Growing confidence in forestry's future Research Programme

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Technical Note

Economics of segregation based on wood properties

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Summary: An international review of the literature showed that although technologies are available for segregating stems, stands and logs based on some internal wood properties the benefits are not always clear due to high variability of wood properties, poor market signals (in terms of price) for wood with superior properties, and poor understanding of the costs involved across the value chain. A structure for an economic model to determine the viability of segregation for various intervention points in the standing tree to mill supply chain is presented.

Introduction

All of the participants in the standing tree through to finished product value chain operate in a globally competitive environment. Each needs to ensure that they maximise their returns and minimise their costs if they are to be adequately compensated for the investments needed to participate in the value chain. Log properties, particularly from plantation stands tend to be highly variable in characteristics influencing final product yields and value. Segregating stands and logs according to external dimensions and internal quality characteristics that best align with the markets and products of the end user is one activity that may contribute to improvements in competitiveness. Segregation is only likely to take place, however, if the economic benefits outweigh the costs for all involved in the value chain.

This technical note summarises some of the key points from an international review of stand, stem and log segregation technologies and economics [1]. It also outlines forthcoming research on the economics of segregation based on wood properties within the Growing Confidence in Forestry's Future programme.

Methods

An international review of the literature related to technologies for, and the economics of, log segregation was completed in 2015. The review made reference to 118 reports and papers. It covered international trends generating an interest in segregation based on wood properties, technologies for segregating stands, stems and logs, log tagging and tracking technologies, the costs and benefits of segregation, and economic models for evaluating the viability of segregation based on wood properties.

Review Findings

International Trends

There are a number of international trends generating an interest in the economics of segregation based on wood properties. These include:

- A decline in per capita consumption of industrial wood due to improved processing efficiency, recycling, and the development of technologically advanced wood products that provide similar performance but use less wood;
- Substitution of other materials for wood as the price of wood rises;
- A tendency towards fewer, but larger, more cost-effective sawmilling operations;
- Mill managers obtaining log supplies from outside their region or country when the cost of locally produced wood is too high or supply of suitable logs limited;

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- A downward trend in pulp log prices and changes in the prices of pulp logs and sawlogs becoming more highly correlated over time as wood processors essentially apply a “technological fix” to nature, and produce higher quality products from smaller logs with lower quality wood;
- Substitution to alternative land-uses from timber production when the returns from timber production are not high enough, potentially resulting in a decrease in raw material supply available for mills;
- Concern about increased production and logistics costs due to increases in the number of log sorts being handled;
- A rapid expansion of industrial plantations with fast growth rates and a higher proportion of corewood with poorer mechanical properties;
- Better understanding of the nature of within-tree and between-site variability in major wood properties.

Segregation and Tracking Technologies

Visual standing tree grading methods (size, shape, sweep, branches) were developed in the past to evaluate the potential of a tree to produce specific products. It is now known that wood product performance depends to a high degree on patterns of physio-mechanical properties such as wood density, microfibril angle (MFA), spiral grain angle (SGA) and shrinkage. However, inclusion of actual internal wood properties in standing tree assessment has proved much more challenging, partly because of some uncertainty about the most influential properties for specific products, and partly because of the additional effort required to measure them.

In general, external characteristics have almost no relationship with internal wood properties (with the possible exceptions of taper, resin bleeding, and sweep) and so are of limited value for stem segregation based on intrinsic wood quality, particularly when the issues are mainly with wood that was formed early in the life of the tree.

Wood density has also been commonly used in survey work as an indicator of regional variation in stem stiffness. Methods such as increment cores, acoustics, and near infrared spectroscopy (NIR) show reasonable correlations with density and stiffness. By necessity, measurements are usually acquired at breast height, and algorithms used to assign properties to other parts of the stem. These work well for broad scale resource assessment only.

There is currently no cost-effective method of assessing MFA and internal SGA in standing trees, apart from collecting large cores for SilviScan analyses. This technique is well suited to fundamental research rather than operational segregation. Also, despite the known contribution to wood stiffness, at least in the corewood, there appears to be little regional variation, indicating that overall, wood density dominates in the effect on wood mechanical properties.

While NIR is promising for standing tree assessment, particularly for some properties, there remain some limitations to its application due to the need for physical samples, regular calibration, and errors introduced during sampling and data processing.

Operationally, only acoustic tools are practical on a large scale. Their development has to some extent overcome the issue of expensive wood analyses. Standing tree acoustic tools can be operationally used for indicative stand level comparisons of stiffness or for comparative tests, such as in selection of genetic material, assessment of thinning impacts, but need further development for widespread application.

