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Value Chain Pilot Study

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EXECUTIVE SUMMARY

To better understand how to build future value chain systems, a pilot study was undertaken to model scenarios through existing modelling tools and frameworks that represent parts of the forestry value chain.

Two scenarios, involving genotype and regime combinations on a CNI site, were simulated through stand growth, stem modelling, log making, sawing and end product performance in terms of stiffness and stability.

The outcomes of this study have been very worthwhile in terms of improving the understanding of how modelling components work, what are their deficiencies, and what improvements can be made. Key outcomes are:

1. Proof of concept that stems with different intended end uses can be modelled along the value chain, and that the end use performance of the wood products derived from these stems can be predicted.

2. There is a need for an integration framework. The current modelling is via a string of disconnected software packages. This issue is addressed in Objective 3.

3. Accurate and detailed wood property functions are required before the future prediction of end use performance of wood from virtual stems will be possible. This emphasises in the short term the need for the wood quality modelling work of Objective 1, and in the longer term the simulation work in Objective 2.

This study does not attempt to quantify the accuracy or validity of results. Any results given are for demonstration purposes only.

BACKGROUND

Objective 3 in the Radiata Management Theme research programme begins with a survey of members on decision making and expectations of tools by key decision makers. It then goes on to run a pilot study of value chain modelling, while concurrently assessing from a selected user group, the likely requirements these users will have of the system. This report gives details of the pilot study.

To better understand how to build future systems, it was considered of value to model a scenario through existing modelling tools and frameworks as a pilot study. This exercise would improve the collective understanding of the strengths and weakness of current modelling tools, and gain insights into the gaps and technical challenges in Objective 3.

INTRODUCTION

This study arose from a workshop with fellow wood quality and forest management scientists in CSIRO, particularly M. Battaglia and G. Downes. When one describes modelling and simulation concepts, much can be misunderstood and misconstrued. The phrase "the devil is in the detail" is very apt, and unless concepts are taken further into data models and simulation processes, where assumptions are transparent and methods fully understood, little progress is made in terms of a shared understanding of how to build broader systems.

Past and present modelling systems already attempt some level of value chain modelling (not supply chain), but generally relate to only sections of the chain, and generally give results as standing volumes, log grades, and lumber grades, i.e., not end product performance.

Value chain models can operate at differing levels of resolution, i,e., forest estate issues, (yield regulation and resource allocation); stand issues, (yield tables, regime evaluation), or tree/stem level, with 1 Dimension, 2D, or 3D resolution for final product end use performance modelling.

This study attempted to use only stand level tools that provide stem models which could be enhanced and transferred to log processing tools and finally to product performance models. The intention of the study is to gain understanding of system construction, not to produce useful and meaningful results. The systems are simply not ready or validated to produce results that can be used or trusted.

METHODS

Initially scenarios were constructed to provide a useful range of sites, genotypes and silvicultural regimes. Because the aim here is not to get meaningful quantification of differences, but to gain understanding, and because processing logs at the required level of detail can currently take several days of computation time to process each iteration, only two scenarios were selected.

Scenarios

Scenarios are as follows: (see Appendix 1 for greater detail)

a. One site; Central North Island, New Zealand
b. Two genotypes of radiata pine – Growth & Form (GF) multinodal/straight/small branch type and Long Internode (LI) large branched/less straight type.
c. Two silvicultural regimes – Framing regime for GF genotype and Clearwood regime for LI genotype (see Appendix 2)
d. Logs from the Framing regime were sawn into structural dimensions (100x50mm) and logs from the Clearwood regime were sawn into appearance-dimensioned (150x25mm) lumber.

The intention of these scenarios was to produce two contrasting “Target Tree or Stand” types – one intended for structural/framing lumber purposes, and the other for appearance/clear cuttings lumber purposes.

