40.0
E. astringens (Brown Mallet)	41 y.o.	8.1	22.9	39.9
E. leucoxylon (Yellow Gum)	44 y.o.	0.9	7.4	35.9

The major defects, in varying degrees for each species, contributing to the poor recoveries were decay, pith, knots (both green and dead) and wane. The poor recoveries were partially attributable to the small diameter logs sampled in this study. This is best shown by comparing the low appearance recovery for the 29 year-old *E. cladocalyx* (1.0%), with that achieved from the comparable 3m long butt logs of older (40 y.o.) and larger trees of the same species (20.6%) in a previous study[1].

Using a conservative air-drying schedule, in the absence of other defects, 15% of the dried boards had surface checks that would have limited them to below select grade.

Conclusions

Despite the poor recovery of appearance products in this study, the review of growth data and the good recovery in the previous study[1] suggests that *E. cladocalyx* has the best potential for producing high-value solid-wood products in the lower rainfall zones. *E. occidentalis* and *E. astringens* followed closely behind providing form and branching characteristics can be improved in the latter two species. *E. leucoxylon* has little potential unless significant form improvements could be made.

For a viable solid wood industry to be established green recoveries of appearance products (select grade and better) of at least 30-35% (of log volume) are likely to be required. To achieve this a minimum diameter at breast height (DBH) of 40cm is necessary to obtain a reasonable volume of clear outer heartwood. Trees of this diameter are likely to take at least 40 years to grow in this region.

These results highlight the critical importance of improved genetic stock and appropriate silviculture to grow high-value sawlogs in this region. To achieve this organisations such as the Australian Low Rainfall Tree Improvement Group (ALRTIG) are vital. Silvicultural practices in low rainfall regions should allow for wide spacings to minimise competition and maximise diameter growth.

This study is the first step in utilising low rainfall tree species for high-value solid wood products. Much more work is needed to characterise the wood properties and product potential of these species. Further work is also required to develop pre-drying practices and schedules to reduce drying times, while keeping surface checking within reasonable limits. Species properties such as colour, hardness, stiffness and stability require investigation so that the market opportunities and acceptability of these properties, including acceptable variability, can be tested.

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The application of native forest processing strategies for the production of high-quality appearance grade timber from plantation-grown *Eucalyptus nitens* (Deane & Maiden)

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Introduction

In southern Australia an impediment to the development of plantation forestry for production of high-quality solid timber is the lack of confidence in the existing hardwood industry in processing of plantation-grown trees. This situation is not surprising as few results are available from timber processing trials. Despite this considerable plantation development is underway and one of the species being grown is *Eucalyptus nitens*. There has been some CSIRO-FFP evaluation of back-sawn products from plantation-grown *E. nitens* over recent years. In two of these studies Waugh and Yang[1] examined unpruned 27-36 year-old trees from the Central Highlands, while Reid and Washusen[2] examined intensively managed 10 year-old pruned trees from the Otways. In the latter study, the potential for high recoveries was clearly demonstrated in pruned logs even though the relationship between recovery and log diameter showed that greater recoveries could be achieved in older trees. However, in both studies, surface checking was a significant source of degrade. The reason that back-sawing was the chosen processing option in both trials was the small diameter of the saw logs. However, in intensively managed stands, large diameter logs can be grown relatively quickly[2] and quarter-sawing strategies can be considered.

Currently large diameter (>40.0 cm mid diameter) logs from native forest regrowth *E. nitens* are being processed by the hardwood industry. Because of the problems with surface checking, which is a major problem even in older regrowth, quarter-sawing and drying strategies are used by industry. These strategies produce 25 mm thick slabs that are air and kiln-dried to stabilize the timber before re-sawing to final product width. These high-quality products of varying length and width are finding widespread market acceptance. The success of this strategy suggests similar results may be possible in much younger plantation-grown logs. This paper reports the results of a preliminary evaluation of such plantation-grown material using the existing processing methods.

The plantation, processing methods and timber grading

The plantation selected for study was located near Running Creek in North East Victoria. The trees were 33-34 years old at harvest. By current standards the establishment and management was poor. The trees were not pruned and the stand was not thinned. The tree diameters were usually less than 40 cm DBHOB. Despite the small diameter, ten straight, vertical and dominant trees were selected for harvest. This selection method aimed to compensate for the lack of a thinning where smaller and/or poor formed trees would normally be culled.

The logs were transported to the Ryan and McNulty sawmill at Benalla and processed in a conventional sawmill using a quarter-sawing strategy to produce 25 mm thick slabs. The slabs were racked out in early December 2000, and air-dried initially in an open shed in the timber handing yard without any special protective covering. Some parts of the stack were exposed to direct sunlight. Ambient conditions varied in the early stages of drying and were at times very harsh with daytime temperatures occasionally exceeding 40°C. Drying in the early stages was rapid and some collapse was evident. After a period of about one month, the stack was shifted and placed in the mill yard still without protective covering. In April 2001 the timber was below fibre saturation point and it was reconditioned and kiln dried to final moisture content.

Defects were docked to meet specific market requirements and the timber graded with the CSIRO-FFP Appearance Assessment Criteria[3] and the Australian Standard AS 2796-1985. The recoveries of select grade differ between the two grading methods. The former was applied so comparisons could be made with earlier studies and grades to select grade on the face and two edges and stipulates a minimum length of 2.4 m. The Australian Standard was applied to grade the face, back and edges to select grade and the minimum length was 0.9 m. This latter method is the usual grading method employed by the mill.

Results, discussion and conclusions

The dried recovery results are reported in Washusen and McCormick[4] and were good considering that the mean diameter for the logs was only 32.4 cm. The maximum recovery from an individual log of select grade using AS 2796-1985 was very high at 25.7% of log volume and the mean recovery of select grade and better was 20.4% of log volume using the CSIRO criteria. In addition 58% of the final sawn outturn was select grade (CSIRO criteria). These recoveries are similar to what would be expected from much older native forest regrowth of similar diameter. The good results were partly attributed to the tree selection process that eliminated poor formed trees and trees that displayed poor branch shedding.

However, the results were also due to the very good drying performance. There was little surface checking, no internal checking and distortion was usually within the allowances for select grade. The very good drying results suggest that the quarter-sawing strategy should be tested in younger plantation grown trees of both *E. nitens* and *E. globulus*. If the results in the present study can be repeated in younger trees, and drying degrade reduced to negligible levels, then the results reported by Reid and Washusen[2] suggest that recoveries of select grade products from pruned large diameter logs could exceed 80% of the sawn outturn in rotations of 15 to 25 years.

The results of this study leave the door open for processing of plantation grown trees by the existing hardwood industry using industry practices that have widespread market acceptance. However, to further assist plantation development in southern Australia it would be desirable to determine the optimum silvicultural regime (in terms of both log volume/quality and economic returns) for the production of sawlogs from pruned and certified stands on a range of sites and distance from markets. Also the compatibility of younger plantation material to be marketed with native forest regrowth should be assessed.

Acknowledgements

Due acknowledgment is given to the staff at the Ryan and McNulty sawmill in Benalla particularly Mr Greg McNulty who carried a large part of the cost of this study. Also to Ms Philippa Noble of NRE and Mr Bernie Evans of Plantations North East who provided some funding.

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The development and simulation of a mathematical model for drying timber in a solar kiln

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Introduction

The performance of a solar kiln depends on a number of factors, namely: kiln design, wood species, weather conditions, drying conditions and kiln control. There are several reasons for studying solar kilns through a combination of mathematical modelling and experiments. First, the energy efficiency of solar kilns may be improved. Traditional design methods based on trial and error and on past experience involve considerable time, money and pilot plants to repeat the small-scale testing stage sufficiently [1]. In addition, the variability in solar energy inputs (due to cloudy days, for example) and timber properties can be quantified consistently in a mathematical model, enabling the operation of a solar kiln to be improved. The operation can be improved by adjusting the air circulation during day and/or night, and venting strategies by controlling the amount of air and frequency of venting, and by avoiding ineffective venting, e.g. venting is not allowed when the ambient humidity is higher than the internal humidity of the kiln. The aim of this study is to assess the performance of solar kilns to make the drying behaviour more predictable using a modelling and simulation approach. The understanding of the heat and mass transfer processes in and around a solar-heated kiln for drying timber would help to test a complete solar kiln model. This model can be used to improve the efficiency and operation of a solar kiln.

Materials and Methods

This research has improved an existing mathematical model for energy flows around a solar kiln [2], has combined it with a product-drying model and is validating an overall complete system model (distributed dynamic mathematical model) for solar kilns. The energy flow model is a set of first-order ordinary differential equations, developed from unsteady-state energy balances for each element of the solar kiln. All the possible heat-transfer mechanisms present here such as convection and radiation are considered in this model. The product model consists of a wood drying model and a stress model. The wood drying model is based on Fickian diffusion and predicts the drying time (which is a measure of the productivity), as well as supplying the temperature and moisture content profiles that are inputs for the stress model. The stress model is based on the mechanical properties of timber and indicates the product quality measure, i.e. the output is stress and strain developed during drying. The stress and strain can exceed the limiting failure strain if the drying rate is too fast for a particular timber species, causing the timber to crack. All the inputs and outputs have been measured experimentally for validating this model.

Results and Discussion

The thickness of timber board is an important variable that requires assessment in a drying kiln. The typical simulated result for drying boards with different thickness is shown in Figure 1.

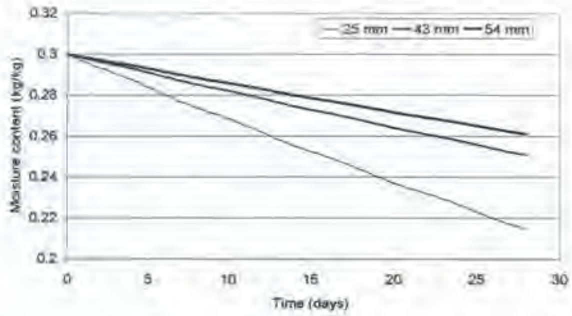

Figure 1: Prediction of drying time for 25, 43 and 54 mm thick blackbutt boards for the month of January.

This assessment showed that the board thickness has a significant influence on the drying time. The final moisture contents were 0.21, 0.25 and 0.26 kg kg^{-1} for 25 mm, 43 mm and 54 mm thick green blackbutt boards, respectively, from an initial moisture content of 0.30 kg kg^{-1} (Figure 1) after 28 days. This means that the drying rates were 42% and 54% higher for 43 mm and 54 mm thick boards, respectively, compared with the drying rate of 25 mm boards. For this simulation, there was no additional heat used and the fans were assumed to be running only during day times. The effect of other variables and parameters, such as the effects of continuous fan operation, air-flow speed, venting amount and frequency, water spraying for controlling humidity, drying schedules, timber properties, kiln design variables, geographical location, external weather conditions, all can also be assessed with this model for drying Australian hardwoods in a solar kiln.

Acknowledgements

The authors would like to thank Boral Timber and the Department of Chemical Engineering, University of Sydney for their financial support.

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Controlled drying of eucalypt timber

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Eucalypt plantations are being established at an increasing rate in Australia and worldwide for wood products, carbon sequestration and other environmental benefits. *Eucalyptus nitens* and *E. globulus* plantations are primarily established to supply pulpwood for paper manufacturing. As available resources of old-growth and re-growth natural hardwood forests are increasingly reduced, these eucalypt plantations may provide a source of sawn timber. Exploratory studies[1,2,3] have indicated that there are difficulties in processing timber from these two species for solid wood products, particularly with drying degrade. Effective and economical drying processes are vital before these emerging hardwood resources can be utilized for high value products. Better techniques are needed for assessing the development of degrade while conducting drying research, as traditional techniques are destructive and time-consuming. Surface checking in the early stages of drying is a problem with both of these species, and also with regrowth Ash eucalypts, limiting the severity of drying conditions and hence the drying rate that can be used.

Drying tests were conducted with timber from 13 year-old plantation-grown *Eucalyptus nitens* and *E. globulus*, to determine shrinkage and drying degrade of tangential (back)- and radial (quarter)-sawn boards. The tests were designed to assess the feasibility of using non-contact measurement of the shape of timber during drying to monitor drying progress and stress development, particularly during the critical early stages of drying. The objective was to identify techniques that could be used to develop fast and economical drying practices that would minimise drying degrade. Figure 1 shows details of the specimen preparation.

The eucalypt species investigated exhibited a high level of collapse that was difficult to distinguish from normal shrinkage and confounded the results. Nevertheless some useful conclusions about the potential for these techniques to indicate drying stress in plantation grown *Eucalyptus* were drawn from the qualitative work undertaken:

- Cup measurements on a half-thickness board[4], sealed on one face, provided a qualitative indication of stress reversal. This was confirmed with stress prongs.
- Width of an artificial check[5] did not provide a useful indication of the development of stress.
- Transverse surface shrinkage measured across specimens[6] and across a fixed core did not provide a useful indication of the development of stress.
- Cup measurements and stress prongs indicated transverse strains at the surface while surface moisture content was still above fibre-saturation.

