# Wood quality variability – what is it, what are the consequences and what we can do about it?

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## Abstract

In recent years there has been a renewed focus on wood quality, and the recent Forest Growers' Science and Innovation Plan identified it as the common research priority of both forest growers and wood processors. Variations in the properties of the wood raw material supply affect the quality of the end-products produced by wood processors, which in turn affects their profitability. The forests that will provide the raw material for New Zealand's domestic processing sector are already in the ground and growing, and a key priority will be to better characterise the wood properties of the trees in these forests to ensure that they are sent to the most appropriate processing stream. New advances in remote sensing and other segregation technologies may help, but they will only be used when the benefits outweigh the cost of implementing them. Understanding the drivers of variation in wood properties and developing strategies for dealing with this variation is important when establishing new forests that will provide the wood supply of the future. It is important in all these areas to understand the implications of decisions on end-product quality and not just surrogate measurements such as wood density. Knowledge and modelling tools that connect tree breeders, forest growers and wood processors are required to enable the impacts of various decisions to be measured in terms of end-product quality. Relating this back to a return-to-log measure will enable the benefits of improving wood quality to be better quantified, potentially leading to better price signals for higher quality logs.


## Background

Forest managers and wood processors want to realise the greatest value from their resource by getting the right balance between the quality and quantity of wood produced. However, current market conditions only provide a small premium for higher quality logs, so do we simply conclude that our focus should be on maximising value from our forests by maximising volume production? Back in May 2014 Scion ran a workshop which asked the question 'Wood quality – is it still relevant?' The answer from the 110 people who attended was a resounding 'yes', it is.

It should be intuitively obvious that the profitability of wood processing depends on 'good' wood, with poor quality logs and the poor quality parts of logs often generating negative margins for processors. This is not new, and a paper in the *New Zealand Journal of Forestry* in May 2004 made the case for improving wood quality (Cown & van Wyk, 2004). Despite this, we frequently hear that 'there is no premium for improved wood quality', other than the price differences for different log grades, and even these can be quite small. As a result, one of the challenges for forest growers is to put a dollar value on improving wood quality. In comparison, it is relatively simple to quantify the economic impact of say a 10 per cent improvement in volume yield, but as an example what is the benefit of improving log average wood stiffness by 10 per cent and who do these benefits accrue to?

At a macro level, it is easy to argue that the investment in infrastructure needed to increase the