Modelling

Both CSIRO’s Cabala and Scion’s ATLAS Forecaster modelling systems were used to grow theoretical stands through to maturity. Cabala can be used to simulate forest productivity for ‘Greenfield’ sites, and in association with CSIRO’s Cambium model, can produce cell growth patterns by ring number at breast height. Cambium was not used in this study, but shows potential for better modelling of wood properties by taking into account dynamic influences on tracheid development (such as climate and competition).

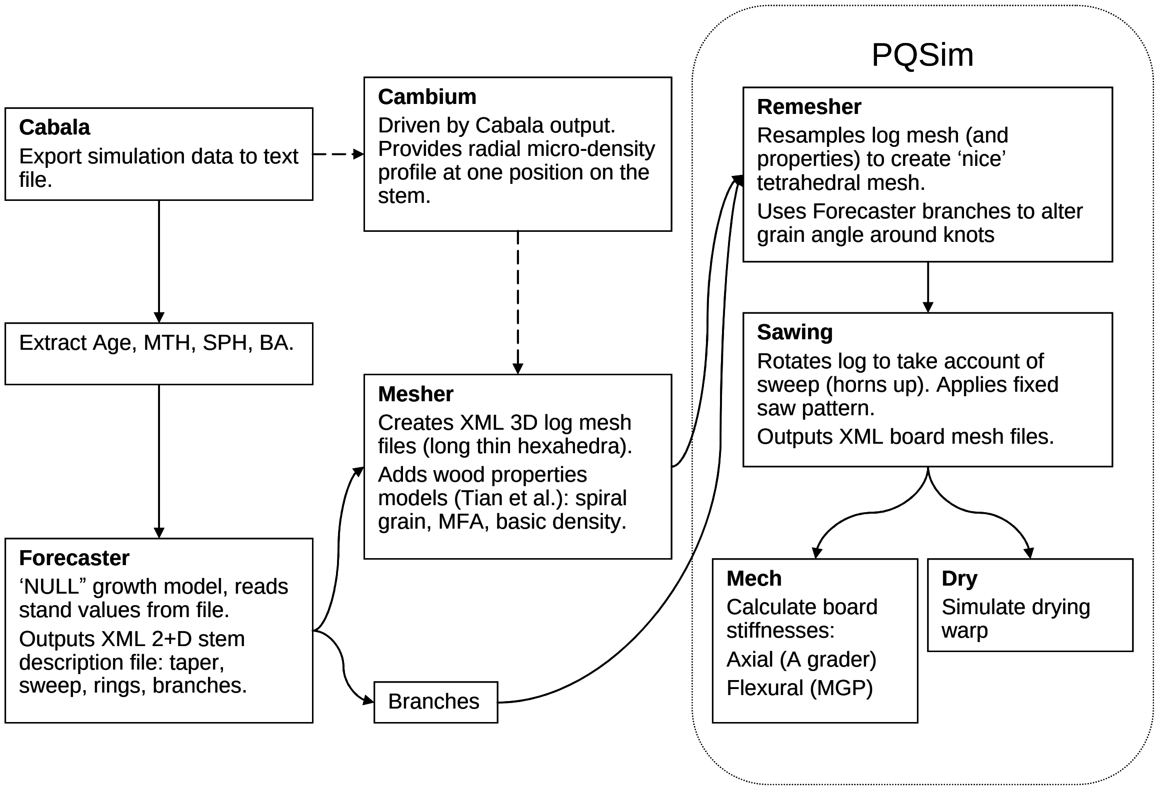
Cabala was not used directly; rather, Forecaster was altered to accept growth output from Cabala, and can be used in the future to combine the process growth modelling with empirical branching, sweep, and log making capabilities.
In New Zealand the tree growth rate can be calibrated to a productivity level - 300 Index (MAI of 300 pruned stems at age 30yr) using, where possible, actual plot data averaged for the region. (Plantation Management Coop report 92, 2005)

The branch and stem modelling were simulated in Forecaster, and branches were grown via BLOSSIM; this process creates stem models. Stems are cut into logs, and pulpwood has been discarded.
Stems were viewed by the Stem Piece Viewer, and one representative stem was selected from the distribution modelled, from near the mean DBH, representing the Target Tree type, i.e., in total two stems were taken further down the value chain.

