Forest & Wood Products Australia

Project Report

ASSESSING & MANAGING MID-ROTATION WOOD QUALITY IN AUSTRALIAN SOFTWOOD PLANTATIONS TO PRODUCE FIT-FOR-PURPOSE LOGS

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Assessing and managing mid-rotation wood quality in Australian softwood plantations to produce fit-for-purpose logs

Prepared for

Forest & Wood Products Australia

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Executive Summary

This project has underpinned a revolution in the easy access of information about the wood quality for softwood growers and processors. Resi data from pre-harvest assessments has predicted mill site-mean board stiffness in sawing studies across multiple sites in Australia and is now used routinely by many companies.

YTGen has incorporated Resi data to allow predictions of yield and wood (log) density of harvest age plantations. Simulated mid-rotation Resi measures in YTGen provided good estimates of harvest age mill measures of site mean green board stiffness. This can contribute to decisions on rotation length.

Sources of error between Resi instruments, operators, drill bits and batteries have been investigated and found to be negligible at a commercial scale. This gives confidence that Resi measures from a range of tools and/or operators can be treated as equal.

Specifically, the project has addressed a wide range of factors affecting the operational commercial use of resistance drilling technology using the IML Resi. Sources of variance between instruments, operators, sampling conditions, trees, plots and forests has been quantified.

- Relationships between preharvest measurements and mill production quality has been examined and confirmed that Resi data predicts mill out-turn at a compartment level.
- Additional functionality from Resi metrics to explain radial variation and consequently effects of silvicultural treatments has been demonstrated.
- Improved understanding of radial and longitudinal variation in wood quality has been generated, and how this varies between tree, site and age class.
- Findings from the project have been incorporated into a new version of the Resi web trace processor to ensure the industry has access to the improved algorithms that predict density and MoE.
- Models have been developed and incorporated into YTGen to predict log density and yield of harvest age trees in commercial applications.

Recommendations

Resi use needs to be taken to the next level to support grower-processor communication to optimise wood flow in the medium term and increase the volume and value of wood in the future through superior plantation management. In addition, a better understanding of the importance of site, climate, management, and genetic factors on MoE and structural grade percentages, using large, estate-wide datasets is needed and now possible.

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Introduction

This document provides a high-level summary of the project outputs within the context of the initial deliverables defined in the proposal documentation.

Research activity was focussed on the following sub-projects.

1. Standardising the use of Resi across the industry
2. Linking Resi to mill output
3. Linking Resi to Yield and Value tables
4. Resi-based early selection for harvest-age MoE
5. Resi, rCambium and the environment

The following is an overview of the commercially important outcomes, directing the user to over 600 pages of detailed sub-project reports for those seeking more information. This work builds on 10 years of FWPA-funded research. The focus of the current project, the questions posed and where in the plantation cycle this was implemented is shown in Figure 1.