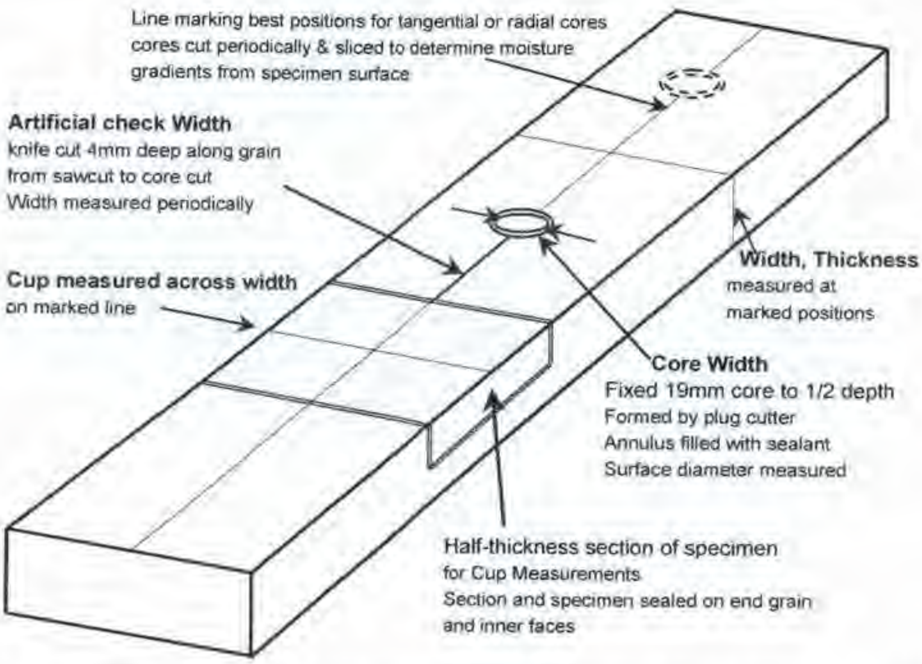

Figure 1: Specimen for periodical measurement of Cup, Check Width, Core Shrinkage and determination of moisture gradients.

Non-contact measurement of shape change during drying showed some potential for indicating drying stress but needs high resolution scanning and special image analysis techniques to be developed. Optical profiling and image analysis may be useful in the development of a kiln control system based on material behaviour.

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QFRI exotic and hoop pine wood quality research.

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B CRC for Sustainable Production Forestry

Background

QFRI wood quality research initiatives are outlined to provide an insight into coniferous plantation research directions in Queensland. Wood quality research has emerged as a high priority for both forest growers and processors. Economists are encouraging growers to significantly reduce rotation lengths; from 28-30 years to around 20 years for exotic *Pinus* species, and from over 50 years to less than 40 years in *Araucaria*, to improve the returns from these plantations. The forest processing industry is interested in the silviculture being employed in these reduced rotations and its implications for the wood quality of their products.

In 1999, QFRI became a research institute under the umbrella of the Queensland Department of Primary Industries' Agency for Food and Fibre Science (AFFS). However, most of its pine research program is funded under agreements with DPI Forestry (DPIF), with inputs from and contributions to the CRC for Sustainable Production Forestry (SPF), and with significant inputs from the Forestry and Wood Products Research and Development Corporation (FWPRDC) and processing industry collaborations. QFRI's Forest Products Program is positioning itself to further develop these partnerships to achieve improved plantation quality for both growers and processors.

Genetics and tree improvement

Genetic parameters for density and spiral grain in twelve-year-old slash X Caribbean pine F_1 hybrids and their parental taxa have been estimated by ANU FWPRDC PhD student, Dominic Kain. These will be used to review estimates used in selection indices developed from an FWPRDC funded breeding objectives and selection index project conducted in 1996-2000. **MaxDeploy** is a software tool developed as a significant component of this selection index project. It has been upgraded with CRC SPF and other collaborative funding. It enables the comparison of gains available from the application of assessment resources to different traits, at different selection intensities, to select clones in a multi-staged screening process. This allows for the differences in cost needed to conduct growth trait, compared to wood property, assessments to be accommodated when assessing the merits of screening for various traits.

Screening of priority breeding parents for wood properties in both exotic and hoop pine will be undertaken by sampling ramets in clone banks and seed orchards. The resources needed to estimate breeding values of parents is impractical due to age and site differences among the ortets, which is complicated further by incomplete representation of their progenies over a range of sites in progeny tests of differing ages. This strategy of sampling ramets will provide a ranking of parents while minimising the need for broad sampling of site populations to provide for site correction factors. It will provide direct comparisons among significant numbers of parents cloned on the same sites, established at the same time by grafting either in clone banks or seed orchards.

Screening clonal tests for wood quality is a high priority to select an elite pool of clones for use in the deployment population, which DPIF will use for its entire planting program in SE Queensland from 2002 onwards. This screening activity focuses on classifying the early juvenile wood characteristics of clones to assess their potential to be used in shortened rotations without compromising current wood quality yield expectations.

Silviculture

Impacts of ex-pasture sites on exotic pine wood density are being investigated in line with reports from New Zealand and Western Australia that significant decreases in average wood density can occur on these sites.

Impact of reducing hoop pine rotation length is being assessed with FWPRDC support for the Arakaria Australia Group (AAG) to provide broader options for hoop plantation management. Early felling of some of the currently maturing plantation would increase the deployment rate of more productive and better quality improved hoop pine families.

Nutrition

Resin defect incidence in southern pines results in significant loss of recovery for both structural and appearance grade products. Preliminary studies have provided encouraging evidence of possible links to nutrition and trace element availability. A program of research is being planned to prove these links and then determine what remedial actions can be taken to minimise the amount of resin defect in Queensland plantations.

Modelling

Wood property and branch architecture modelling to support decision support tool development with the CRC SPF has commenced. A conversion model is planned as part of a comprehensive decision support project and this will require models for within-stem variation of wood density and microfibrillar angle, in combination with branch architecture to assign knot locations and sizes, to predict wood stiffness. Microfibrillar angle and spiral grain models will also be required to predict distortion in sawn wood products.

Virtual Mill is a software tool developed as part of the FWPRDC breeding objectives and selection criteria project (1996-2000). It estimates graded product proportions and value from the assessment of a few key standing tree traits and then uses the models developed for the FWPRDC project to predict grade recovery of structural timber. There is considerable interest from the sawmilling industry to broaden the predictive capacity of this tool and/or to investigate other methods of characterising the potential for quality recovery from their input resource. Prediction of the potential for grade recovery in the standing resource will allow scheduling of harvests to better match the product recovery needed to meet customer orders.

Non-destructive evaluation tools

Acoustic, bending and Pilodyn tools are under assessment to determine their potential for cost-effective screening of clonal and progeny tests as well as silviculture and nutrition trials, to rank genotypes or treatments for stiffness and density.

Marketing support

Additional to the above areas of research, processing or timber testing trials to categorise the quality of DPIF's resource are a routine part of QFRI's research agreement, to assist DPIF with marketing their plantation resource. Current studies include an assessment of the far north Queensland coastal plain exotic pine plantations for structural timber, veneer, LVL and appearance grade products with collaborative in-kind contributions from several industry processors.

Estimating wood stiffness using two kinds of light

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X-rays are very short wavelength light rays, far beyond the blue end of the visible spectrum. X-ray densitometry is based on the absorption of x-rays, and has been a part of forestry research for several decades. SilviScan (SS) expands this potential by providing additional information on cell dimensions (radial and tangential diameter). These allow the environmental effects on density to be resolved into effects on cell diameter and wall thickness. Further development has added x-ray diffraction methods for the measurement of microfibril angle (MFA), longitudinal modulus of elasticity (E_L), cellulose crystallinity and crystallite width. The relatively low cost and high speed makes it possible to analyse large numbers of samples.

SilviScan was designed to measure many thousands of samples per year. The system utilizes increment cores greater than 10 mm (preferably 12mm) in diameter. SilviScan is now available for use by research and industry groups on a routine commercial basis, and is being accessed by a wide range of national and international users covering an equally broad range of issues. One of the predominant uses is resource assessment, with an increasing global interest in understanding not only the volume of forest resource available, but also the wood quality it represents and how this quality varies with site and silviculture.

Near infrared (NIR) radiation is a form of long wavelength light. NIR wavelengths are just beyond the red end of the visible spectrum. Properly calibrated, NIR spectroscopy may be used to estimate a large number of material properties. In order to improve both the speed and cost of analysis, research is being conducted into the use of NIR spectroscopy to predict a range of wood properties when calibrated with SilviScan data. Previous work has demonstrated SilviScan's ability to predict stiffness, or longitudinal elastic modulus (E_L), and the relationship appears to be a universal one, covering all wood species tested (Figure 1). NIR analysis has now been shown to have the capacity to predict timber stiffness when calibrated against both actual stiffness measurements on short clears, and against SilviScan estimates.

A recent study involved eight *Pinus radiata* D. Don (Radiata pine) increment core samples that were selected from a total of thirty-two increment cores for the development of a calibration based on NIR spectra obtained from the radial - longitudinal face of each sample in 10-mm increments. The $E_{L(SS)}$ calibration was developed using eight factors giving an excellent relationship between SilviScan-2 determined $E_{L(SS)}$ and NIR fitted $E_{L(SS)}$ ($R^2 = 0.97$) with a low standard error of calibration (SEC = 0.91 GPa).

To test the $E_{L(SS)}$ calibration, NIR spectra were obtained in 10-mm sections from the radial - longitudinal face of two intact *P. radiata* increment cores, and $E_{L(SS)}$ of each section predicted. NIR estimates of $E_{L(SS)}$ were in excellent agreement with $E_{L(SS)}$ determined using data from SilviScan-2, with R^2 of 0.99 (core A) and 0.98 (core B) and standard errors of prediction (SEP) of 1.6 GPa (core A) and 1.2 GPa (core B). Both sets of predictions closely followed the patterns of $E_{L(SS)}$ radial variation determined by SilviScan-2. The $E_{L(SS)}$ calibration based on NIR spectra obtained from a set of representative cores provided excellent predictions of $E_{L(SS)}$.NIR spectroscopy therefore provides a rapid method for the routine analysis of stiffness in large numbers of core samples.

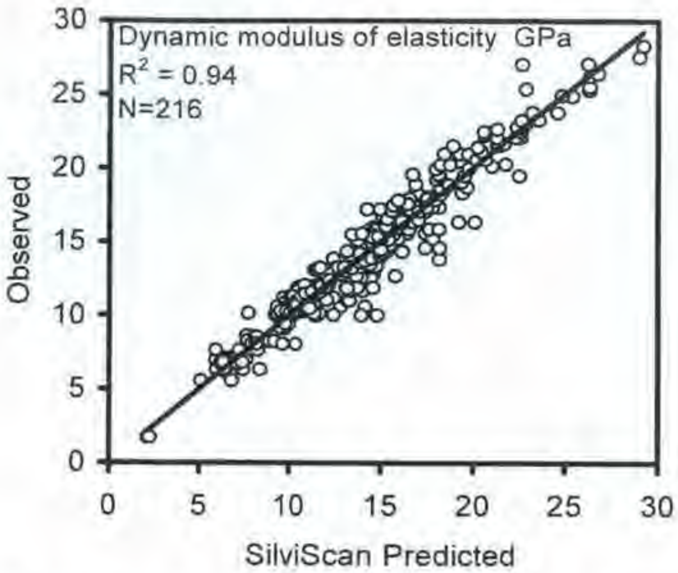

Figure 1: Prediction of MOE of wood from SilviScan diffraction data and density. Data from 104 alpine ash, 52 radiata pine and 60 mixed species, including red ironbark, spruce, southern pine, baltic pine, balsa, paulownia and a wide range of other softwoods and hardwoods. MOE was measured by Jugo Ilic, CSIRO, using a sonic resonance technique.

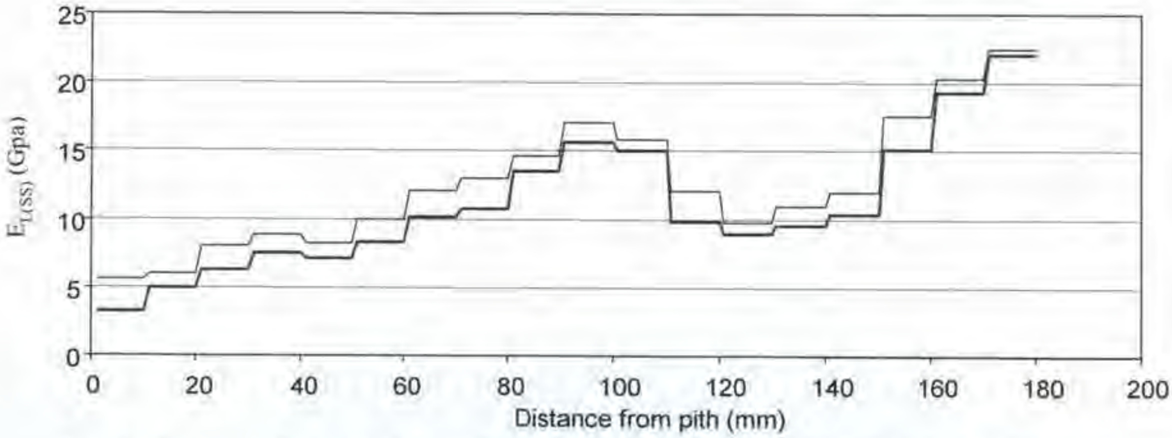

Figure 2: Plots of $E_{L(SS)}$ pith to bark (radial) variation for a *P. radiata* increment core sample. $E_{L(SS)}$ was estimated using SilviScan-2 data (thick line), and predicted by the *P. radiata* $E_{L(SS)}$ NIR calibration developed using selected core samples (thin line). Much closer correspondence would be obtained if the average density of the core were used to correct the positive bias in the NIR predicted density profile.