Many randomly occurring defects in the tree stem, such as resin blemishes, decay, intra-ring checks and reaction wood, play a role in the mechanical performance of timber. With the exception of external resin bleeding, internal defects remain hidden until wood processing, making them largely unpredictable from standing tree assessments.

There is now a possibility of incorporating some stem visual features into remote sensing tools such as aerial and terrestrial LIDAR. Combining LIDAR data with geospatial information to predict timber performance will be a real challenge, however. Within-tree variation is usually a much larger component than between-tree, genetic, or even between site variations.

In Finland, a detailed review was carried out of more than seventy papers which covered technologies that could be applied *post harvest* to the measurement of wood properties at sawmills or centralized processing yards[2]. This review includes laser technology, infrared imaging, acoustic and ultrasonic methods, microwaves, radio frequency scanning, x-ray, gamma ray and computed tomography imaging, magnetic resonance imaging, electric measurements, and visible light imaging. It noted that only a few of these technologies have been commercially applied in mills due to the need for intensive destructive sampling.

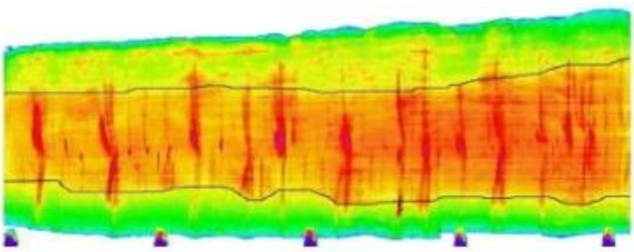


Figure 1. *X-ray and CT log scanning can potentially give very detailed data on internal features such as checks, resin blemishes, heartwood location and spiral grain. (Image Source: www.microtec.eu)*

3D shape scanning has now become almost standard in sawmills to ensure optimum log positioning for recovery but is of limited use for segregating logs based on internal wood properties.

X-ray and CT log scanning can potentially give very detailed data on internal features such as checks, resin blemishes, heartwood location and spiral grain (Figure 1). A small number of installations are in operation around the world.

It is feasible to assess spiral grain in logs using a laser point projected onto the wood surface of debarked logs. However, this only informs the observer about the external grain. Knowledge of the general pattern of spiral grain must be used to infer some log performance characteristics.

Currently acoustic methods have gained a lot of credibility for stiffness sorting. Acoustic log grading is already firmly established in some veneer mills, saw mills and central processing yards which have developed their own in-house sorting guidelines but there are no generally accepted rules for their application.

Due to the influence of resinous features on sawmill recovery of high value appearance grade logs methods have been developed for visually identifying stems and logs likely to give problems. Some companies now segregate logs in the log yard by visual inspection of log ends for signs of resin (Figure 2).

While few technologies and techniques for segregating logs based on wood properties have been commercially applied in mills and central processing yards, even fewer technologies are suitable for commercial application at the time of harvest in the forest.

Figure 2. *Visual assessment of features on log ends can be used as the basis for log segregation for appearance grade mills. (Image Source: commons.wikimedia.org)*

Knowledge of regional factors affecting wood quality and within-tree patterns has led to some forest companies using general rules that logs of a certain grade are only cut below a specified height or position in a tree. However, there is huge variation in properties from tree to tree within a stand.

Acoustic log grading is one of the few technologies that can be routinely used for sorting saw and veneer logs in the forest. The potential to include this technology into a felling head is currently being investigated (Figure 3).

Visual assessment of features on the ends of logs after they have been cut, such as resin bleed and checking, can be used as the basis for segregating logs in the forest for appearance grade mills.

Figure 3*. Acoustic log grading on a processing head. (Image Source: www.fibre-gen.com)*

While technologies are becoming available to assess and segregate individual stems and logs in the forest, in order to capitalise on the information gathered and the segregation undertaken it is vital to track the stems and logs further along the supply chain. Traditionally, logs have been marked or tagged on the ends with paint, a stencil, mechanical imprints, or a paper or plastic label at the forest or log merchandising yard prior to transport. New approaches such as the “fingerprint” approach (using unique features about each logs external shape and visible characteristics), radio frequency identification tags (RFID), and 2D-laser etched codes on log ends are being considered (Figure 4). Currently, however, there is no low cost, perfect tagging and tracking system available. Some segregation errors and associated costs should be expected.