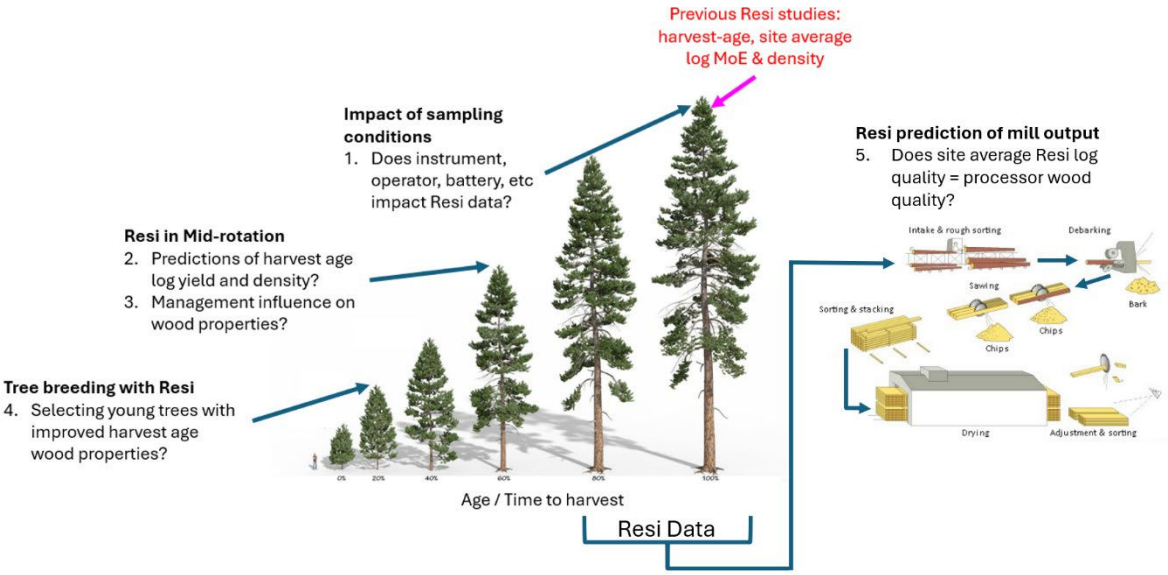

Figure 1. Age of plantation sampled by Resi and the focus and questions asked during the current project[1].

Methodology

The methodology for each component of the study is presented in the detailed subproject reports cited throughout this report.

[1] Images adapted from: https://cornucopia3d.e-oncontent.com and https://www.globalspec.com/learnmore/specialized_industrial_products/wood_processing_products/lumber_sawmill_equipment, accessed on 30/07/2024.

Results and discussion

Standardising and optimisation operational use of Resi for the industry

A key component of this sub-project has been to explore and quantify the effect of factors affecting the relationship between drilling resistance and basic density estimation. These factors include between-instrument variance, needle diameter and wear, species, operators, forward and rotational drill speeds. While a major industry focus has been on the prediction of log MoE, this component of the project has focussed on factors affecting Resi amplitude and basic density estimation, underpinning the development of predictive log MoE models.

To this end, a standard use protocol has been developed, based on an existing document prepared by FCNSW in 2019 for their internal use. This document provides users with the information required to use and maintain the Resi tool in an effective manner (1).

Factors affecting the Resi amplitude – basic density relationship have been investigated with the following outcomes:

- Between instrument bias among 7 different instruments has been found to be small and in the order of +/- 8 kg/m^3 (2)
- The effect of different operators on Resi amplitude values has been found to be non-existent (2).
- The effect of different sampling conditions (RPM and feed speed) on resistance amplitude has been quantified across a range of log types, obtained from 6 different commercial species with widely varying mean basic density. This has led to improved standardisation algorithms which have been incorporated into Version 5 of the ResiProcessor. The volume of wood removed (chip thickness) from each revolution of the needle has been found to be the optimal factor to minimise the effect of sampling conditions. For the commercial softwoods (radiata and southern pines) the focus species of this project, the sampling conditions of 200 cm/min feed speed and 3500 rpm have been recommended as optimal to maximise amplitude while minimising instrument wear. This represents a change in the rpm setting from 2500 rpm as recommended at the start of the project (3, 4).
- The effect of drilling distance on needle wear, and the consequent effect on Resi amplitude has been quantified across a range of species, represented by individual logs of varying basic density. For the commercial softwoods, the existing recommendation of changing the needle every 1000 traces taken has been found to be conservative (5, 6) however this recommendation is maintained.
- For higher density hardwood species (e.g. spotted gums) more refinement of the sampling conditions is required, as needle wear is greatly increased (4).
- Battery and needle size impacts on MoE and density predictions are significant under test conditions (0.5% and 1.7% respectively) but not significant at a commercial scale (5, 6).
- Resi data has been evaluated against other gold standard non-destructive sampling tools (e.g, SilviScan and USMoE) and found to be operationally accurate but it has a larger bias. Resi does not predict stiffness of the inner wood near the pith as well as these gold standard tools (7-10).

Linking Resi to Mill outputs

The commercial value of, and confidence in, the use of non-destructive evaluation tools for assessing wood quality (WQ) has been increasingly recognised. This is demonstrated by the number of industry research partners who have invested in a Resi instrument and especially those that have purchased multiple Resi instruments. For many of these partners, using Resi for WQ assessment has become routine, as has the supply of compartment WQ metrics to sawmill customers (OFO/GTFP>OFO; OFO>AKD; TPPL>Timberlink; HQP>Hyne). While sawmill customers are typically in the stage of data-gathering, the evidence supporting the commercial value of these metrics is increasing.