Towards high value wood products from plantation grown eucalypts – an overview of wood quality research by Queensland Forestry Research Institute

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"Hardwoods Queensland" is a Queensland Forestry Research Institute R, D & E project initiated from the South East Queensland Forests Agreement to support the development of a plantation hardwood industry in Queensland. The goal is a viable hardwood industry based on 25-year rotations and primarily producing high value solid wood products. To realise this goal, the project is addressing and providing solutions to four major challenges.

- Desirable species and provenances are being identified, genetically improved and mass produced for appropriate sites.
- Silvicultural prescriptions for optimal productivity are being developed by identifying appropriate nursery, plantation establishment and stand management practices.
- Improved pests and disease resistance and management options are being developed to reduce the risk of damage to the eucalypt plantations.
- Increased knowledge of wood properties and solid wood quality in relationship to site, silvicultural management and genetics is being sought, and optimal processing and utilisation solutions are being developed.

This presentation outlines the studies conducted by QFRI to provide an understanding of the wood quality of sub-tropical and tropical eucalypts (*Corymbia variegata*, *Eucalyptus cloeziana*, *E. pellita*, *E. pilularis* and *E. urophylla*) grown in plantations for solid wood products. The investigations have focused on assessing wood properties important for solid timber utilisation, and evaluating the feasibility of processing a fast-grown young plantation resource into sawn timber.

Using marketing to define the research process- a timber perspective

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Introduction

Internationally wood is seen as the material for the future, not only from an engineering viewpoint, but also from an environmental one. The research community in Australia has responded well to use what nature has given us and we can be proud that some of our domestically produced ideas have proven successful overseas. A product such as the Parallel Strand Lumber (PSL) is an example of how our research has contributed to the worldwide forum of timber innovation.

In analysing projects similar to PSL it is intended to see how a more effective review process can improve the returns on any research. The purpose of this paper is to not only passing on research directions but to also investigate was of better connecting the review process with the outcomes.

A review of current market trends and how the Victorian Hardwood Timber Industry (VHTI) is trying to meet demand, and using some case studies, the research directions that this provides.

Market Demand

What is clear is that there is a great deal of demand for timber products, not only on the domestic construction front, but in appearance and furniture applications.

The use of timber in domestic construction has increased 8%. This increase reflects timbers inherent advantages as a material that is easy to work with, stable and reliable and importantly cost effective.

Timber flooring is now more popular than ever, growing by 15%, and consumers are demanding diversity and performance in its use. This is driving the need to better understand how our domestic timbers can perform.

The local furniture industry is trying to deter imports that have increased from 21% in 87-88 to 36.2% in 99-00. All indications that consumers have not stopped buying timber, in fact, they are buying more of it. Likewise consumers are looking for greater variety in product, and in turn providing opportunities to the local industry to improve their product offering and maintain a stronger marketing differential.

Obviously with this type of increase in demand it is important to review the opportunities and assess how they can provide direction to the research community. The intent is then to review how we can improve the research process to tie better with market direction.

The Research Process

The challenge for any research process is to ensure that it investigates and seeks to establish new facts and derive new conclusions while balancing the commercial needs of those that can benefit from it.

Traditionally, the research process has been seen in a linear manner, and minimised the interaction between the beneficiary and initiator. This process resulted in good technology, but poor product to market results. What if we begin to instigate a process that is more interactive and mindful of market demands than one of total isolation and separation from the market.

Case Studies

Through the use of some examples the intent is to review how we can learn and direct future research needs for the timber industry. The case studies will review where the successes have been and will cover such areas including:

- **Structural Applications:**
  To achieve better understanding of the needs of the structural market and some learnings from successes including laminated timber, finger jointed materials, and requirements for development.
- **Natural Feature Furniture.**
  The domestic furniture industry has been seeking ways to be more competitive and Natural Feature Furniture is seen as a way to create a unique proposition. However the types of timber that fit the category are still poorly understood and need better definition to meet industry's requirements.
- **Interior Directions.**
  As timber flooring becomes more popular, and provides more opportunities both domestically and internationally, the need for higher performance is in greater evidence. The directions that the market is taking will be explored, as will the needs that it demands.

Wood Futures© V 1.0 - a new look at wood product flows

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Introduction

Wood Futures© was developed as an Excel based spreadsheet model to evaluate regional wood flows. The model was initially developed to examine eucalypt plantation management and product options, benchmarked against existing *Pinus radiata* (radiata pine) management practices. The plantation management scenarios include a low intensity management regime, currently being practiced, through to intensive thinning and pruning regimes. The model provides information on wood flows and value adding on a per hectare basis and, according to the assumptions inherent in the model, predicts the product volumes (m^3/ha) and values ($/ha).

The model framework

Wood Futures© is a Microsoft Excel workbook model consisting of the following worksheets:

- *Summary sheet*: providing an index and a table outlining primary inputs and outputs of the model,
- *Data sheet*: outlining the different plantation management regimes, constraints, product prices and product recovery factors.
- *Employment sheet*: outlining processing throughput requirements and employment, along with estimates of multipliers associated with employment in the particular activities in each processing industry.
- *Plantation Scenario sheets*: Four eucalypt management regimes are examined, and compared with an existing *Pinus radiata* regime. Each spreadsheet examines wood flows from thinnings, provides a breakdown of the volume of logs directed to different processes and product volumes and values from those processes. Different options are given for veneer and roundwood products. All of the data required for these sheets are obtained from the data sheet.

The Plantation Scenario and Summary sheets are locked. All of the input requirements for running the model are to be found on the Data and Employment sheets and can be changed by the user. Information regarding rotation length, mean annual increment (MAI), tree height, % basal area removed, stems/ha (prior to treatment), pruning time and heights, minimum diameters for processing for different products and estimates of variability in tree diameter, for hardwood and softwood plantations can all be changed, but the number of thinnings applied to each regime cannot be changed. Likewise, information in the data sheet on product prices and recoveries for veneer, sawn, fibreboard, paper and export chip products can be changed by the user, but product flows are fixed. The wood flows for harvested wood and sawn and veneer products are shown in Figure 1 (A & B). A similar wood flow exists for roundwood and residue products.

Three sawn and four veneer product grades are recognised and further processing of low-grade products is taken into account. The recovery factors (both overall and for different quality material) have been derived from about 12 years of data accumulated by CSIRO FFP for sawn and veneer product processing of planted *E. globulus* or similar species. The recovery factors for solid wood residues are also provided in the *Data* spreadsheet. These are added to roundwood volumes to determine potential chip volumes. Different conversion factors apply to chipping roundwood and processing residue. Other residues such as dried sawn offcuts, sawdust and planer shavings are assumed to be used for energy production.

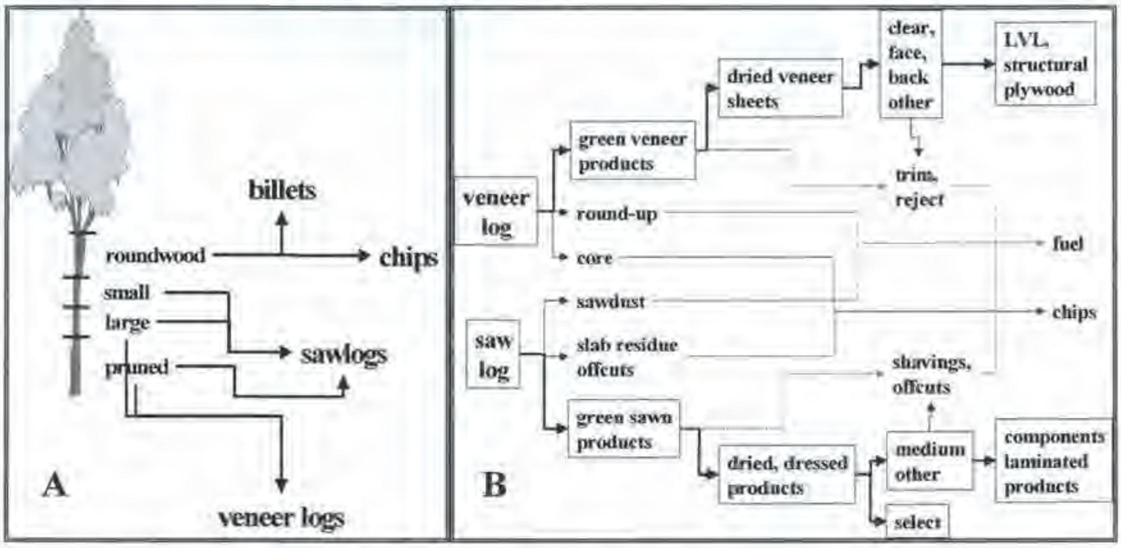

Figure 1: (A) Wood flows from harvested trees
(B) Material flows from logs processed for solid wood products

The *Summary* spreadsheet brings together the information generated in the *Options* spreadsheets, from the user-supplied information from the *Data* spreadsheet. The summary Table outlines the parameters for the different plantation management regimes, the wood flows generated and the estimated value of these wood flows. The two sawn product options for the softwood regime are presented. While the volumes and values for sawn and veneer products can be added together, the volumes and values for paper and composite products are presented as alternatives and only one should be selected in determining values per hectare. In the Table, export chips has been selected, as it is the major existing market objective for most growers and is applicable to a relatively small estate and across all regimes examined. A much greater return can be generated through local processing for paper products or wood composites.

Paddle-pop sticks - not just for licking

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Elastic properties (modulus of elasticity (MOE)) and density are fundamental to the evaluation of wood quality. They can be determined non-destructively from logs, boards, structures, standing trees, small laboratory samples and increment cores using several different techniques. Stiffness is an important characteristic for wood strength that is related to other wood characteristics, but its assessment is costly using conventional bending tests.

Considering current pine plantations, it may be useful to correctly target trees from coups for thinning and to enable rapid selection of trees with desirable wood properties for end products. While there are emerging acoustic technologies to segregate logs for stiffness after harvesting, there are few reliable options for assessments from standing trees. Apart from the stress wave timer, currently there are no other options for rapidly measuring MOE directly with the exception of removing specimens with big enough dimensions for conventional bending tests or by bending the entire stem of the tree. However, these methods tend to be rather destructive, involved, and time consuming.

This study goes some way to explore the possibility of another approach that may be useful for estimating the stiffness of the outer wood from standing trees by using small wood specimens (paddle-pops).

To test the feasibility of using small specimens, material from previous standard[1] static bending experiments was used to evaluate a new dynamic technique from 22 pine, and 13 ash eucalypt specimens. Thin radial specimens measuring 1.6 (t) x 20 (r) x 150 (l) mm resembling paddle-pop sticks were cut from boards previously tested. It was essential for the thin specimens to be of uniform thickness, although this cannot be accomplished easily without an experienced wood machinist or special equipment. The thin strips were tested dynamically in cantilever mode. One side was clamped firmly; the free end was deflected momentarily and released to vibrate freely. A non-contact laser displacement-transducer detected the vibration. Spectral analysis produced clear frequency peaks. The fundamental frequency was used to calculate the dynamic elastic modulus (E_d) according to the following relationship:

$$E_d = 48\,\pi^2\,\rho\,L^4\,f^2 / (1.88\,T^2)$$

E_d = dynamic elastic modulus (Pa), ρ is the density ($kg.m^{-1}$), L = test length (m), f = fundamental frequency of vibration (Hz), and T= thickness of specimen (m). The small beams were sufficiently slender (L/T=120/0.6) to obviate shear effects.

MOE and E_d are highly related for both wood species. The dynamic MOE of small strips explained, 85% and 95% of the variation of MOE for 22 pine and 13 eucalypt specimens respectively.

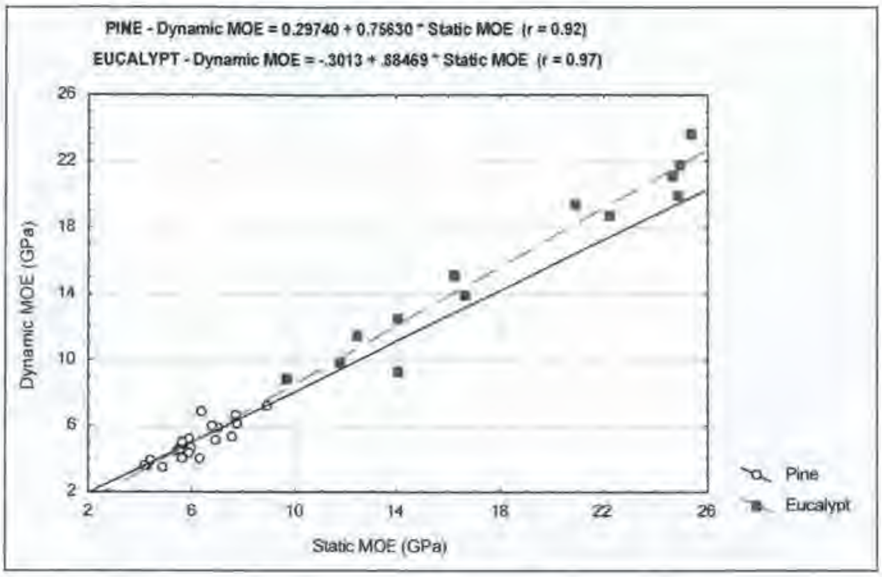

Figure 1: Relationship between dynamic and static MOE for pine and eucalypt strips and standard short clears.