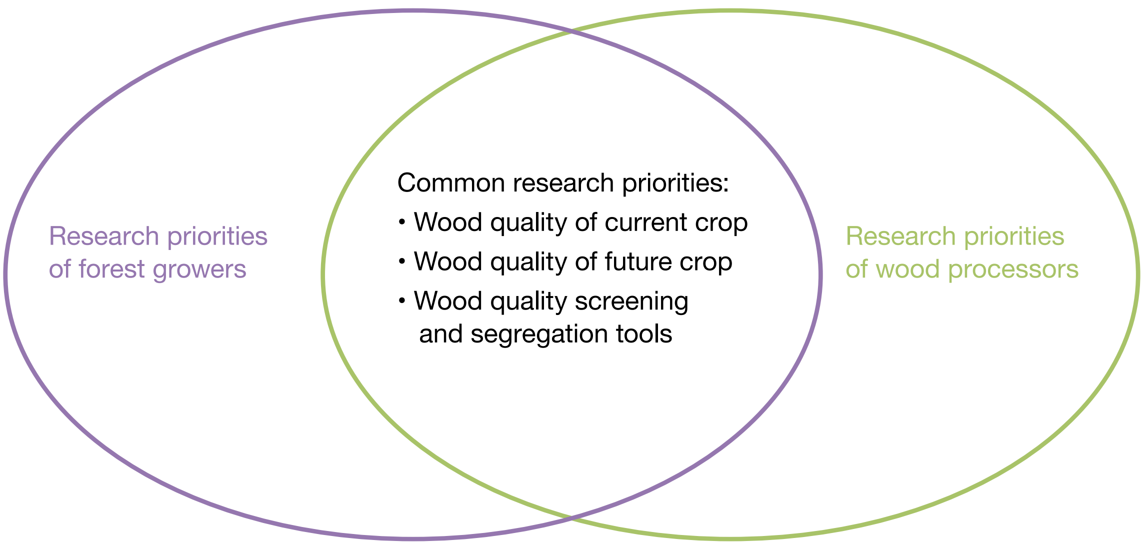



Figure 1: Common research priorities for wood processors and forest growers

amount of added-value domestic processing, and therefore export earnings, requires confidence in both the quality and quantity of the future wood supply. The revised Forest Growers Science and Innovation Plan – see presentation on this by David Balfour at www.ffr.co.nz/nz-forest-growers-science-innovation-plan – perhaps unsurprisingly identified wood quality as the common research priority for both the forest growing and wood processing sectors (Figure 1). More specifically, the following three research themes were identified: 1) wood quality of the current crop; 2) wood quality of the future crop; and 3) wood quality screening and segregation tools. Both forest growers and wood processors want to improve both quality and uniformity, but what does this mean and how might we achieve it?

In this paper we discuss what is meant by wood quality variability, the consequences of this variability for wood processors, and what can be done to address this for both current forests and future forests.

## What do we mean by wood quality variability?

It is worth spending a few sentences defining what is meant by the term 'quality', not as some academic exercise, but because it is important for helping to guide the industry's thinking and targets around quality. The International Standards Organisation (ISO) defines quality as 'the totality of features and characteristics of a product or service that bear upon its ability to satisfy stated or implied needs', or more simply – does it do what the customer expects it to?

For forest growers, the immediate customer is generally a sawmill, pulp mill or panel mill who have requirements for their raw material feedstock, but these mills are not the final consumers of wood products. These consumers expect wood products to meet certain performance criteria but there are other dimensions to product quality that must be considered including: features; reliability; conformance; durability; serviceability; aesthetics; and perceived quality (Garvin, 1984). New Zealand's wood products are not just competing against wood products from other countries, but against other materials that claim advantages in one or more of these aspects of quality. An obvious and recent example is the residential construction sector, where steel framing claims to have advantages over timber framing.

Like in any product, there is variation in the quality of wood products. This variability is acceptable, provided that it does not fall outside some specified range (Figure 2). For example, structural timber must achieve certain stiffness requirements for a particular grade, but also has to meet the customers' expectations around distortion. These expectations may be higher than the levels of distortion permitted in the grading rules (Perstorper et al., 1995). When the variation in quality means that a significant proportion of the product falls outside acceptable limits, this creates a problem for the producer as significant cost has already been incurred to make the product, and the value of fall down products is generally much lower.

The term 'wood quality' really refers to wood properties, such as density, microfibril angle, colour, tracheid length, cell dimensions and grain angle, but also to factors such as log size, straightness, and branch size and distribution. These properties affect the performance of final products, such as sawn timber, panel products and paper, and they vary both within and between trees. However, it is important to note that these properties are surrogates for end-product quality, rather than product quality parameters in their own right. In a large project examining the quality of structural timber products in Sweden, Perstorper et al. (1995) commented that 'the modelling and