Stem models from Forecaster were enhanced by a “Mesher” that creates a 3D mesh and adds key wood properties (density, spiral grain and MFA) to the mesh points (see Appendix 5) for each log. Log information was then passed to “Remesher” that adds branches (ex Forecaster) and alters grain angle around knots.

Sawing of logs was simulated with a simple fixed sawing pattern (150mm cant with 25mm boards for appearance, and 100mm cant with 50mm thickness for Framing). Boards are described with a high resolution (5x5x5mm) mesh (see Appendix 6), and the board files are then evaluated for stiffness or stability.

The following diagram provides the flow of data and activity points.



RESULTS

Output

The log grades and volumes for the Forecaster simulations are given in the standard log yield reports in Appendix 3. Details of the two stems chosen are given in Appendix 4.

Issues Identified

The feasibility of value chain modelling with current tools has been considerably advanced. Gaps and enhancements have been highlighted.
In particular, and by stage:

Forecaster:

1. The addition of the ability to add a "null" growth model to the system (i.e., provide only rotation end – Age, BA, SPH, MTH, Vol) has been proven, but reporting on assumptions in the growth modelling is separate.
2. Modelling of long internodes is not achievable within the current LI model selection (data used to construct this function were not very uninodal), but the structure and implementation is very easily changed, and the probability of 1, 2, 3, or 4 nodes occurring in a growth shoot was manually set in this study.
3. Stems modelled in Forecaster are only 3D in terms of branch azimuths; otherwise all wood quality attributes are 2D. Forecaster xml does not have grouping entities for Stratum, Plot or Stem, which limits post-processing and analysis to the 'Piece' and 'Run' levels.
4. In Forecaster, branches (and annual shoots) are created on the 'birthday' of the date the stem was created, and branches are created at the final size for that year. This means there will be some overestimation of branch size.
5. Branches are currently described with two points defining a cone. An extra point could be added to locate the start of bark encasement for dead branches. This is important only for visual grading, and was not done in this study.
6. Stem taper is derived using taper functions. The applicability of these to earlier ages, and thus the internal distribution of annual ring boundaries, is not known. Fitting taper function at ages where tree height is less than 4m requires further assumptions about stem form.
7. StemPiece holds planting and harvest dates, so the amount of growth in the outermost annual ring can be known. Currently wood properties for that ring are for a complete ring.
8. Currently Forecaster includes a density model that gives average density for an entire cross-section. These values were not used in this study, as ring level detail was required.

Stem Modelling:

1. The wood properties models used in this study (basic density, spiral grain, MFA) are old and in need of upgrading – they are not the latest available.
2. A way is needed to add pith to stem models without affecting under-bark diameter at the stem surface. We have done a scaling from 5mm at first ring to 0 at the outermost ring, but this slightly inflates the size of the juvenile core.

Sawing:

1. Sawing was simulated with only primary breakdown, with no resawing or docking for grade, and no saw kerf

Product performance:

1. The computational processing time to make stability calculations is currently very long. Stiffness calculations are also slow. The main determinant here is the expanding amount of information in association with increasing spatial resolution. In Forecaster, an entire tree can be described in terms of a few numbers (DBH, height, volume). Each tree is then bucked into several logs, each of which is described with a relatively coarse 3D mesh, resulting in 1-10 MB of information per log. Each log is then sawn into several boards and re-meshed with a fine mesh, resulting in around 200 MB of information per board.
2. Sensitivity analyses are required to understand the trade-offs between accuracy of stability and stiffness results and processing time (mesh resolution).
3. No visual grading capability was available for this study. The SMAPs component of AUTOSAW, utilised several years ago in TreeMaps, would provide adequate functionality (preferable to the alternatives: no visual grading; or developing a purpose-built component from scratch). Proposal: link SMAPs to PQSim for interim functionality, and begin development of a replacement component (1-2 year timeframe).
4. The hexahedral elements currently used to build log meshes result in a small region of void around the pith. The remedy is to change to using tetrahedral elements.
5. Branches are grouped within the Cluster entity in the xml file. This does not apply to all species, it is only a grouping, and carries no information. But it is useful when calculating fibre distortion around branches.