The scatter was somewhat greater for the pine specimens because of slightly poorer matching. Differences in gradients between the pine and eucalypt probably resulted from differences in moisture content at the time of the tests; the short clears were equilibrated to 12% while the strips were at laboratory EMC. However this point needs further investigation.

The results presented here indicate that small strips can be used to obtain a very good estimate the MOE of wood. By the virtue of their small size, in spite of their green condition, strips of a similar size cut axially from the outer wood of standing trees may be potentially useful for estimating tree stiffness. A good relationship can be expected between green and dry wood[2]. The stiffness and basic and air-dry density of the specimens can also be determined after drying. In addition, variation of MOE within growth rings can also be measured easily from larger radial wood strips.

The accuracy of the current measurement method depends on specimens having uniform thickness. However, more rapid and convenient measurements would be possible by inducing vibrations in the axial direction. In this case only specimen length would be important. This latter approach would simplify sample preparation and measurement considerably.

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Microwave modification of wood: Influence on wood properties

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Microwave energy has been used in industrial food processing for many years. Microwave energy is seen as an attractive option for wood processing and drying. Large amounts of microwave energy can be absorbed and applied to a given amount of wood compared to conventional heating and drying methods. Recently, intense microwave energy has been used to modify wood by rupturing the ray cells to form a large number of micro voids in the radial- longitudinal planes [1]. The microwave-modified wood is more permeable, has a higher volume, reduced moisture content and lower density as compared to the natural wood. Mechanical properties are also reduced.

Subsequent resin treatment can restore and increase the original wood density. A corresponding increase in strength properties has also been observed. The new timber product "Vintorg" has an appearance of solid wood but with improved performance attributes. Vintorg produced using isocyanate resin has resulted in an increase in Modulus of Elasticity (MOE), Modulus of Rupture (MOR) and Janka hardness of natural *P.radiata* heartwood by 28.9 %, 10.6 % and 10.8 % respectively[2].

This study focused on Melamine formaldehyde (MF) as an alternative resin for the manufacture of Vintorg. MF resin has a lower viscosity and is more environmentally friendly than isocyanate resin. The aim of the study was therefore to manufacture Vintorg from heartwood of *P. radiata* using MF resin and to determine the basic mechanical properties of this new material.

Quarter sawn *P.radiata* heartwood timber, obtained from the Ballarat Timber Processors log yard, was modified by microwave at the School of Forestry, Creswick. 43x43x410 mm square sections of the microwave modified timber were used in preparation of Vintorg samples using a formulation of MF resin to which ethylene glycol (5%) and F-25 (2 %) were added.

The treated samples were placed in oven bags and pressed on the radial face using a hydraulic press (a Baioni press) to a dimension of 39.7 mm at a temperature of 130 °C for 2 1/2 hours. The strength properties were determined using a Hounsfield Strength Testing machine (10 KC series) as per standard methods described by Mack (1979[3]).

Microwave modification of *P.radiata* increased its uptake of MF resin by 746.1 % from 16.7 Kg/m^3 to 141.3 Kg/m^3 after 20 minutes of soaking. Resin uptake increased significantly ($P=0.001$) with duration of treatment.

Treatment of the microwave modified wood with Melamine formaldehyde resin resulted in about 4 % increase in the initial MOE after 90 minutes of soaking treatment. However, only 73.3 % restoration of initial MOR was achieved. Both strength properties had very weak correlations with resin uptake. However, there was a correlation observed between the strength properties and microwave modified wood density ($r= 0.4$ and 0.54 for MOE and MOR respectively) and also with density of Vintorg ($r=0.3$ and 0.4 for MOE and MOR respectively). The increase in density of Vintorg being due to additional mass of resin and slight decrease in cross-sectional area of the wood, it was concluded that strength properties can either be enhanced by reducing the extent of microwave modification or by further compressing the timber.

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Permeability and strength of microwave modified Eucalyptus regnans heartwood

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Eucalyptus regnans F.Muell. is a very large hardwood of the mountain regions of Tasmania and eastern Victoria. The timber is used for furniture, joinery, plywood, handles, cooperage, flooring, paneling and general construction[1]. The timber is refractory and difficult to treat with non diffusible wood preservatives The heartwood of Eucalyptus regnans is not durable and can be treated with boron by diffusion but it is resistant to pressure treatment[2]. This study was undertaken to determine the changes in the penetrability of heartwood of *Eucalyptus regnans* by preservative treatments following microwave modification. The influence of the treatments on modulus of rupture, (MOR) modulus of elasticity (MOE) and Janka indentation strength (Hardness) was also investigated. Strength tests were performed using a Houndsfield Strength Testing machine with the specimen supported on a span of 300 mm and the pressure applied mid span. Specimens were loaded on the radial surface with a rate of loading of 1.0mm/minute.

Permeability of the *Eucalyptus regnans* was increased by microwave modification. The extent of this increase was determined by soaking samples of in a water bath and assessing the gross absorption of liquid by the samples with respect to time After 120 minutes of soaking the Microwave Modified Timber had exhibited a 900% increase in gross absorption.

Microwave Modified Timber was treated with linseed oil (LO), furfural alcohol (FA), a melamine formaldehyde resin (MF) or water. Microwave Modified Timber had lower strength properties when compared to the unmodified control. Treatment of the Microwave Modified Timber with linseed oil resulted in an increase to hardness (28%) and MOE (20%) but a reduction in MOR (15%). Furfural alcohol treatment exhibited the greatest increase in timber strength properties with increases of 62%, 90% and 48% for the hardness, MOE and MOR respectively. The MF resin effected the largest increase in surface hardness (77%) but had only a minor influence on MOE (20% increase) and MOR (4% decrease).

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Commercial opportunities for environmental tree crops

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The threat of dryland salinity in much of the Western Australian wheatbelt and the Murray Darling Basin has created considerable interest in new plantings of woody perennials. Bringing trees back into the landscape is seen as one way to manage and ultimately reduce the impact of salinity on productive agricultural land and rural infrastructure.

However, while the logic of extensive tree planting is generally accepted for many of the areas prone to dryland salinity, the economics of reforestation is a complex issue. The costs associated with (1) the establishment of new plantings and (2) the productive land that is taken out of agricultural use are real, immediate and quantifiable. However the on-farm and off-farm environmental benefits from salinity mitigation are harder to quantify (and value) and may take place over a much longer time frame than the establishment of the trees.

The difficulty of matching costs against environmental benefits is a major barrier to large scale tree planting for salinity alone. For this reason, there is considerable interest in the development of parallel commercial uses for trees planted to manage salinity in dryland regions. However many of the areas prone to dryland salinity have rainfall or locations that preclude competition for traditional saw log or pulp and paper markets. In these areas new opportunities need to be researched and developed. Potential tree crops need to be matched to potential new markets.

In Western Australia, CALM and the Oil Mallee Company have addressed this issue in an innovative way by working towards an industry based around growing mallee trees for salinity and also for production of saleable products. To date, some twenty million mallee trees have been planted in coppice rows across farms in south west WA, allowing the farmers to maintain their involvement in wheat or sheep while achieving considerable reforestation of their land.

As managing licensee for CSIRO activated carbon and energy technology, Enecon is actively involved in linking new technology to new environmental tree crops such as the WA mallees. CSIRO has taken its technology to the pilot scale and has assisted with test work during the subsequent commercialisation exercises. Engineering is now well advanced at Enecon for the first full scale plant using the CSIRO carbon technology on mallee feedstock in Western Australia, underpinned by financial support from Western Power Corporation as well as the AGO, Ausindustry and JVAP. This multi-million dollar plant will process whole mallee trees to produce activated carbon, eucalyptus oil and renewable electricity. The plant will be commissioned in the middle of 2002 and will hopefully be the first of a number of such plants through the Australian wheat belt regions to provide new rural industry and help combat salinity.

Many new industries such as this are required for commercial support of tree planting on the scale required. There are several research programs underway at present to address this issue, including the Search program in WA, Florasearch in the south east of Australia, and the Best Bets program.

One new industry that is receiving particular attention is the provision of renewable energy. Woody biomass can be used as a feed material for production of electricity as well as liquid transport fuels such as ethanol and methanol. Technology is available for the production of each of these energy forms, however production using current technologies is generally uneconomic when compared with other forms of fossil-fuel or renewable energy. Fortunately, there are major research programs underway overseas to improve technologies and bring down costs. Links to these programs, and strategic research in Australia, will help renewable energy provide a solution to a uniquely Australian problem. If greenhouse gas reduction via renewable energy can be linked to salinity reduction via new tree crops, this will be a double benefit for the environment. Achieving this double benefit at minimal cost to the community, with the use of world's best practice in renewable energy technologies, is an exciting and challenging target for Australian research in the years to come.

Green Gasifier Generator – A micro gasifier turbine development

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Development has commenced by CSIRO Forestry and Forest Products, J.C. Smale & Co and Capstone Turbine Corporation on a micro gasifier turbine system to generate electricity for remote and regional power production with access to fuelwood. Funding assistance for the development has been received from the Renewable Energy Commercialisation Program of the Australian Greenhouse Office. The Green Gasifier Generator (GGG) integrates CSIRO's gasifier[1] (Figure 1) with the Capstone MicroTurbine™ (Figure 2) into systems with electricity outputs of 25 – 200 kW range according to the size of micro turbine. The gasifier converts wood into combustible gases comprising carbon monoxide, hydrogen, methane and other organic compounds. The pressurised gases are cleaned and burnt to run the turbine which drives an electrical generator with sophisticated electronics to enable connection to the electricity grid for distribution to local users, townships and cities connected to the grid.

The gasifier can use green or dry fuelwood. Depending on their configuration, Capstone MicroTurbines™ are achieving from 17% to 27% electrical efficiency.

The project will design, construct and operate a prototype GGG unit to demonstrate electricity generation of approximately 30 kW from renewable wood fuel. Assuming medium term GGG capital costs of $1500/kW installed capacity, total operating costs may fall to $0.10/kWh.

The GGG concept is not expected to compete directly against large-scale fossil fuel (coal / gas) power stations close to their generating sites. However, as transmission distances (and losses) increase, the GGG concept will become more attractive.

The attractiveness will also be increased where there is:

- A ready availability of lower cost (possibly negative cost waste) fuel wood (more likely in regional and remote areas - usually also at longer distances from existing generators)
- A requirement for continuous supply of renewable electricity (which is not guaranteed from wind or solar)
- An isolated site not already connected to the grid
- A site where the existing grid capacity is limited by transmission capacity. A GGG installation will avoid transmission line augmentation
- A need to increase total grid capacity without installation of extra transmission lines by positioning GGG units at the end of the transmission lines and / or along their length.

The GGG system is expected to have markets in developing and industrialised countries with access to sustainable forest biomass resources. The system is not reliant on existing

[1] Anon. Electricity from woodwaste. *Onwood*. Autumn issue No. 24, 1998, p 1.

forests and, provided there is land available, the concept can operate with the establishment of new fuelwood farms created specifically to serve the GGG and other uses of the short rotation plantation.

The GGG prototype / commercial scale demonstration is expected make a significant contribution to the Mandatory Renewable Energy Target of 2% new renewable electricity generation by 2010 to reduce Australia's Greenhouse Gas emissions. In Australia, even with our internationally low fossil fuel costs, it is expected that as production and operating costs are reduced down the experience curve, and where there are readily available renewable wood sources, the GGG will be cost competitive with electricity generated from fossil fuels and transmitted to remote or regional locations. The distributed generation provided by the GGG will be even more attractive particularly in developing countries with higher fossil fuel costs, and / or where there is inadequate centralised generating capacity, and thus there will be good opportunities to export Australian technology and / or equipment. The GGG will offer developing countries with limited or polluting fossil fuels (such as those with high sulphur contents), the opportunity to generate electricity using the establishment of "Fuelwood Farms" based on renewable plantations.

Figure 1: CSIRO FFP Gasifier

Figure 2 Capstone MicroTurbine™

Characteristics of the solid, liquid and gaseous products formed during pyrolysis of Jarrah wood at different temperatures

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patterns and to determine charcoal, condensable liquid and gas yields when samples of eucalyptus wood are pyrolysed. It was shown that sequential decomposition of hemicelluloses, cellulose and lignin occurs and this results in a characteristic sequence of peaks in the rate of weight loss curve obtained during pyrolysis experiments. It has been found that product yields and decomposition patterns are affected by cracking, heating rates, the final temperature reached by the samples, the size and shape of the wood pieces pyrolysed, and by the way wood pieces are cut relative to the wood grain.