Resi has been demonstrated in various mill trials (within and prior to this project) to provide strong indicators of green and or dry mill product quality on a site average level. In a study conducted in conjunction with OFO/GTFP and the OFO Jubilee Mill Trial in 2021 as part of this study the following was found:

- Strong links between preharvest breast height Resi and green and dry mill board density and stiffness across 10 sites sampled.
- Strong links between Resi, HM200 individual log metrics and mill product (11, 12).

In a study by HQPlantations and Hyne Timber, strong relationships between preharvest southern pine coupe assessment using Resi and green mill product were found (D. Kain pers comm, 2022).

Data from the OFO Jubilee mill trial (this study), in conjunction with data from seven other mill trials involving 18,000 logs has demonstrated that Resi was useful at ranking sites (not individual trees) and estimating mill out-turn of green/dry mill boards (13).

Variance partitioning

During the study, mid-rotation Resi sampling in radiata pine could explain variance in harvest age log and board properties and inform management to maximise volume and value (14) but the predictions were biased as Resi data was collected from the butt-log whereas the mill data was based on all logs from the trees (15).

Linking Resi to Yield and Value tables

A major component of the project has been to identify sources of variance in basic density estimation. Much of this has been undertaken within the context of developing yield table functionality as part of the development of the **YTGen software**. Utilising a large selection of data sets contributed by OFO and GTFP as part of the Jubilee Mill trial, a major report was delivered that identified variance components between trees, plots and forests (16). Similar work was also undertaken within the softwood resource in NSW (FCNSW data), Tasmania (TPPL), and Queensland (HQP).

As part of the commercial use of breast height Resi data, patterns of longitudinal variance in density and volume were analysed within the context of taper study data sets contributed from HQP, FCNSW, TPPL and HVP. Field work protocols were defined in collaboration with the

industry partners. These data sets allowed the BH Resi data to be developed within YTGen to produce models allowing log volume and density estimations (16, 17).

Resi-based early selection for harvest-age MoE

Forward prediction from mid-rotation sampling

Forest planning is assisted by understanding how mid-rotation wood volume and quality relates to, or predicts, harvest age volume and quality. A series of analyses demonstrated that partial Resi traces, representing early-age sampling, were strong predictors of harvest age Resi traces, but more importantly also provided good estimates of mill measures of site mean green board stiffness (15, 18, 19).

Detecting the impacts of stocking on wood quality

A series of trials examined the use of Resi data to better assess the effect of initial stocking on wood quality. Often these trials showed no significant effect on wood density or stiffness when examined at the individual tree mean level. Utilising the radial variation patterns provided by Resi sampling, allowed the effects of initial stocking on the trajectory of volume and wood density to be differentiated more clearly. Ultimately this allows better forward prediction of stocking effects on harvest age log volume and quality (20-22). This is demonstrated in Figure 2 showing a *Pinus radiata* trial assessed by Resi at age 15 years. The density trajectories of the different stocking rates are clearly shown with the lowest stocking having the lowest density both now and into the future.

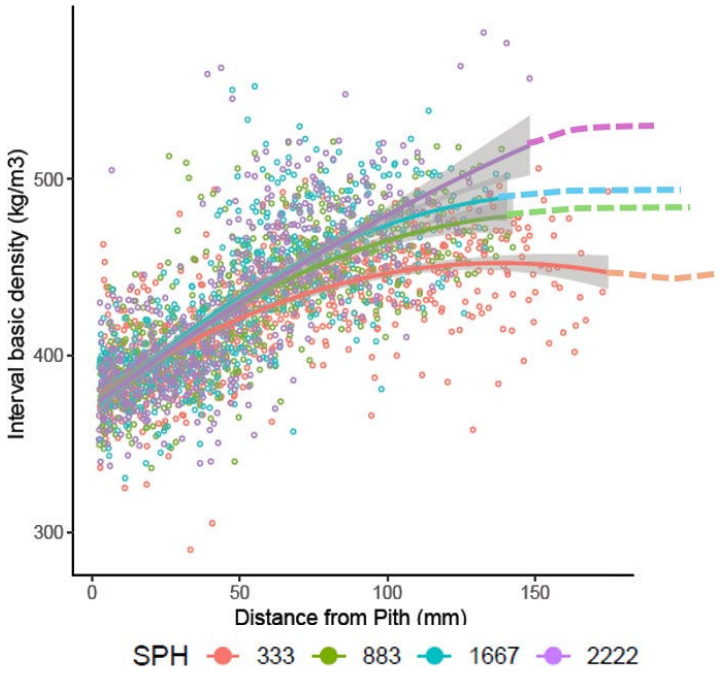

Figure 2. Resi trace trajectories of fifteen-year-old *Pinus radiata* trees planted at different stockings and predicted future basic density (dashed line).