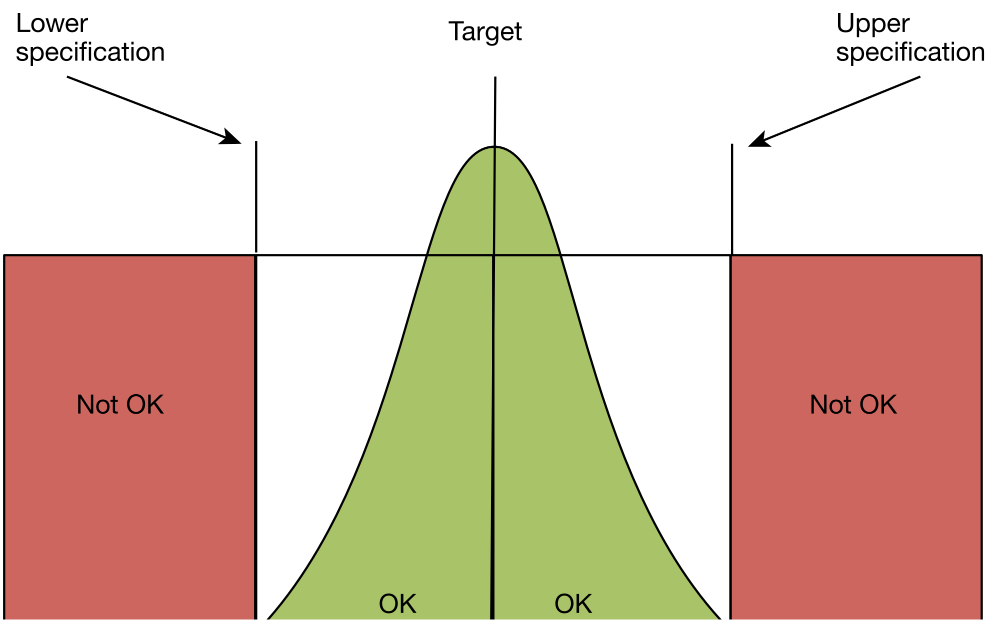



Figure 2: The relationship between the variation in end-product quality and acceptability

optimisation of silvicultural practice should be focused more directly on end-user related quality variables rather than on substitute parameters such as density.' Some of the main performance criteria for selected wood products are summarised below.

### Structural products including laminated veneer lumber (LVL) and glulam

- Stiffness
- Strength
- Dimensional stability – warp and in-service movement
- Connector performance, e.g. nail-holding
- Durability – natural or ability to be treated – where required.

### Appearance products

- Dimensional stability – warp and in-service movement
- Colour
- Visual features – grain pattern and absence of defects such as resin, knots and checks
- Durability – natural or ability to be treated – where required.

### Paper and paperboard

- Tensile, tear and burst strength
- Printing quality – a function of brightness, smoothness and opacity.

Understanding the implications of wood property variation on end-product quality is therefore important for informing strategies on how to deal with the existing resource, guiding tree breeders and developing management regimes for future forests. Demonstrating the impact of wood property variation on end-product quality and expressing this in terms of a 'return to log' would enable the financial impact of improvements in wood quality to be calculated. One would hope that it would also provide the basis for a conversation between growers and processors around premiums for better quality logs.

## Implications for processors

Logs are the highest cost item for a wood processor. Because the variability in log properties influences both the breakdown process and the end-product quality, mills impose specifications on the quality of their log supply. Despite this, variability in the properties of logs entering a mill creates a number of issues for wood processors. First, variation in log geometry means that logs must first be sorted into diameter classes and may also be sorted according to knot size, sweep and shape. Second, many of the factors that affect end-product quality are internal log characteristics, i.e. wood properties. Variation in these characteristics within a log, for example, from pith to bark, means that a variety of product grades are produced

Resin show through in a painted fascia board. Source: Scion Digital Image Library

Example of intra-ring checking in a radiata pine moulding. Source: Scion Digital Image Library

Extreme example of warp in structural timber. Source: Scion Digital Image Library from the same log. There exists at least as much, if not more, variability in wood properties within a tree than between trees in a stand and between sites.

Generally, the better timber grades generate a higher positive cash margin for the processor while the poorer grades generate a negative cash margin. The weighted average of these cash margins determines the overall profitability of the mill. In addition to the known radial variation in properties that exists within logs, random defects such as resin features, compression wood and internal checks, which often do not become apparent until the log has been sawn, can result in significant downgrade and loss of value. This is particularly true for pruned logs, where it is incorrect to simply assume that if a log is knot-free then it will yield clear timber (Miller, 2002).