In this project, pyrolysis experiments were undertaken using Jarrah (*Eucalyptus marginata*) wood to establish its decomposition characteristics and the amounts and compositions of the solid (ie.charcoal), condensable liquid and gaseous products formed. Jarrah is currently used for charcoal making and yields a strong charcoal with a high fixed carbon content. A constant heating rate was employed but the maximum temperature achieved within the retort differed.between experiments. This was done in order to investigate what happens in the various stages of decomposition identified by previous researchers. Final temperatures of 190 °C (moisture evolution complete), 270°C (hemicellulose decomposition complete), 350°C (cellulose decomposition complete) and 475°C (lignin decomposition complete) were employed.

At the start of each experiment, eight sample blocks (30mm x 30mm x 580mm) were placed in the retort. They were carefully positioned on a stand designed so that heating would take place as evenly as possible over all sample surfaces. An external condenser was used to recover volatiles emitted during the decomposition process, and the rate at which aqueous liquid and tar accumulated in the collection vessels was recorded. Condensable vapours were first observed and collected when the temperature of the gases leaving the pyrolysis equipment was approximately 110°C; at this stage moisture was starting to be removed from the wood samples. (The moisture content of the wood was around 15%.) The rate of condensate production passed through a maximum at approximately 320° C. Yields of condensate per mass of wet wood undergoing pyrolysis were found to be 13.1%, 19.2%, 36.8% and 46.3% for maximum final temperatures of 190 °C, 270°C, 350°C and 475°C respectively. The condensate samples were analysed using a GC-MS (gas-chromatograph/mass-spectrometer) and the forty-four most prevalent compounds identified. Guaiacol, syringol and syringol derivatives were present in all samples. Of particular interest was the transfer of guaiacol derivatives from the aqueous liquid phase to the tar phase that occurred in samples obtained at higher maximum pyrolysis temperatures.

Gas leaving the retort was sampled at regular intervals and analysed using gas chromatography. Carbon dioxide, carbon monoxide, hydrogen, methane and ethylene were found to be present. The pattern of carbon dioxide production with changing temperature closely followed that identified during effluent gas analysis studies of pyrolysing rice husks. Two major peaks were identified, one at 260° C and the other at 370°C; these can be attributed to the evolution of gases during the decomposition of hemicellulose and cellulose respectively.

When the maximum pyrolysis temperature was reached, the energy supply to the furnace was immediately switched off and a blower used to cool the retort. This ensured that the desired maximum temperature was not exceeded. Once the retort was cool, the charcoal was recovered, weighed and examined. The average solid product yields were 97%, 84%, 57% and 38% respectively for the maximum temperatures of 190 °C, 270°C, 350°C and 475°C. This pattern of decreasing solid yield with increasing temperature is in line with expectations – the higher the final temperature, the greater is the extent of decomposition and volatilisation.

The carbon content was expected to increase with increasing maximum pyrolysis temperature, however ultimate analysis revealed a lower than expected fixed carbon content for the 475° C experiment. This somewhat anomalous result requires confirmation. The effect of sample density on carbon yield was investigated and it was concluded that no direct correlation exists.

As previously recorded in the literature, shrinkage in the longitudinal direction was observed to be substantially less than in the horizontal and vertical directions. The effect of grain direction could not be quantitatively assessed as all samples were cut along rather than across the wood grain.

The findings obtained during these studies have extended our knowledge of the processes occurring during various stages of the pyrolytic decomposition of Jarrah and of the solid, liquid and gaseous products formed during these processes. It is intended that further research will be undertaken, using SEM and permeability measurement techniques, into the structural changes occurring during decomposition.

Acknowledgements

The authors would like to thank the following CSIRO staff for their valuable assistance and advice during the course of this project: Vanessa Dusting for organising the GC for gas analysis and ultimate analysis of samples, Soo H. Ng for preparing the pyrolysis and gas condensation equipment, Ross Wearne for undertaking the GC mass spectrometric analysis of the pyrolysis liquids and identification of the components and Adrian de Vos for cutting the Jarrah test samples.

Eucalypt utilization in China – an emerging trend

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China is a net importer of wood fibres and forest products. In 1998 alone, it imported 53,670,000 m^3 of forest products[1]. The chronic shortage has been exacerbated by the logging ban on large areas of native forests following the disastrous 1998 flood and increasing awareness of environmental problems in the country. China is in great need to establish more plantations and to improve the efficiency in utilizing its available forest resources.

Eucalypts are now widely planted in temperate, tropical and subtropical regions outside Australia, because of their high productivity on marginal sites and their ability to produce a range of useful forest products[2]. The total eucalypt plantation area in China is estimated at 2 million ha, of which approximately 1.5 million ha is for commercial usage and domestic harvesting. Most of China's eucalypts are planted in eleven southern provinces but principally in Gaungdong, Gaungxi, Yunnan, Hainan, and Sichuan. Eucalypts are one of the three major plantation hardwood groups in China (eucalypts, poplar, and paulownia) and are considered to have a much greater potential for high-value wood products than the other two groups (pers. comm. Luo, J.J.). During the last decade, a few sawmills in southern China had tried to produce sawn timber from locally grown eucalypts as a matter of interest, but the product quality was poor due to low-quality raw material and lack of knowledge of eucalypt processing (pers. comm. Luo, J.J.). No doubt new eucalypt processing trials are currently carried in the southern regions of China. To maintain an updated and detailed account of these trails will require considerable effort due to the sheer size of the country and the way information flows between different units.

Overall, eucalypt wood products are hardly known in China (except for wood chips). In the southern provinces where most eucalypts are planted, eucalypt wood has a very poor public image – it is unstable, it has cracks, it carries low price tags therefore it is not something one is proud to have. Fortunately, after seeing in Australia the extensive usage of regrowth eucalypts for high-quality appearance products, Chinese researchers and government officials who visited Australia over the years have gradually changed their perception. They have recognized that eucalypts can offer more than just pulp and paper, charcoal, fuel wood, poles and mining timbers. More importantly, they have recognized that value-adding eucalypts is a future economic necessity. The Chinese Academy of Forestry (CAF) has given high research priority to the utilization of Chinese plantation eucalypts for high-value products. CAF have secured a relatively large funding from Chinese government last year and recently obtained another large grant from the International Tropical Timber Organization (ITTO). The theme of these two projects is processing eucalypts for higher-value products. Another ITTO project, currently in progress at Guangdong Forest Research Institute, is to develop preservative treatment processes for treating young eucalypt stems.

CSIRO Forestry and Forest Products has developed an extensive and strong network with Chinese counterparts at various government levels, research institutes and universities. It has carried out a number of collaborative research and aid projects in genetic selection and tree improvement, and new collaborative projects in eucalypt processing are coming up. The knowledge and outcomes from these joint projects have benefited, and will continue to benefit both Australia and China.

The shortage of wood supply in China and its entry to WTO will continue to present export opportunities for the wood products of Australian timber industry. Its growing furniture export industry also represents a real market for reprocessing imported high quality sawn timber into furniture. Finally, the development of plantation eucalypt processing in China will provide economic opportunities for Australian timber processing companies to export processing technology as well as products in areas such as preservation and composites.

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Prediction models for engineered durability of timber

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Project

Durability is one of the most important considerations in the use of timber in construction. Representatives of competing construction materials typically cite this as one of the 'disadvantages' of timber for certain applications compared to their products. To address the concerns of the wider community, building regulators around the world are now seriously considering explicitly including durability requirements in future building codes. This has already been done in the current New Zealand building code and is currently being planned for the future Building Code of Australia (BCA). Thus, building and construction products that do not address durability issues can potentially lose their traditional market share fairly fast and can be shut out of overseas markets that demand durability performance data/information.

While many timber durability guidelines and design aids are available to engineers and designers, the current approach to durability design is very much an art. To address these issues, a major multi-disciplinary project in Australia primarily funded by the Forestry and Wood Products Research and Development Corporation (FWPRDC) and various research organisations (CSIRO, State Forests of New South Wales and Queensland Department of Primary Industries, Forest Research Institute) was initiated several years ago to develop an engineering approach to durability design of timber construction[1]. The project covers: (1) Decay attack on in-ground elements, above-ground elements, and elements protected within a building; (2) Corrosion attack on fasteners embedded in timber and fasteners exposed to atmosphere; and (3) Attack by termites, marine borers, and lyctus. The development of prediction models for in-ground fungal decay and termite attack are presented in separate presentations in this conference.

Scope and Framework

General prediction models are too complex to be used directly in design codes. Figure 1 shows an idealised diagram of how a general prediction model or an analysis based on "first principles" can be used to develop an engineering design procedure and eventually to develop simplified prescriptive design rules. Current methods have been formulated via Path A. The present work is primarily focused on the development of prediction models, which are calibrated using the available durability knowledge base (Path C) as described earlier. Ultimately, the models will be used to improve prescriptive durability design rules either directly or through an engineering design procedure (Paths E and D).

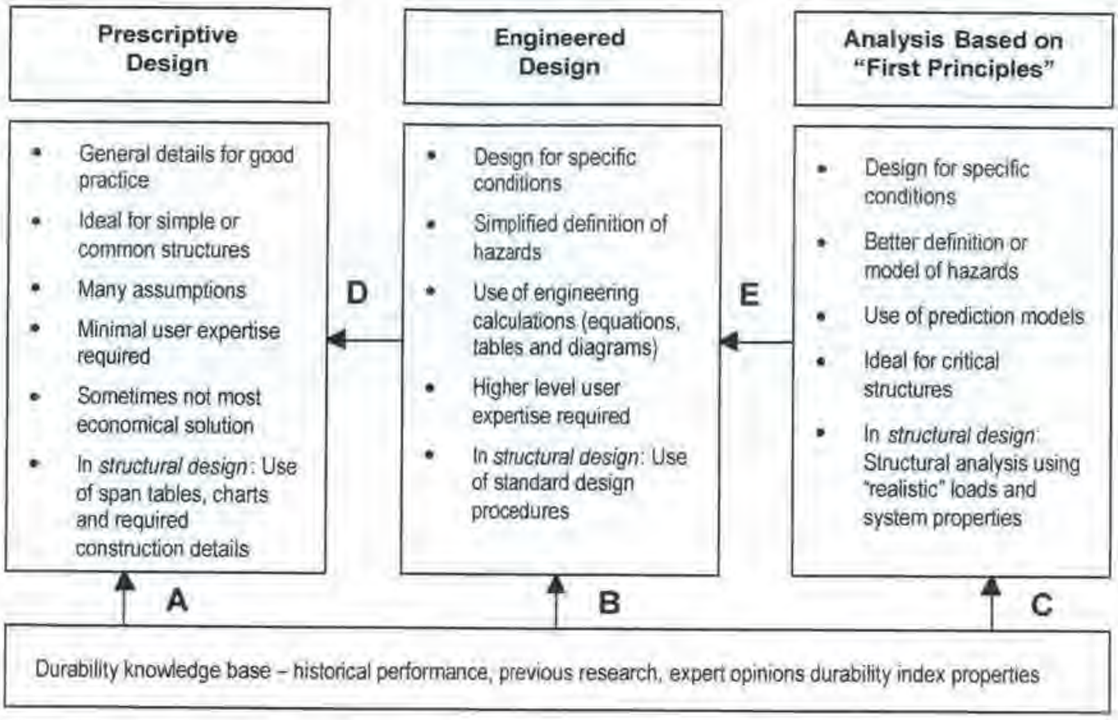

Figure 1: Durability design methods.

The general prediction models can also be used to assess the performance of new and innovative products and the impact of rapid changes enforced by legislation (e.g., banning of chemicals). In conjunction with a non-destructive testing method, the models can be used to predict the residual life of a timber element and to develop an optimised inspection and maintenance program. Thus, the models are key components of an improved asset management system for timber structures

Model calibration and computer software

Collection of filed data from real wood construction and calibration of the prediction models have been undertaken. Once completed, these models should prove to be extremely useful for for developing durability design procedures and detailing guidelines to serve timber users and customers in the building and construction industry. Computer software based on the developed models has been written and can be used to assist in the design and evaluation processes.

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Prediction models for in-ground attack by decay fungi

C-H. Wang[A], *R.H. Leicester*[A], *G.C. Foliente*[A], *D. Gardner*[B], *J. Thornton*[C], *G. Johnson*[C] *and M. Cause*[D]

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Introduction

Prediction models for in-ground attack of timber by decay fungi are developed [1] based on small clear test specimens of some 80 species and 30 preservative treatments observed over 30 years around Australia. The effects of soil moisture content, important climate parameters (such as rainfall and temperature), timber species, preservative treatment, and maintenance are considered. Collection of field data from real structures for model calibration is being undertaken. The models would be extremely useful for developing durability design procedures and serving customers in the building, construction, and utility industries.