CONCLUSION

This study has been very worthwhile in terms of improving the understanding of how the current value chain modelling components work, identifying deficiencies, and what improvements can be made. It has provided proof of concept that stems with different intended end uses can be modelled along the value chain, and that the performance of the wood products derived from the stem can be predicted.

The current modelling is via a string of disconnected software packages that need greater integration, and there is a need for a system-wide framework that is in progress in Objective 3. What has been learned here has been taken into the requirement analysis (Task 3.1.3) and new frame work design (Task 3.1.4) projects.

The study has also highlighted that the future prediction of end use performance of wood from virtual stems is dependent on the development of accurate and detailed wood property functions. This emphasises in the short term, the need for the wood quality modelling work of Objective 1, and in the longer term, the simulation work in Objective 2.

This study does not attempt to quantify the accuracy or validity of results. Any results shown are for demonstration purposes only.

APPENDICES

Appendix 1 : Function Settings

Target Tree	Clearwood	Framing
Site	CNI	CNI
300 Index	26	26
Site Index	32.3	32.3
Tree Volume Fn	237	237
Height/Age	112	112
Taper Fn	237	237
Branch Fn	Blossim	Blossim
Br. Region	CNI	CNI
Br. Breed	Uninodal	X850
Sweep	Generic	Generic
Forking	Generic	Generic
Breakage	Kang 1976	Kang 1976

Appendix 2 : Silvicultural Regime

	Clearwood	Framing
Planted stocking	900	1200
Height of first thinning	12m MTH	15m MTH
SPH at final thinning	325	450
Rotation age	30	30

Appendix 3 : Log Yields

Framing

Log Yield Report

ScenarioID: f8b0d27b-4ec7-4818-adf6-db9137c185eb
Project: \Projects\Value Chain\NZ CNI
Crop: \Crops\VC crop\Framing Crop
Regime: \Regimes\VC\Framing

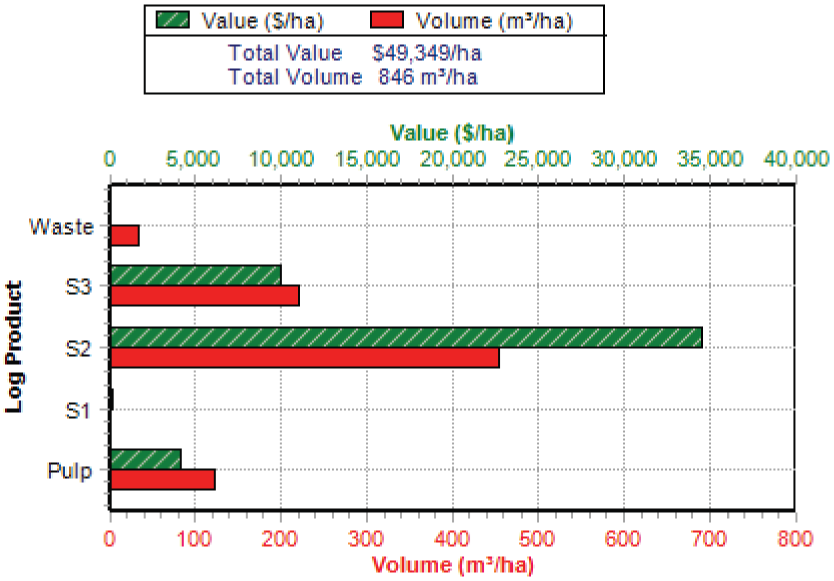
Simulation Start Time: 22/04/2008 9:11:47 a.m.
Site Name: \Sites\PMC Default Sites\Bay of Plenty
Function Set: \Function Sets\VC Funct\NZ CNI GF
Cutting Strategy: \Cutting Strategies\VC Fram\VC Frame