In 2012, a small survey was commissioned by Future Forests Research to try to understand the impacts of variability in log quality for sawmills. Sawmill managers who responded to this survey stated that log variability influenced mill layout and reduced the productivity of headrig and sorting operations. In their opinion, reduced log variability could see carriage mills replaced with higher throughput single-pass sawmills. However, the biggest reported impact of variability was on value recovery. Managers of sawmills producing appearance grade lumber estimated that eliminating variability in the log supply could reduce production costs by approximately $22 per cubic metre of product. Most of this saving was estimated to occur by reducing the difference between corewood and outerwood. The problems caused by corewood are well known (Cown, 1992) and reducing these should be a major focus of forest management.

Further savings could be realised if mill layout could be reconfigured to increase throughput, giving a total reduction in costs of almost $30 per cubic metre of product produced. Variability in timber stiffness and dimensional stability were the most important factors affecting the cost of production for the structural mill surveyed, followed by corewood/outerwood differences and log diameter. We know that much of the lumber with low stiffness and poor dimensional stability comes from the corewood region of the tree, so corewood content is very important for structural mills. If variability in these factors could be reduced, the sawmill manager estimated that the cost of production could be reduced by $37 per cubic metre of product. These figures are based on a very small sample of mills, but they serve to illustrate how the competitiveness of New Zealand's solid wood processing sector could be improved through having a less variable log resource.

Variation in wood properties also has implications for other processing streams. For example, variability in the wood properties of pulp mill feedstock affects both the pulping process and end-product quality. Reduced variability enables pulp mills to increase yield, reduce operating costs, optimise wood consumption and increase profitability. The producers of engineered wood products are also affected by variability in the wood raw material resource. For example, LVL requires high stiffness logs in order to manufacture products that have higher strength and stiffness properties. They cannot afford to accept too many logs with low inherent wood stiffness, otherwise the grade recovery of veneers will fall.

## What can forest managers do to reduce variability?

### Characterisation and segregation of current forests

The forests that will provide the next 25 years of wood supply are already in the ground and are growing, while the wood that will be harvested in the next 10–15 years is growing in stands that have received their final silvicultural treatments. The opportunities to manipulate the wood properties of these stands are therefore limited. The main option for dealing with variability is to characterise the resource and ensure that material is sent to the most appropriate processing stream given its inherent wood properties. One might naturally question why this work is needed when we have been studying wood properties of radiata pine, and other plantation species, for more than 50 years. The short answer is that the resource that will be harvested in the next 10–15 years is likely to differ from the resource being harvested now due to:

- The large area of forest planted on ex-farm sites in the 1990s
- A shift in genetics – open pollinated seedlots based on the 850 breeding series being replaced with control pollinated seedlots based on the 268 breeding series
- Changes in silvicultural practices, particularly stand stocking and pruning.

Historical data on wood properties may therefore not necessarily be applicable to these stands that will be harvested in the future. Furthermore, we need to understand the implications of wood property variation on end-product quality. In the past this has often been done through sawing studies (e.g. Cown, 2002). However, new predictive approaches are being developed by Dr Jonathan Harrington and colleagues at Scion that enable the stiffness and distortion of solid timber to be predicted from information on stem shape and the internal wood properties distribution within a log.

The key wood properties that affect timber stiffness and distortion are density, microfibril angle, spiral grain angle and chemistry, and knowledge about the extent of variation in these properties within and between trees is required to predict timber performance. Information on the regional-scale variation in properties such as density is available from previous studies (e.g. Palmer et al., 2013), while new techniques have been developed to obtain information on the within-tree variation in wood chemistry, spiral grain angle and microfibril angle (Thumm et al., 2010; Riddell et al., 2012).