Climate index and hazard map

The most important climate parameters affecting in-ground timber decay are mean annual rainfall and mean annual temperature. But when annual rainfall at a site concentrates in relatively short periods of time in a year — as experienced in parts of northern Australia — using annual rainfall only is likely to overestimate fungal decay. Consequently, the number of dry months in a year is also considered, in addition to rainfall and temperature, to account for this effect. A dry month is defined as the month during which the total rainfall does not exceed 5 mm. A climate index, a function of annual temperature, rainfall, and number of dry month, is proposed as an indication of hazard to in-ground decay at a given site. An in-ground decay hazard map produced according to the computed values of climate index for Australia is shown in Figure 1.

Capabilities of the model

Prediction models for decay of untreated (heartwood, centre corewood, and sapwood) and treated timber are available. For a given lag time to decay and decay depth after 20 years of installation, the models predict the decay depth over time, using a bi-linear function. An example of predicted pole strength over time is shown in Figure 2. Preservative-treated timber by CCA and creosote are taken into account. The effects of maintenance treatment, such as the external diffusing chemical barrier, external non-diffusing chemical barrier, insertion of diffusing material, and physical barrier (including tar enamel), are considered by extra lag time to decay. The models apply to both softwoods and hardwoods of all natural durability classes.

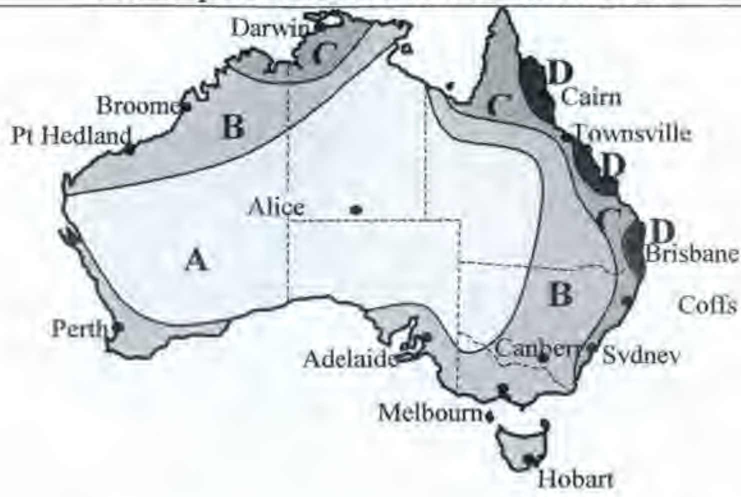

Figure 1: In-ground fungal decay hazard map (Zone D has the highest hazard).

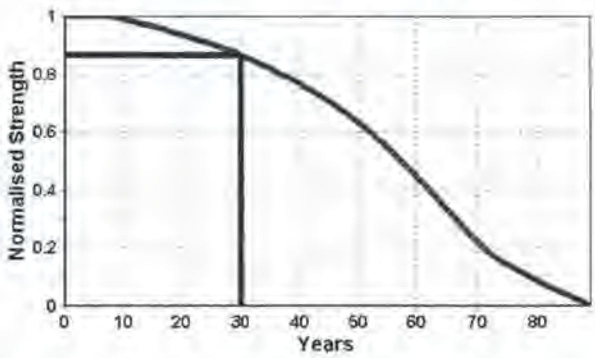

Figure 2: Prediction of strength over time.

Model calibration

The most ideal data for calibration are those obtained from field measurements of real construction because they take into account in the most realistic way what actually occur in service. To date, timber specimens have been collected from the states of Queensland, New South Wales and Victoria. Once delivered at the laboratory, the timber is examined in detail for decay and mechanical degradation. The measured data is then entered into a durability database. With the developed prediction models, the established computer database, and the field data that we have collected and analysed, calibration of the durability models is currently being undertaken. When the models are validated by the field data, they should be extremely useful for developing durability design procedures and detailing guidelines to serve timber users and customers in the building, constuction, and utility industres.

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Timber utility pole reliability under decay attack

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Introduction

A lifetime reliability assessment procedure for timber utility poles in ground contact under fungal decay has been developed[1]. This method uses an in-ground decay attack model[2] that takes into account climate parameters such as temperature, rainfall, wind speed, and wind direction. In addition to the self-weight and wind load, loads from the conductors attached to the pole are also considered. A limit-state function of bending resistance, which deteriorates over time due to decay, is used to gauge the service-life performance of the pole. The developed procedure provides an efficient and rational way to risk and service-life management of utility poles.

Probability models of random parameters

The most important climate parameters affecting in-ground timber decay are mean annual rainfall and mean annual temperature[2]. Based on the analyses of recorded data over 30 years from the Bureau of Meteorology (BOM), mean annual temperature and mean annual rainfall are assumed to follow a normal distribution and a weibull distribution, respectively.

Wind speed, also based on the recorded BOM data, is found to follow a Type-II extreme value distribution of the largest value. Due to lack of reliable data, however, fluctuation of wind direction is assumed as uniformly distributed between 0° and 360°.

Currently the probability model parameters, such as the mean value and standard deviation, of those random phenomena have been derived for major cities in Australia. These model parameters for a specific site can be readily determined if required.

Model for in-ground attack by decay fungi

Prediction models for decay of untreated (heartwood, centre corewood, and sapwood) and treated timber are available [2]. For a given lag time to decay and decay depth after 20 years of installation, the models predict the decay depth over time, using a bi-linear function. Preservative-treated timber by CCA and creosote are taken into account. The effects of maintenance treatment, such as the external diffusing chemical barrier, external non-diffusing chemical barrier, insertion of diffusing material, and physical barrier (including tar enamel), are considered by extra lag time to decay. The models apply to both softwoods and hardwoods of all natural durability classes.

Limit-state criterion

A utility pole may be considered as a cantilever element resisting bending moments subjected to horizontal forces. The bending moments are induced primarily by: (1) The wind pressure on the pole; (2) The shearing forces, perpendicular to the axial direction of conductor cables, caused by the wind pressure on the conductors; (3) The tensile forces of conductor cables caused by the wind pressure on the conductors; and (4) The tensile forces of cables due to self-weight. The limit-state function at time t, $g(t)$, is defined as $g(t) = R(MOR, d_c(t)) - M(t)$, where $R(MOR, d_c)$ is the bending resistance of the pole, depending on the modulus of rupture, *MOR*, and decay depth d_c at a given time; M is the resultant bending moment at time t. When $g(t_f) < 0$, pole failure occurs at time t_f.

Survival probability over service life

After determining the probability models of random phenomena and the external forces mentioned above, the survival probability (or reliability) of a pole over its service life can be determined. With the advent of computer power, Monte-Carlo simulation procedures can be employed without difficulty. An example for the lifetime survival probabilities of timber poles in Sydney for the 4 natural durability classes is shown in Figure 1. With assistance of the proposed reliability assessment method, optimal maintenance strategies can be developed to minimise the life-cycle cost of timber utility poles.

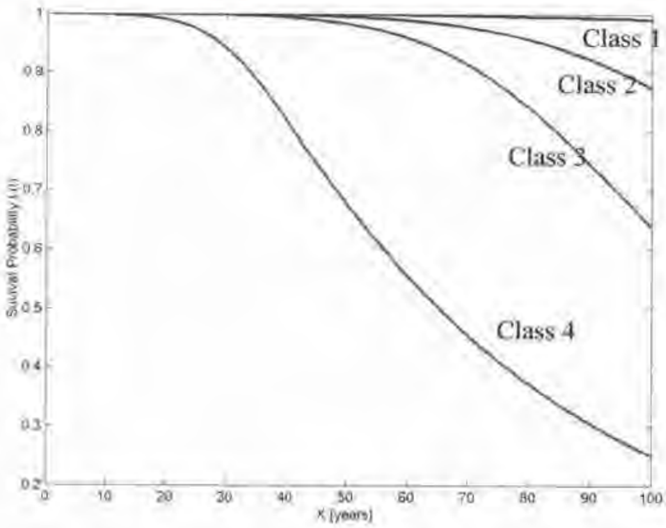

Figure 1: Survival probabilities of timber poles in Sydney for the 4 durability classes.

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A prediction model for termite attack

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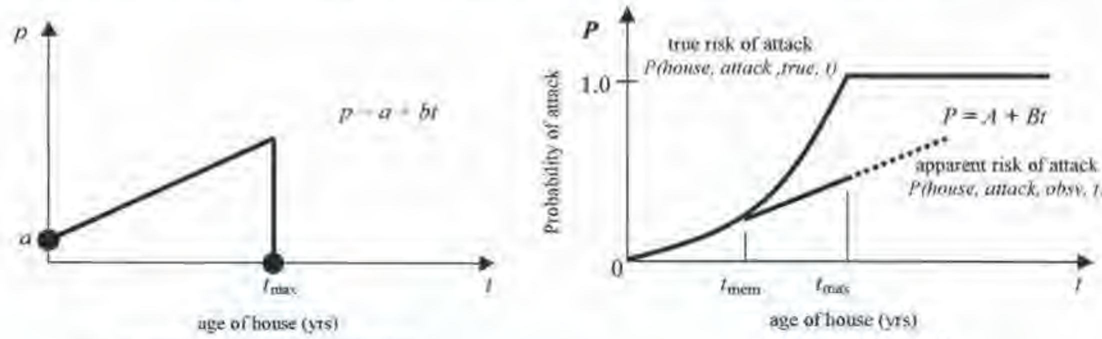
Introduction

A probability model to predict the time for termite attack on timber construction is developed[1]. It makes use of results from two previous studies, one from a collection of expert opinions, which provides a basis for establishment of statistics of four sequential event times, and the other from a Termite Tally around Australia, giving the data needed for identifying important parameters and constructing a hazard map as well as calibrating the proposed probability model. The latter was conducted by the CSIRO Division of Forestry and Forest Products and led by Dr. L. Cookson. The proposed termite attack model is the world's first predictive model of such an attack. Computer software has been written based on the model that can be used for collecting additional expert opinions and for making risk predictions on termite attack.

Capabilities of the model

The termite attack model takes into account the effects of numerous parameters such as geographical location, age of surrounding suburbs, number of potential nest sites, soil condition, food source, period between inspections, maintenance, building elements in ground contact, type of material, and timber environment. Moreover, a novel aspect of the model is that it introduces a parameter that represents the historical memory of a house occupant. The risk computed based on the historical memory is referred to in this study as the "apparent risk", as opposed to the true risk. The probability density function of the risk, the apparent and true risks are shown schematically in Figure 1.



(a) probability density function (b) cumulative risk

Figure 1: Probability density function as well as cumulative apparent and risks.

Application of the model shows that the differences between the true and apparent risks may not be significant for low-risk scenarios, but may be significant in high-risk scenarios. For the timber industry, the apparent risk may be extremely important since it is the risk that the public perceives and uses as a basis for judgment on termite protection, choice of building materials and building design.

Termite hazard map

Analyses using the Termite Tally data show that mean annual temperature has important effects, whereas annual rainfall has little effect, on termite hazard. A termite hazard map of Australia, therefore, is developed based on the mean annual temperature, as shown in Figure 2.

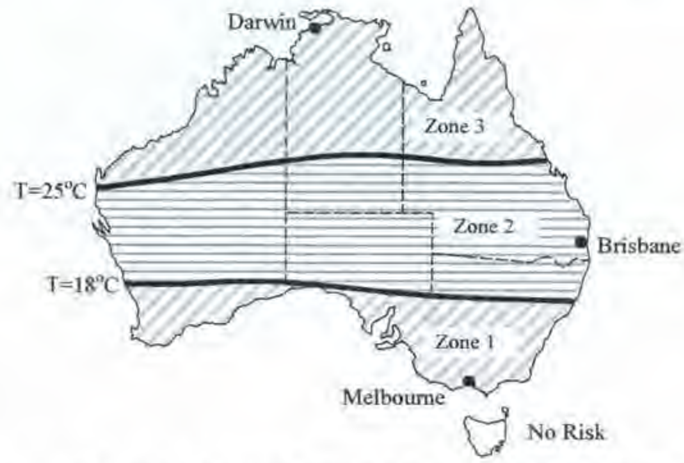


Figure 2: Termite hazard map (Zone 3 has the highest hazard).

Benefits of the model

The developed probabilistic model for termite attack would be a useful tool in development and assessment of asset management strategies and building regulations. The model may also be used to provide a probabilistic format for defining the performance specification of termite barriers and inspection procedures.

Computer software based on the developed model has been written and can be used for collecting expert opinions and for risk prediction of termite attack.

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European practices in wood waste management: A 2001 Gottstein fellowship presentation

M. Warnken

Australian Wood Waste Management

Introduction

Wood waste is a valuable and untapped resource, representing approximately 10% (by weight) of the total waste disposed of to landfill in Australia. However, Australia has only recently begun to address the issue of resource recovery from wood waste. EcoRecycle Victoria and Resource NSW (formerly the NSW Waste Boards) are leading the investigative research and development work to establish a secondary resource industry in wood waste.

These issues have been well researched and developed by European countries. There are many operations that have developed the experience and equipment to manage the materials handling of wood waste and make a range of beneficial wood waste products. These products include feedstock material to manufacture particleboard, combustion of wood waste for heating purposes and the generation of electricity. Recently the technology to reclaim wood fibre from particleboard and medium density fibreboard has also been developed.