Clearfell at Age 30.04

	Volume		Value		Logs	Log Volume	Log SED	Log Length
	m3/ha	%	$/ha	%	logs/ha	m3/log	mm	m
S1	3.1	0	286	1	4	0.7	400	4.9
S2	456.7	56	34710	70	908	0.5	340	4.9
S3	224.6	28	10105	20	768	0.3	256	4.9
Pulp	125.0	15	4249	9	389	0.3	193	7.1
Total Recov. Volume	809	100	49349	100	2068			
Waste	36.9							
Total Extracted Volume	846.2							

Clearfell at Age 30.04

Log Yield Graph



Clearwood

ScenarioID: d3e247de-64ba-41ca-ab5d-41a3478d2ad1
Project: \Projects\Value Chain\NZ CNI
Crop: \Crops\VC crop\Clearwood Crop
Regime: \Regimes\VC\Clear no P

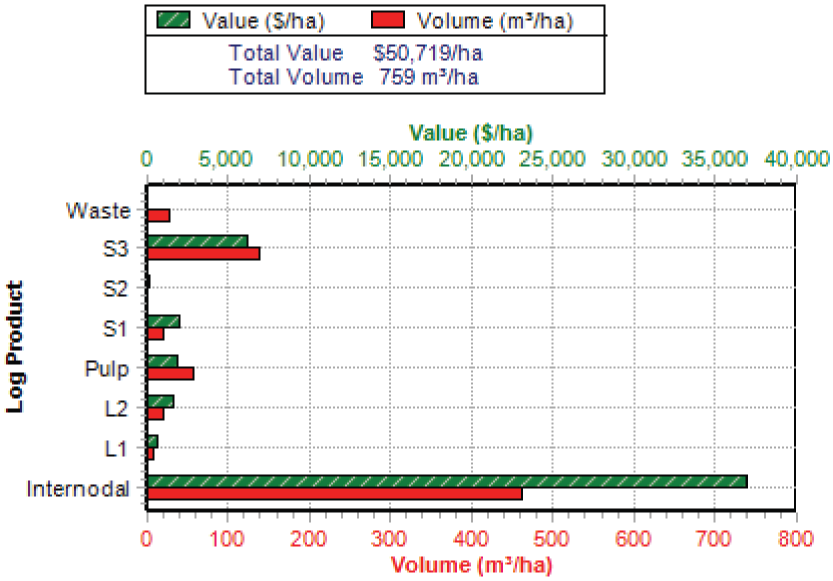
Simulation Start Time: 22/04/2008 9:11:47 a.m.
Site Name: \Sites\PMC Default Sites\Bay of Plenty
Function Set: \Function Sets\VC Funct\BCs NZ CNI LI
Cutting Strategy: \Cutting Strategies\VC Int\VC Int