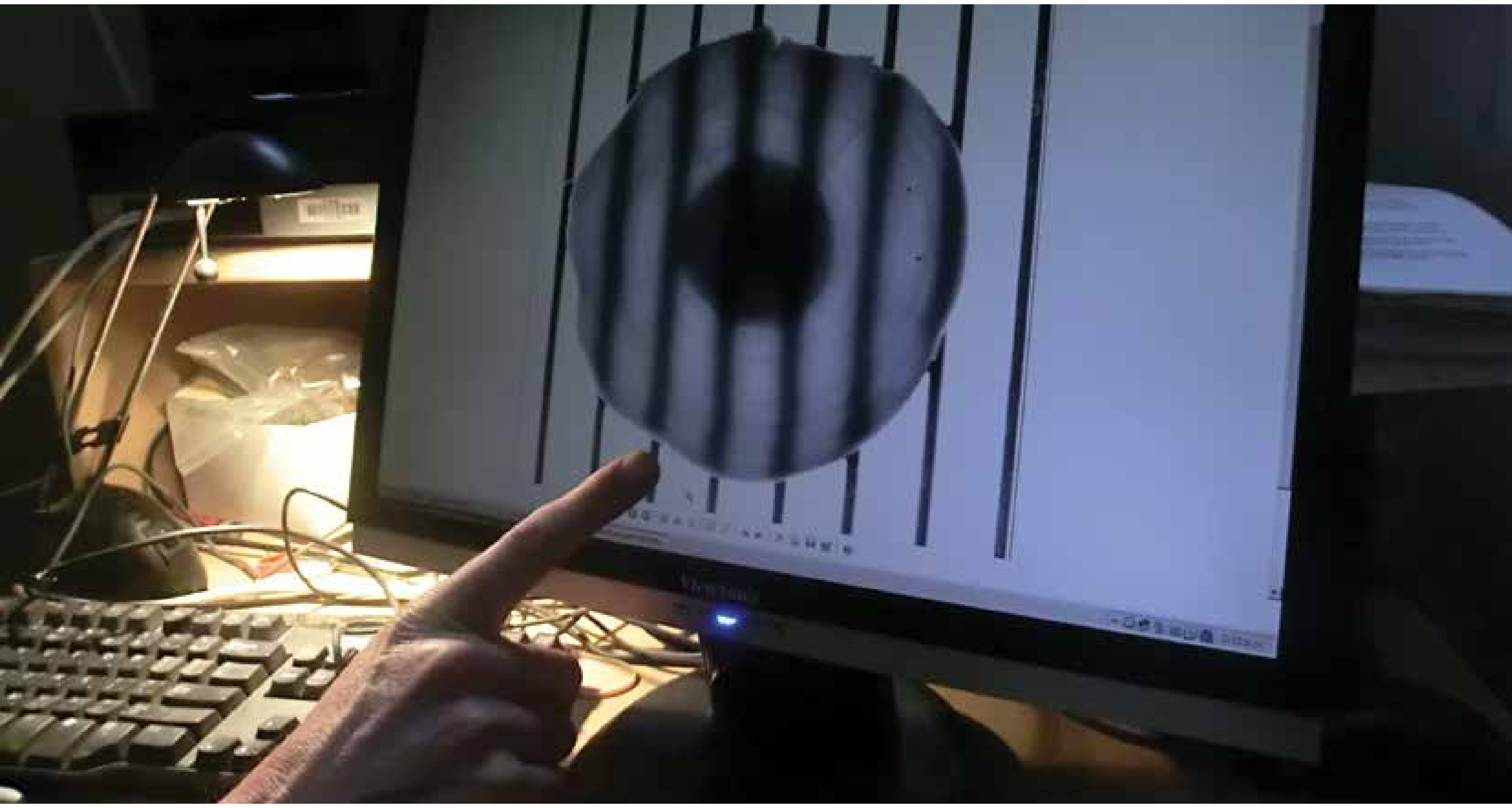
Scion is building a system that will enable rapid measurements of these properties on whole discs that will, in turn, enable wood properties to be characterised at a scale necessary to enable the end-product performance to be predicted. This approach can then be applied to determine the impact that different combinations of site, silviculture and genetics have on end-product quality. Data for this analysis will come from the network of replicated trials that were established in the late 1980s and early 1990s and which contain different radiata pine seedlots growing at different stand densities (Carson et al., 1999). As an aside, one of the field trip options at the 2014 NZIF conference in Napier visited one of these trials at Glengarry Forest, which was arguably one of the most productive radiata pine stands in New Zealand. The trial is scheduled for felling in 2015, and it will be interesting to observe the wood properties of these trees and the resulting end-product performance.