This presentation delivers an overview of these technologies and practices. The information in this presentation was collected as part of a 2001 Gottstein Fellowship study tour to the United Kingdom, Germany the Netherlands and Austria.

The Challenge of Wood Waste Materials Handling

Wood waste in Europe tends to be classified according to a three tiered "A-B-C" system that relates to the type of wood product and what (if any) treatment has been applied to the wood product. A-wood represents all of the untreated wood waste, B-wood groups waste from the panel products such as particleboard, medium density fibreboard and plywood while C-wood accounts for the waste from treated wood products. The grade of input wood waste material directly impacts the potential end product that can be manufactured. However, all grades of wood waste have similar materials handling issues

Wood waste is an extremely light weight material, especially when in an unprocessed state. This is owing to the irregular size of offcuts and end-of-life items. Even when processed the bulk density of wood waste is approximately 250 kg per cubic metre and the processed wood chips have a tendency to bridge in traditional bulk handling systems.

The principle materials handling stages include receival, size reduction (primary, secondary and tertiary), separation of contamination, screening, conveying, storage and finally transport to market by road, rail or barge.

Utilisation Options for Wood Waste

A-wood waste is used as a feedstock material to manufacture particleboard. There are stringent quality controls on the utilisation of recycled wood and so great effort must be undertaken in the sorting of contamination like metal, plastic and grit from the wood waste.

With recently developed technology for the reclamation of wood fibre from panel products like particleboard, it is now possible to close the product loop for particleboard. Thus, with minor losses due to damaged unusable fibre, particleboard can become a fully recyclable product.

B-wood and A-wood waste are used as a fuel for heating purposes. At a domestic level this ranges from simple "fire place" technology to fully automated wood pellet fired boilers. Larger scale boilers are used to combust wood waste chips and provide district heating. Process heat for a number of industry applications is also provided from large scale boilers.

Similarly B-wood and A-wood waste are used as a fuel for electricity generation. The combustion of wood waste, either in a grate fired boiler or in a fluidised bed combustor, can be used to make steam to drive a turbine. Wood waste can also be used to generate syngas through a gasification process. The syngas can either drive a turbine directly or can be combusted either to generate steam or used to directly power a generator. The process of pyrolysis can produce a liquid biofuel that can also be used to power a generator.

There are issues related to the efficiency of electrical conversion in addition to some community and NGO concerns regarding the emissions from these technologies. The question of "highest resource value" also needs to be addressed in order to get an optimal configuration of technologies and practices.

Australia is uniquely placed to benefit from a transfer of overseas technology and practices in order to "leapfrog" over current barriers to wood waste utilisation and achieve worlds best practice in the recovery of resource value from wood waste.

Acknowledgements

This paper is based on data collected during a wood waste study tour that was primarily funded by the Joseph William Gottstein Memorial Trust Fund. The author gratefully acknowledges the assistance and opportunity provided by the Gottstein Fellowship.

The Joseph William Gottstein Memorial Trust Fund was established in 1971 as a national educational Trust for the benefit of Australia's forest products industries. The purpose of the fund is *"to create opportunities for selected persons to acquire knowledge which will promote the interests of Australian industries which use forest products for the production of sawn timber, plywood, composite wood, pulp and paper and similar derived products."*

Further information may be obtained by writing to,

The Secretary,

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Clayton South, VIC 3169, Australia

Harvesting wasted timber: Opportunities, challenges and needs

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Introduction

This discussion paper will possibly raise more questions than it answers. It is based on previous and current work by EcoRecycle Victoria to improve systems for diverting timber from landfills. It is not a 'policy' document and is designed to stimulate discussion and action around four questions, namely:

- How much waste timber is there, where is it coming from?
- How much timber is currently being diverted?
- What are the opportunities and challenges for achieving higher levels of timber diversion?
- What is needed to promote more sustainable management of waste timber resources?

How much timber and where is it from?

In Victoria, it is estimated that timber contributes 12% by weight, or 516,000 tonnes per year to the total landfilled waste stream. The contributions of the different sources to the landfilled timber wastestream are approximately:

- Commercial and Industrial = 325,000 tonnes per year (mainly off-cuts from timber products manufacturers and transport pallets/crates)
- Construction and demolition = 100,000$^+$ tonnes per year
- Domestic/municipal = 90,000$^+$ tonnes per year (largely fencing and home renovation waste)

Detailed data about the composition of the timber waste stream in Victoria are not available. Anecdotal information suggests that most is hardwood, although the incidence of treated pine is increasing.

How much timber is currently diverted?

About 25% of waste timber is already diverted from landfill in Victoria. Recent research by EcoRecycle Victoria identified over 151,000 tonnes of waste timber diverted from landfill in 1999 – up from 10,000 tonnes identified in 1994. This is diversion of previously landfilled timber, and does not count 'non-waste' timber that does not enter the waste-stream such as salvaged demolition timber and the mountain of pallet and other scrap timber that is scavenged by households for domestic firewood.

The rapid increase in diversion rates reflects the establishment and growth of organics diversion and processing facilities across the state. Most of the diverted timber is currently mulched for landscaping or as an input into composting. EcoRecycle Victoria has been active in supporting the organics reprocessing sector and will continue to work to facilitate the establishment of infrastructure and markets for diverting organics.

What are the opportunities and challenges?

There are emerging, and potentially strong, markets for waste timber.

Several players in the particleboard and renewable energy markets are willing to exploit the high level waste timber available and are looking for partners to invest in infrastructure for diverting, sorting and pre-processing timber. While energy recovery has an important role to play in the management of waste timber, it may not be the best environmental outcome if it monopolises access to good quality timber, and damages the establishment of markets that 'close the loop' and reduce reliance on virgin timber resources.

The main challenges to achieving greater and sustainable diversion of timber waste are:

- the potential for product contamination, particularly due to treated timbers, glues, nails and laminates, as well as contamination with other types of waste;
- the high costs of segregating, processing and marketing timber relative to market values and disposal costs;
- the limited number of facilities for drop-off facilities for large loads of timber;
- the limited number of facilities for segregation and processing of timber to meet the needs of higher order uses;
- a lack of awareness by most timber waste generators and waste collection services of opportunities (facilities and services);
- fluctuating markets for mulch and compost products; and
- a lack of accurate market information about the composition of the timber waste-stream that could be used to inform investment opportunities.
- Lack of access to recycled timbers by general markets

What is needed?

To meet these challenges and avoid potential pitfalls, the Victorian waste timber sector needs:

- Cooperation of stakeholders (private processors, Regional Waste Management Groups, Local Government and private waste management companies) to develop integrated systems for segregating and diverting timber to 'best' uses.
- Identification of what the 'best' uses are (in particular, is energy recovery a better environmental outcome then recycling or composting?)
- Infrastructure for receiving and processing both small and large vehicle loads of timber
- Pricing and landfill/transfer station gate policies that reward segregation over landfilling
- Sorting systems and labelling protocols to cost effectively segregate timber to go to best uses (i.e. timber processing facilities that serve, but have independent management to, markets. This will allow the facilities to meet higher order markets as they become economically viable)
- Waste/materials collection services that promote segregation of timber (price incentives and education)
- Development of markets for timber products (including something to do with treated timbers)
- Education of timber waste generators of opportunities

- Market information that aids market/investment decisions
- Facilities that make it easier for general markets to access recycled timber
- Information provision that links generators with processors and processors with high value markets
- Data collection that monitors the diversion rates

The Role of EcoRecycle Victoria

EcoRecycle Victoria is a state government agency, funded by a levy on landfilled waste, promoting waste minimisation and more sustainable resource use. Since 1996, EcoRecycle Victoria has carried out and provided funding for community education, infrastructure & service support, data gathering, strategy development and market development. EcoRecycle Victoria actively promotes the waste minimisation hierarchy, with emphasis on avoidance/reduction of waste in the first instance, and then preference for diversion to higher order, more sustainable uses (ie. Reduce, Reuse, Recycle, Recover).

EcoRecycle Victoria'sGreen Waste Action Plan is implementing programs for diverting more timber from landfill. EcoRecycle has contributed to the development of infrastructure and markets for diverting and processing waste timber. Work is currently being undertaken to facilitate the establishment of systems for diverting more timber to viable markets.

Other current initiatives include:

- Waste Wise Business/Industry Advisor Program – making businesses aware of opportunities and linking them with markets
- Market Development support through grants and business development assistance
- Support for 'Buy Recycled' promotion
- Development of a Solid Waste Strategy for Victoria
- Waste and market data collection and reporting
- Working with industry associations to promote reduction and segregation of waste timber

We also propose to bring together stakeholders to identify opportunities and needs for diverting more timber to higher order uses, and invite participants at today's conference to be involved.

Value adding to forest products – some new R&D initiatives

W. Raverty

CRC for Functional Communication Surfaces

Wood fibre is the key raw material that determines the value of the majority of forest products, from solid timber to paper. Two new R&D initiatives, one now fully funded, the other currently at the application phase, are aimed at providing technologies that will add value to both existing forest products and create many new products.

The first initiative is a new Cooperative Research Centre (CRC) for Functional Communication Surfaces that was funded by the Commonwealth Government for 7 years from 1 August 2001. The new CRC is a collaborative venture between Amcor, Norske Skog, PaperlinX, CHH Tissues, Note Printing Australia, Monash University, ANU and two divisions of CSIRO (Forestry and Forest Products, and Molecular Science). Total funding is A$55 million over 7 years with the objective of developing a range of innovative new and improved products for the paper, packaging, printing and security industries. There is a heavy emphasis on use of pulp fibre in these products.

The second initiative is the Centre for BioFibres for which funding is being sought from CSIRO, industry and the Victorian Government, through its Science, Technology and Innovation (STI) Initiative. If funded, this Centre will complement the CRC and bring together a suite of instrumentation for measuring wood and fibre properties which will be unique in the world. Instrumentation and equipment will include CSIRO's award winning SilviScan, Swinburne University's 2-photon confocal microscope, a new CSIRO MDF Pilot Plant and a new laboratory paper former, developed jointly by the University of Melbourne and CSIRO. A total budget of A$6.6 million is envisaged with up to 50% support coming from the Victorian Government. A preliminary application for funding was lodged in October and there will be opportunities for many more companies involved in the forest products industry to become partners in the Centre, or to use its services to improve quality and productivity if the application is approved. This presentation provides details of these two exciting initiatives and the opportunities that will come from them for industry members.

CRC Wood Innovations

P. Vinden

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CRC Wood Innovations is a Cooperative Research Centre uniting a dynamic group of researchers and industry organisations. Two research programs focus on the microwave modification of wood and high value-added wood products. These are supplemented with an innovations program, to design new materials and products and processes for the Australian furniture industry. The CRC is committed to assessing the technical and commercial feasibility of new developments and facilitating their transfer into industry as well as integrating training and education in forest industries.

FWPRDC

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Abstract not ready at time of printing

Short rotation mallee oil Eucalypts and Acacias as feed-stocks for Medium Density Fibreboard[1]

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Saline degradation of land in the wheat belts of Australia is becoming an increasing problem. The planting of woody perennials has been identified as one possible solution. In Western Australia trial plantings of mallee oil eucalypts and acacias have been undertaken to assess their effectiveness in arresting salinity. A further and important aim of the trials was to determine whether the biomass produced by the plants could provide economic returns for farmers in the form of biomass derived energy, activated carbon[1] and eucalyptus oil. However, whilst the latter has been the main focus of attention, there are other potential uses for the woody stems produced on 3 to 4 year rotations. The aim of this work was to assess whether the materials could be used as a feedstock for Medium density fibreboard (MDF).

Chipped samples of mixed 2-4 year old eucalyptus species (*E. loxophleba, E. polybractea* and *E. horistes)* and approximately 7 year old acacias *(A. saligna* and *A. microbotrya)* were refined at elevated pressure using a pilot scale single disc Sunds Defibrator (CD300). With the exception of *A. microbotrya*, bark was included with all chipped samples. Dried fibre was mechanically blended with an experimental PF resin; resin addition levels were high at 10 and 15%. 12mm thick panels were manufactured at two densities: 730 and 800 kg/m^3.

Panels made at the lower density generally had poor properties. At the higher density, panel properties were typically acceptable, though internal bond strengths, whilst meeting minimum standard requirements, often fell below those of commercial panels. This may in part have been attributable to the high fines contents of the furnishes. The thickness swelling of panels made from *A. saligna* was significantly lower than that of other experimental panels. Overall, the results suggested that the materials showed potential as feedstocks for MDF.

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[1] "National Forest and Timber" February 2001, p13.
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A preliminary study of the timber properties of *Elaeocarpis grandis* thinnings from an eight -year old, mixed species plantation

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Introduction

The plantation potential of Australian rainforest trees remains underdeveloped (Borshmann & Lamb 1996, Keenan 1996, Herbohn *et al*., 1996). Russell et al (1993) sees high value, cabinet timber production as an initiative that can provide excellent commercial returns as well as enhancing and protecting the environment. Unfortunately, the economic and environmental benefits of rainforest plantations has been largely overlooked (Cameron and Jermyl 1993, Keenan 1996, Herbohn et al., 1996,Specht 1998). The establishment of viable plantations requires the selecting of species and matching them to the site (Specht 1998). The application of modern forestry techniques to high value rainforest species is only beginning to be carried out (Russell *et al* 1993). Keenan (1998) sees the production of high quality timber products for niche markets, such as cabinet timbers, as having the highest potential for long term returns to forest growers.