Benefits and Costs of Segregation

Information on tools and techniques that could be used for measuring wood properties is more abundant in the literature than on the economics of log segregation based on wood properties. Market signals for wood properties tend to be weak, other than wood buyers preferring not to buy from some wood suppliers or regions. In practice, premiums are rarely paid to suppliers for material with superior internal properties. As noted by some authors, without price incentives processors will continue receiving the highest quality logs only sporadically.

The benefits of segregation don't always outweigh the implementation costs for the participant in the value chain undertaking the segregation.

In a Swedish study on sorting logs at a mill based on SGA it was concluded that the costs outweighed the revenues. Costs included the initial cost of installing equipment, raw material costs, and sawing production costs. Revenues came from bark and chips, from rejected logs with too large SGA [these were used for pulp], from studs with acceptable twist, and from studs with unacceptable twist [downgraded to lower value products]. Follow up interviews with some small and medium-sized Swedish sawmills showed disagreement with the results of the study. The mills claimed that their investment in sorting technology paid for itself very quickly and that the study did not take into account the cost savings from reducing production problems caused by large SGA logs, or the economic value of customer perception when producing better quality sawn timber in terms of straightness.

Internal checks that develop in mountain pine beetle killed trees cause lumber value losses from 17 per cent to 40 per cent in Canada. X-ray scanners can detect up to 60 per cent of checks depending on the check width and orientation with respect to the direction of the X-rays. A Canadian study found that the return on investment of an X-ray scanner was insufficient (2 per cent) when the log supply was lightly checked, but could be as high as 27 per cent when the log supply was comprised of severely checked logs.

Figure 4. *Tagging and tracking logs segregated on the basis of internal wood properties helps to ensure that the right wood gets to the right customer. (Image Source: www.cumberlandsystems.co.nz)*

Two New Zealand studies on the benefits of acoustically sorting radiata pine logs for stiffness found that there was a trend of increasing revenue from logs with higher acoustic velocities; up to 27% higher revenue for one study. The authors of one study noted however, that under current market log prices, "processors have more incentives to purchase [high quality logs] than the growers have to produce them and without incentives processors will continue receiving the highest quality logs only sporadically".

Similarly, a study on the benefits of acoustically sorting Douglas-fir logs for a laminated veneer lumber mill in Oregon also reported a positive relationship between the economic value and the average log acoustic velocity for each of the six stands included in the study.

An Australian study showed that an acoustic measurement system fitted to a harvester head could be used to identify and segregate low stiffness saw logs in a radiata pine plantation without having a significant effect on harvesting productivity.

Central processing yards (CPY) are facilities, on- or off-forest, in the supply chain where log processing and segregation can take place. Two studies carried out in western North America and New Zealand found that CPYs provide an opportunity to more closely examine log characteristics, but increase handling costs in yards. When segregation was accomplished in a CPY in western North America net returns were US$1.50 m^{-3} lower than when less accurate segregation was undertaken at a landing in the forest. It should be noted that segregation in both studies was based solely on external stem characteristics.

Some of the benefits of operating a CPY accrue to the forest owner, rather than the CPY operator. These include reduced forest engineering costs due to smaller forest landings, reduced unproductive forest area, reduced in-forest extraction and loading costs, improved stock control, reduced forest waste disposal issues, and increased harvesting productivity.

If segregation is done in the forest at the time of harvest it can have an impact on a range of harvesting production variables such as equipment requirements, value recovery, waste generation, productivity, costs and landing size.

Studies carried out in eastern US have found profitability for the forest owner increasing up to six sorts. Beyond six sorts for tree length harvesting systems and nine sorts for roadside log processing systems net revenue was reduced by 6 to 15 per cent.

A recent New Zealand study found that the optimum number of sorts for steep country harvesting operations was nine when gross value recovery, expressed in dollars per hour of production, was considered.

A study was carried out in New Zealand to determine if the additional costs of data collection, log segregation and supply chain complexity, associated with sorting and segregating radiata pine logs on the basis of internal wood characteristics as well as external characteristics, could be sufficiently covered by higher log prices[3]. This was the only study we found that considered the supply chain from standing tree through to end-product leaving the mill. Segregation of structural wood was assumed to be based on density cores for stands, and on sonic tests for stems and logs. Appearance grade wood was assumed to be segregated on the basis of resin bleeding for stands and log end resin pockets for logs. Similar conclusions were drawn in regards to segregation based on stiffness or resin properties. Where forests contained high or low amounts of high stiffness material (or resinous material), segregating stems or logs in the forest offered only limited marginal net returns compared with no segregation. Only where there was a roughly even distribution of stems with the wood property, would segregation of logs increase marginal net returns compared to segregating at the stand level only. The authors also noted that there was a lack of good data on the impacts of log segregation on supply chain productivity, engineering and wood handling costs, processing costs and product outturns.