The broad scale characterisation described above enables stands to be selected based on their average wood properties, but what about individual trees within these stands? The variation in wood properties that occurs between trees growing in a stand is generally less than the variation between stands or the variation within a tree, but it is still important, as it is generally the 'rogue' logs that cause the problems for processors. Trees within a stand are processed into logs on the basis of visual features, but not generally on the basis of wood properties as these are potentially more time-consuming and costly to measure (Young, 2002).

In addition to the use of portable or harvester head-mounted acoustic tools, recent advances in remote sensing also offer the possibility of assessing tree characteristics that affect end-product quality (van Leeuwen et al., 2011). Terrestrial LiDAR enables features such as diameter, shape and branching patterns to be quantified on standing trees (Figure 3). Early research into the biology of wood formation proposed a link between crown structure and internal wood properties of trees (Larson, 1969). Information on crown size and shape are readily available from aerial LiDAR (Figure 4), and this could be used to segregate trees on the basis of their internal wood properties if a link between the two can be established. However, for this segregation method or indeed any segregation method to work and be implemented the benefits must outweigh the cost.

## Creating high quality future forests

Having harvested a stand, the challenge for a forest manager is deciding on the management objectives for the next rotation. This, in turn, will guide decisions on the choice of tree stocks and the silvicultural regimes to employ at a given site. It is not possible to know exactly what the market will want in 30 years' time when the trees planted today are harvested, but it is certainly reasonable to assume that features such as compression wood, internal checks, resin pockets, large knots and low stiffness wood that is prone to distortion are unlikely to be desirable. Many of the key wood properties that affect end-product performance are under strong genetic control, but early tree breeding efforts mostly focused on growth and form traits rather than wood properties



Assessment of spiral grain angle on logs using transmitted light from a flatbed scanner. Source: Scion Digital Image Library

(Burdon, 2008, 2010). Nevertheless, improvements in stem form certainly provided for increased returns for both growers and wood processors.

More recently, radiata pine tree breeding programmes have focused explicitly on wood properties. Both density and stiffness are priority traits within the Radiata Pine Breeding Company's programme, with resin bleeding, internal checking and spiral grain used as culling traits. One of the challenges for tree breeders is the overall adverse correlation between growth traits and wood quality traits.

Figure 3: Terrestrial LiDAR image of a standing tree captured using the ZEB1 instrument. Source: Courtesy of Rod Brownlie, Scion

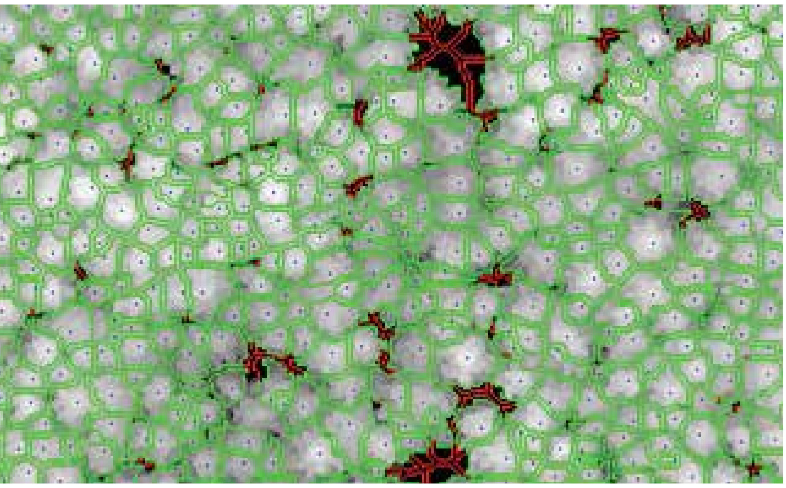


Figure 4: Aerial LiDAR image showing the extent of individual tree crowns in a radiata pine stand. The red lines indicate the area potentially available to a tree but not occupied by the crown. Source: Courtesy of Dave Pont, Scion