The value of timber produced by rainforest trees varies greatly, depending on the working qualities, colour and durability. The value of hoop pine timber is low ($US 70 m^3) based on royalty at stump (felled log), compared with *Elaeocarpis grandis* (Silver Quandong) at $US 154 m^3 (Russell *et al* 1993). The wood of the Quandong is straw coloured, easy to work and suitable for furniture, mouldings and joinery (Bootle 1983, Sewell 1999).

The selection of quandong trees for wood quality analysis is based on favourable results from previous plantation trials (Russell *et al* 1993, West 1998,). Borshmann & Lamb (1996) identified *Elaeocarpis grandis* (Quandong) as excellent in terms of height, volume and form. There has been very little research into the potential of the Quandongs as fast growing plantation tree until recently. The speed at which trees grow as well as the high value of the timber make this species an excellent forestry option on suitable sites (Borshmann & Lamb 1996).

Aim

The aims of this report are to identify the wood quality potential of the species. The species has already been identified as a fast growing, cabinet timber in mixed species plantations when limiting factors are absent. This report should be considered preliminary and will aim to identify if the wood properties of the eight-year old *Elaeocarpis grandis* are favourable when compared to the known results as outlined by Bootle (1983)(assuming that Bootles results are from forest grown specimens).

Method

Three logs of *Elaeocarpis grandis* were retained for wood properties from the thinning operation at Mitchell Park, Samford, on March 3rd 2001. Each log was cut into slabs using a Portable Bandsaw by D & I Kirby & Associates Sawmillers. The centre slab of each log was located as close to possible to the pith and was cut into a 60mm slab. The centre slab was visually located by the presence of the pith from the apex to the base of the log. Each slab was labelled and sprayed with a 2% Ammonium chloride spray to prevent discolouration from mould. Slabs were wrapped in protective covers that had also been sprayed with the disinfectant and transported to Southern Cross University.

Each logs' slab was cut into sections A, B and C and labelled. Further milling of the sections into the respective dimensions was carried out at the QFRI Research Mill at Salisbury using a bench saw. All timber properties testing were carried out in accordance with procedures and formulas identified by Mack (1979).

Results

Density

	Density		
	Green density	Basic Densit	Air dryed density
Samford	861	427	535
Bootle	750	430	500

Mechanical Properties

	MOE (Gpa)	MOR (Mpa)	Stress grade
Samford	8	78	SDS 6*
Bootle	11	72	SDS 6

*based on rules determining classification for positive strength groupings Bootle (1983)

Janka Hardness

	Radial	Tangential
Janka Hardness	3.1	3.6
Janka Hardness Average	3.4*	
Bootle	2.8	

*Janka Hardness average was determined from an average of the radial and tangential faces.

Growth Stress

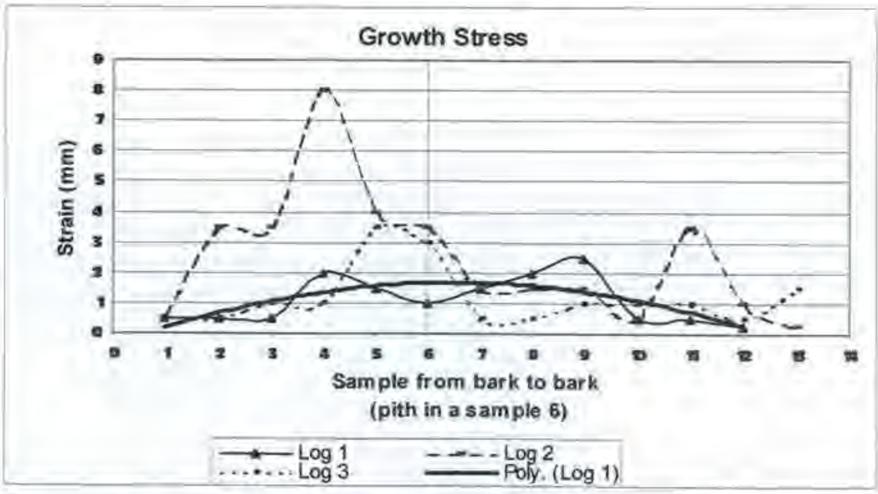

Figure 1: Growth Stress from bark to bark showing strain trendline (Poly. [Log 1]).

Shrinkage

	Radial	Tang.
Samford*	2.5	3.4
Bootle	1.5	4.5

* Only two pieces with true radial and tangential faces were identified so it was therefore not possible to differentiate accurately the radial and tangential shrinkage.

Conclusion

Elaeocarpis grandis grown in mixed species, cabinet timber plantations could generate significant economic, environmental and social benefits. This preliminary study has shown that *Elaeocarpis grandis* has the potential to provide a viable resource early, with good wood properties at conversion and drying based from the tests that were determined. It may have the potential for a high value, niche market. The potential niche product would be a pale coloured, appearance grade timber with sound wood, mechanical and working properties. Silver quandong has long been utilised as a decorative veneer, furniture, frames, and shutters, for bending timber purposes, turnery or boat building. This preliminary study has included three trees at one site so a wider ranging study of wood is needed to confirm these results.

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Wood bending for high value wood products

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Bending, as means of producing curved parts in timber construction, has many advantages over other methods of manufacture, the principal one being greater strength and recovery of timber. Up to 100% higher yield can be gained compared to the traditional techniques used in shaping wood. This, combined with remarkably higher quality and durability of the finished product, leads to lower production costs and an improved cost benefit to the industry.

Bent wood componentry has been extensively used overseas in a broad range of applications such as furniture, joinery, musical instruments, sporting goods, etc. In Australia, bent wood components have only been used to a limited extent by some manufacturers, by craft producers and individual designer makers.

This project which is part of the CRC objectives aims to investigate innovative techniques for the manufacture of bent components from Australian furniture timbers in particular from the younger timber resources to provide the industry with a powerful technique for new designs and future product development.

Research focuses on:

- Investigating the application of microwave technology for modifying timber in order to improve its bending characteristics. Basic research is being undertaken to study the mechanism of wood structural changes and mechanics of plasticity and elasticity during the bending process to enable a mathematical model to be developed.
- Determining bending properties including the optimal radii of curvature and bending parameters for a wide range of species of younger timber resources.

The poster shows some of the current bending techniques and illustrates innovative applications of using microwave technologies which could revolutionise the concept and design of bent wood components.

distribution of structural framing recovered, as a proportion of total structural dried dressed material recovered, was allocated to MOE classes for each clone. To examine which traits contributed to the stiffness of the top 20% and bottom 20% of these clones, they were ranked for each trait. Examining the means of both the trait rankings and the trait values indicates that basic density and stem volume are very important to clone performance at this age. The latter is probably indirectly correlated to wood density reflecting the better recovery of higher density outer wood from larger stems. Stem straightness, spiral grain uniformity (assessed as spiral grain standard deviation) and mean branch diameter also contributed significantly when mean rankings are compared (3). There is also considerable variation among the traits for individual best and worst clones demonstrating how complex the interaction of traits can be.

The same sawing approach is currently being used to obtain sawing study results from a 16-year-old PCH spacing trial. This trial was established by thinning routine plantation stands to 100, 200, 300, 500 and 750 stems per hectare when it was 3-years-old. The results of this study will be added to other silvicultural trial data as part of a decision support system and modelling project.

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Successful acoustic segregation of *Pinus radiata* logs according to stiffness

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Abstract

Wood stiffness varies enormously both within and among trees, so that it is inevitable that low-grade solid wood products are produced from some trees. Accordingly, it would be highly desirable to segregate logs to ensure that only those logs with predominantly high stiffness wood are processed into structural lumber products. This study examined whether sound flight velocity (m/s) could be used as a direct measure of wood stiffness to allow such segregation. Trees of radiata pine were measured before and after harvest with a non-destructive acoustic device (stress wave timer) to see if there was a relationship between sound wave velocity in either standing trees or logs and machine stress-grades of boards derived from those trees and logs. The speed of sound along logs was sufficiently closely correlated with wood stiffness to allow logs to be sorted into classes. A highly significant and positive relationship was found for acoustic measurements made in logs and a weaker, but still significant, relationship existed for acoustic measurements made in standing trees. Such, segregation of logs according to wave velocity measured in the field may save a large sawmill between $1m and $4m each year.

Introduction

Wood stiffness and strength varies greatly among and within stands of *Pinus radiata* and this offers an opportunity to improve the way logs are sorted at harvest time and allocated to processors to optimise the value of lumber recovered. One way of achieving this is to allocate wood with predominantly high stiffness properties to structural markets and wood that does not meet this criteria to reconstituted wood processors (Walker and Nakada 1999). Currently, wood supplies are sorted at harvest only to a limited extent by using surrogate indicators, such as log size, the number and size of knots, straightness, etc that are not closely correlated with wood stiffness or strength.

However, it is possible to use sound wave technologies to more directly assess the mechanical properties of timber (Ross 1999, Ross *et al.* 1997, Kaiserlik and Pellerin 1977). There is a strong relationship between stiffness of logs (measured acoustically) and mean stiffness of boards cut from the logs (measured using transverse vibration techniques) (Ross *et al.*, 1997, Ross *et al.* 1991). Although actual correlations are highly species-specific. For example, the correlation was $r = 0.57$ for Balsam fir and $r = 0.91$ for White spruce. Correlations for individual boards were poorer ($r = 0.41$ and $r = 0.71$ respectively) because of the variation between boards cut from the same log.

Nakamura and Arima (1994) reported a good relationship between stiffness and the square of the wave velocity for standing trees across a range of stands. In their study, they calculate MOE from wave velocity from the equation:

$MoE = v^2 * \rho/g$

in which MOE is the Modulus of elasticity, v is the sonic velocity, ρ is the density and g is acceleration due to gravity (=980cm/s). Variation in MOE is due to v and ρ and a good relationship seems inevitable from this equation.

There are numerous reports of a strong relationship between sound velocity and stiffness of logs, but stiffness or strength was usually determined under controlled laboratory conditions for clearwood. Comparatively few studies have examined the relationship between acoustic sound velocity and machine stress grades, which take into account the effect on stiffness of branch knots and defects both of which reduce stiffness and strength. (Ross 1999, Snyder *et al.* 2000). Further, there are few reported studies linking acoustic measurements of standing trees to machine stress grades of boards sawn from them.

Walker and Nakada (1999) showed that acoustic measurements allowed the sorting of *Pinus radiata* logs according to stiffness. However, this still relied on using felled trees. Clearly, it would be desirable to have a method that measured standing trees non-destructively, but there are a few reports that have related standing tree and log acoustic measurements to machine stress grades.

Nevertheless, as this study shows quick and non-destructive acoustic measurements can be used as a direct measure of wood stiffness in either standing trees or logs of radiata pine. Ultimately, this should lead to a more efficient use of the resource by directing the appropriate quality timber to the right market.

Assessment of the pulpwood quality of standing trees using near-infrared spectroscopy

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In Australia, considerable effort has been directed at improving the pulp yield of plantation grown trees through tree breeding programs. However, an improvement in pulp yield relies on the assessment of large numbers of trees. Traditional methods of assessment are expensive, time consuming and destructive inhibiting their use. Cores can be extracted non-destructively from standing trees using TRECOR, a handheld motor driven drill. The cores are milled, their near-infrared spectra obtained and pulp yield estimated using an appropriate calibration model. The height at which the core is taken is very important. It must represent the whole tree and sampling must be easy and practical.

The longitudinal and radial (within-tree) variation of pulp yield for 15 *Eucalyptus nitens* trees was examined using near-infrared spectroscopy (NIRS). The trees were taken from three families (five trees per family) selected for giving high, medium and low pulp yields respectively. Three trees (one from each family) were examined in detail. Maps of within-tree variation of pulp yield were developed. Pulp yield was found to be highly variable within individual trees and between trees of the same family. The yield of samples from 10 % of tree height (approximately 2.2 m) gave the best correlation with whole-tree yield. Samples from 5 % of tree height (approximately 1.1 m) gave a slightly lower correlation but provided a more convenient sampling height.

Ten *E. globulus* and ten *E. nitens* trees growing on five sites in Australia were used to examine the longitudinal variation of pulp yield. Trees from sites in Tasmania, Western Australia and Victoria were sampled. The optimal sampling height for *E. globulus* was 1.1 m. No single sampling height could be recommended for *E. nitens*.

"The trend in mass-production has been towards uniformity. We design products to please the average consumer, either to reduce costs or because we don't know how to please the individual. New measurement technologies will allow us to understand and manipulate diversity rather than eliminate it. New products will evolve more readily and consumers will retain a sense of individuality. If we measure, and creatively manage, variation in forestry and in forest products we will generate many new and exciting opportunities for adding value by catering for the needs of the individual."

Dr Robert Evans, CSIRO FFP, Winner of the 2000 Marcus Wallenberg Prize for scientific achievements in forestry and technology of the forest products industries.

H.M. King Carl XVI Gustaf of Sweden awards the Prize to Dr. Robert Evans.

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