Resi selection for wood properties

The estimation of stiffness in young (<10yo) softwood plantations has generally been better predicted by ST300 acoustic velocity measures than Resi in previous studies. However, Resi data from young trees was found to be a similar predictor of harvest age wood stiffness with a higher heritability than the ST300 possibly due to the dependence of the ST300 measures on microfibril angle variance whereas the Resi only predicts density (23). The key benefit of the Resi is that it is 3 times faster for data collection than the ST300, hence more trees can be sampled resulting in greater prediction power.

Improved prediction models

Density

As a result of the work identifying the optimal sampling conditions mentioned previously, the non-linear nature of the relationship between Resi amplitude and basic density was identified when basic density exceeded 600 $kg.m^{-3}$ (2). While in the range commonly encountered in softwood plantations, the relationship is essentially linear, a non-linear logarithmic relationship was defined and made available within the Resi processing web platform. The effect of high density, heat generation and potential wood softening as a consequence requires more investigation and understanding.

Modelling pith to bark wood properties

Pith-to-bark wood property variation in plantation softwoods is known to be typically sigmoidal. However, patterns can vary markedly between and within trees as a function of age, growth rate, genotype, stem height, silviculture and environmental variation. Resi data has been segmented into percentage increments of the radius and this better predicts within tree variation of wood properties (24, 25) than the previous models that assumed a linear relationship. This is being incorporated in the new ResiProcessor platform (V5) that was released in August 2024 (see: https://forestquality.shinyapps.io/FWPA-5/).

Future R&D requirements

Resi has been accepted as a commercially useful wood quality assessment tool. To date it is the only tool that seems to meet the viable cost and precision requirements for routine commercial forestry operations. Future work will emphasise 'wood quality assessment' rather than 'Resi development'. The focus has now shifted to the systematic study on wood volume and quality specifically:

- Microsite variation with respect to soil type, water logging, and interactions with fertilisation and stocking / thinning,
- Broader species range (Araucaria, Pinus pinaster, dryland species, hardwoods) to improve the value proposition,
- Within-tree (radial by longitudinal variation in density, MOE and taper) across the landscape as affected by site, latitude, climate, and management factors to make better use of all logs,
- Predict the percentage of structural wood in standing plantations and improve the understanding of wood quality variation (distribution) within coupes,

- Increasing the value of the wood basket through timely interventions to maximise growth and wood quality,
- Improved log – board predictions for processors.
- Explore the effect of moisture on drilling resistance and log MOE relationship. That would allow for improved log MOE predictions using drilling resistance. This could be achieved by directly calibrating tree drilling resistance with dried log MOE.
- Automation of Resi data capture to facilitate log sorting in the field.
- Integration with other technologies e.g. Lidar and photogrammetry) to improve recoveries by processors.
- Cost benefit analysis of the non-destructive evaluation studies over the last 10 years.

Conclusions

This project has underpinned a revolution in the easy access of information about the wood quality for softwood growers and processors. Resi data from pre-harvest assessments has predicted mill site-mean board stiffness in sawing studies across multiple sites in Australia and is now used routinely by many companies.

YTGen has incorporated Resi data to allow predictions of yield and wood (log) density of harvest age plantations. Simulated mid-rotation Resi measures in YTGen provided good estimates of harvest age mill measures of site mean green board stiffness. This can contribute to decisions on rotation length.

Sources of error between Resi instruments, operators, drill bits and batteries have been investigated and found to be negligible at a commercial scale. This gives confidence that Resi measures from a range of tools and/or operators can be treated as equal.

Recommendations

Plantation growers and processors are now appreciating the benefits of working together to understand and utilise Resi data to improve wood flows. Resi use now needs to be taken to the next level to support grower-processor communication with a view to optimise wood flow in the medium term and increase the volume and value of wood in the future through optimal interventions. In addition, a better understanding of the importance of site, climate, management, and genetic factors on MoE and structural grade percentages, using large, estate-wide datasets is needed and possible.

Reports and publications associated with the above deliverables

These reports and publications are available from FWPA.

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