It is often difficult to quantify the positive benefits from improving wood properties of radiata pine, but it is much simpler to quantify the negative consequences in terms of reduced volume growth. However, there are the so-called 'correlation breakers' – those trees that have both enhanced growth and better wood properties. Clonal forestry offers some exciting possibilities here as well as reduced tree-to-tree variation within a stand. This reduction in between-tree variation is demonstrated using data from the FR308 trial in Tarawera Forest, as shown in Table 1. This trial was established in 1996 and was designed to compare the growth and wood properties of seedlings, single-clone stands and mixed-clone stands. Ten years after planting, the single-clone stands were significantly more uniform in diameter growth and stress-wave velocity (a surrogate for wood stiffness) than trees from a GF23 seedlot.

Table 1: Comparison of within-block coefficients of variation (CoV) for DBH, height and stress-wave velocity between single-clone stands and seedling stands. Values in a column followed by the same letter do not differ significantly from one another at p=0.05

| Planting stock | DBH | Height | Stress-wave velocity |
|---|---|---|---|
| Control (GF23) | 14.1a | 5.66a | 12.8a |
| Single-clone stands | 11.1b | 5.00a | 9.4b |

There is still the issue of the within-tree variation in wood properties, which is generally greater than the variations between trees in a stand and between stands. Wood in the innermost rings – generally the first 10 to 12 annual rings from the pith – has lower stiffness, lower density and a higher propensity to distortion due to higher longitudinal shrinkage when dried coupled with high spiral grain angle (Burdon et al., 2004). This wood is referred to as corewood and is undesirable from a utilisation perspective. Because radiata pine exhibits rapid early growth and is managed on relatively short rotations, the proportion of corewood in a tree is relatively high (Cown, 1992).

Tree breeding can be used to alleviate some of the issues with corewood, as both the wood properties themselves and the age of transition to the production of outerwood are under a degree of genetic control (Gapare et al., 2006, 2009). Silviculture also has a role to play (Mason, 2006). If stands are grown at relatively wide initial spacing and radial growth is constrained later on, trees will have a high proportion of corewood. Maintaining diameter growth later in the life of the stand will ensure that there is a larger width of outerwood in a stem, which can be processed into boards rather than being chipped off in a sawmill headrig.

To be able to guide managers, practical tools are required to help them understand the implications of potential decisions. A number of wood property models are now available with the Forecaster modelling system, and these are discussed in more detail in the paper by Dave Cown and Leslie Downing in this issue.

However, it is still important to be able to understand the implications of forest management decisions on end-product performance. In the absence of this information, we are back to focusing on surrogate properties. For example, if we want to grow high quality clearwood for appearance products, what sites should we choose and what tree stocks and management regimes should we employ? Similarly, what combination of site, silviculture and genetics should we choose if we want to target a particular grade of structural timber or engineered wood product such as LVL (Moore, 2012)?

## Conclusions

It certainly appears that the desire to see greater added value processing of New Zealand's tree harvest has put more focus back on wood quality. The competitiveness of the domestic wood processing sector is affected by the properties of the raw material feedstock, while the confidence to invest in additional processing infrastructure depends on certainty around the quality and quantity of the future wood supply. A better understanding of the resource coming on stream over the next 10 to 15 years will hopefully go a long way to providing this confidence, while better knowledge on the factors that control wood properties and their variation will help to create more uniform and higher quality resources for the future. A key enabler in all of this is a better understanding of the implications of various decisions on end-product quality, rather than surrogate traits. This will provide a basis for quantifying the benefits of improving wood quality, something that at present is difficult to do.

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