Models for Determining the Economics of Segregation

Most of the existing economic models tend to look at the economics of segregation from the perspective of a single participant in the value chain, e.g. a structural mill or a central processing yard. Only a few models look across the value chain and these have limitations often poorly representing some participants in the value chain. Good data is also an issue because of the expense of carrying out processing studies and wood property assessments.

A combination of approaches used in previous studies [3, 4] could potentially be used to evaluate the economics of segregation for New Zealand situations. Briggs (1989)[4] utilised mill recovery studies to determine return-to-log values for lumber, veneer, and pulp logs. Mill manufacturing costs, harvesting and transportation costs, and log purchase costs were taken into consideration to obtain net return-to-log values at various points in the supply chain. These net values were then applied to a tree list using a dynamic programming algorithm. The optimal combination of log sorts could then be determined. Dale et al. (2006)[3] determined the marginal profit (or loss) of segregation by subtracting the cost of segregation and the value of logs without segregation from the value of logs with segregation. Values were based on return-to-log at mill door analyses. Segregation costs included measurement costs specifically related to segregation, additional engineering costs for the construction of landings and roads, sorting costs, and additional transportation costs. Costs related to the potential decrease in harvesting crew productivity from having to do the extra segregation were not included in the analyses. Although their model could be used to evaluate segregation for structural or appearance grade mills these were treated as separate sets of analyses; raw material that did not meet minimum standards was assumed to be sold at some other suitable market. Only a portion of the stand or stem is considered in this model.

While models will be useful in examining the broad level implications of segregation, it is clear that individual companies will have to take the initiative in evaluating their own situation regarding resource supply characteristics and markets.

Conclusions from Review

Regional or stand level attribute models will facilitate a coarse level of segregation but not account well for the between and within stem variation.

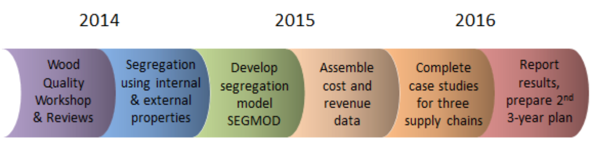
Many tools and techniques are available for segregating wood based on internal properties but few have been implemented commercially. Some are better suited for application in mills than in forests.

The benefits of segregating stands, stems and logs based on wood properties are not clear due to high variability of wood properties, poor market signals (in terms of price) for wood with superior properties, and poor understanding of the costs across the value chain.

Most of the existing economic models tend to look at the economics of segregation from the perspective of a single participant in the value chain, e.g. a structural mill or a central processing yard. Only a few models look across the value chain and these have limitations often poorly representing some participants in the value chain.

Where To From Here?

The international review of the literature, which is summarised above, was supported in 2014 by technical reviews of (a) the wood quality characteristics that can and are being captured by on-board computers on modern harvesting and processing machines, and (b) the strengths and weaknesses of three data sources for resource assessment of internal wood properties; aerial lidar scanning data, terrestrial lidar scanning data, and harvester head data.



In 2015 a model (SEGMOD) of standing tree to mill-door operations will be developed that allows determination of the economics of stand, stem and log segregation from the perspectives of the total system and the agents in the supply chain; forest owner, logger/transporter, central processing yard (CPY) operator, mill-owner. SEGMOD will allow multiple intervention points, levels of segregation, and use of different segregation technologies. SEGMOD will incorporate important features of earlier approaches[3, 4]. A priority list bucking algorithm, developed in 2014 as part of this project and that accounts for both internal wood quality characteristics and external stem characteristics, will be included in SEGMOD[5].

The available revenue data for each of the agents in appropriate supply chains will be assembled. If the market does not provide price signals for segregation, "return to log" analyses at multiple intervention points in the supply chain, will be undertaken using the best available information. Scion's log and lumber database, which includes information from many mill conversion studies carried out over the past few decades, will be a prime source of information. Available cost data related to forest inventory, logging, transport, CPY operation, and millyard operation will be assembled and used to estimate the impacts of increased segregation practices.

The utility of the preliminary model will be demonstrated in 2016 by applying it to three case studies that have opportunities for multiple segregation intervention points along the supply. The case studies are likely to be carried out in Nelson/Marlborough, Hawkes Bay, and Bay of Plenty.

At the end of 2016 a report describing the key findings from the first three year period will be prepared and, if the findings indicate that further research is warranted, a work programme for the second three year period of the project (2017-2019) will be developed.

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