Clearfell at Age 30.04

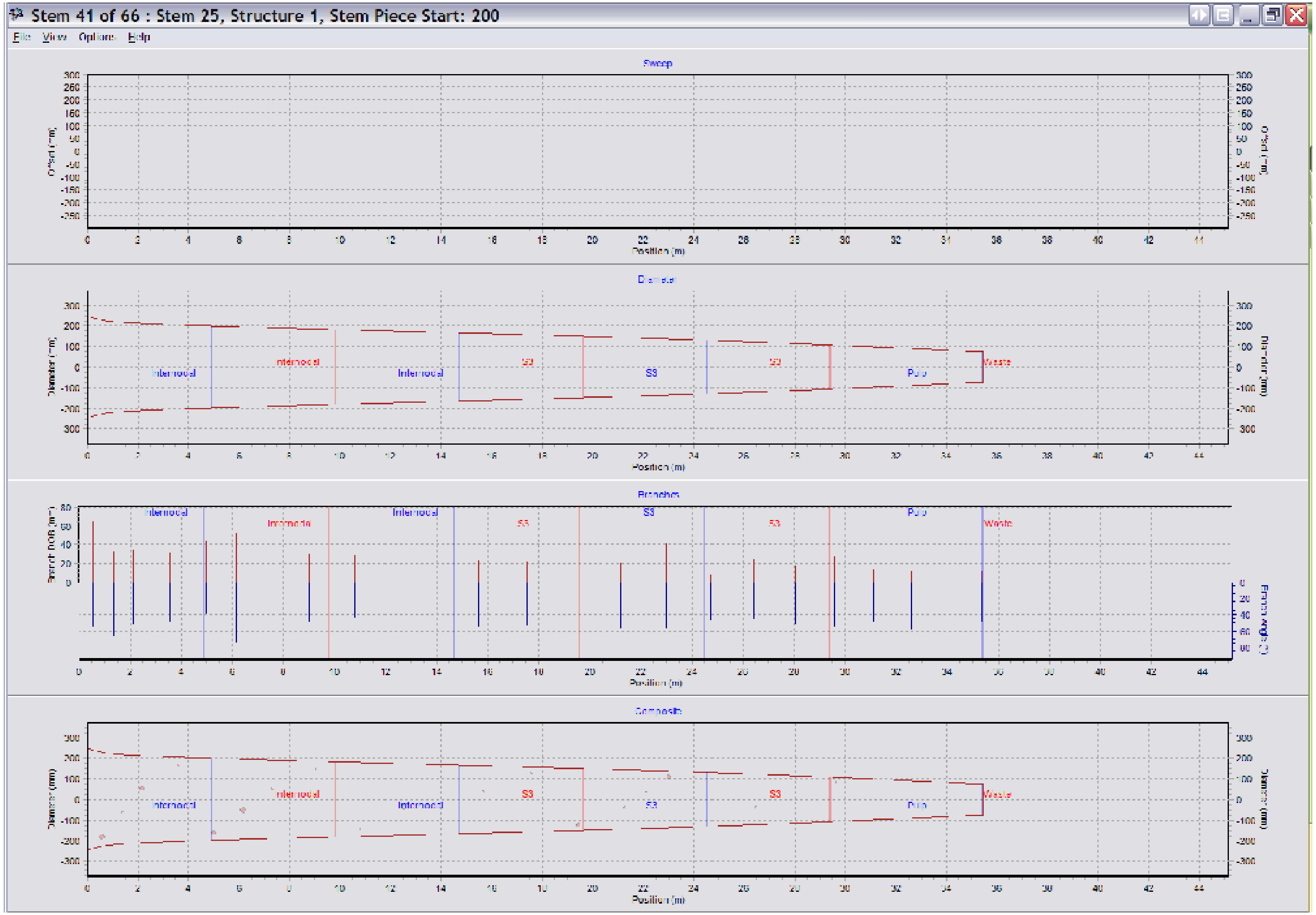
	Volume		Value		Logs	Log Volume	Log SED	Log Length
	m3/ha	%	$/ha	%	logs/ha	m3/log	mm	m
S1	23.6	3	2195	4	32	0.7	407	4.9
Internodal	464.2	64	37137	73	860	0.5	353	4.9
L1	10.4	1	808	2	14	0.7	411	4.9
S2	4.7	1	355	1	9	0.5	336	4.9
L2	24.3	3	1800	4	37	0.7	385	4.9
S3	142.3	20	6402	13	472	0.3	258	4.9
Pulp	59.4	8	2021	4	260	0.2	171	6.7
Total Recov. Volume	729	100	50719	100	1685			
Waste	30.0							
Total Extracted Volume	758.9							

Clearfell at Age 30.04

Log Yield Graph

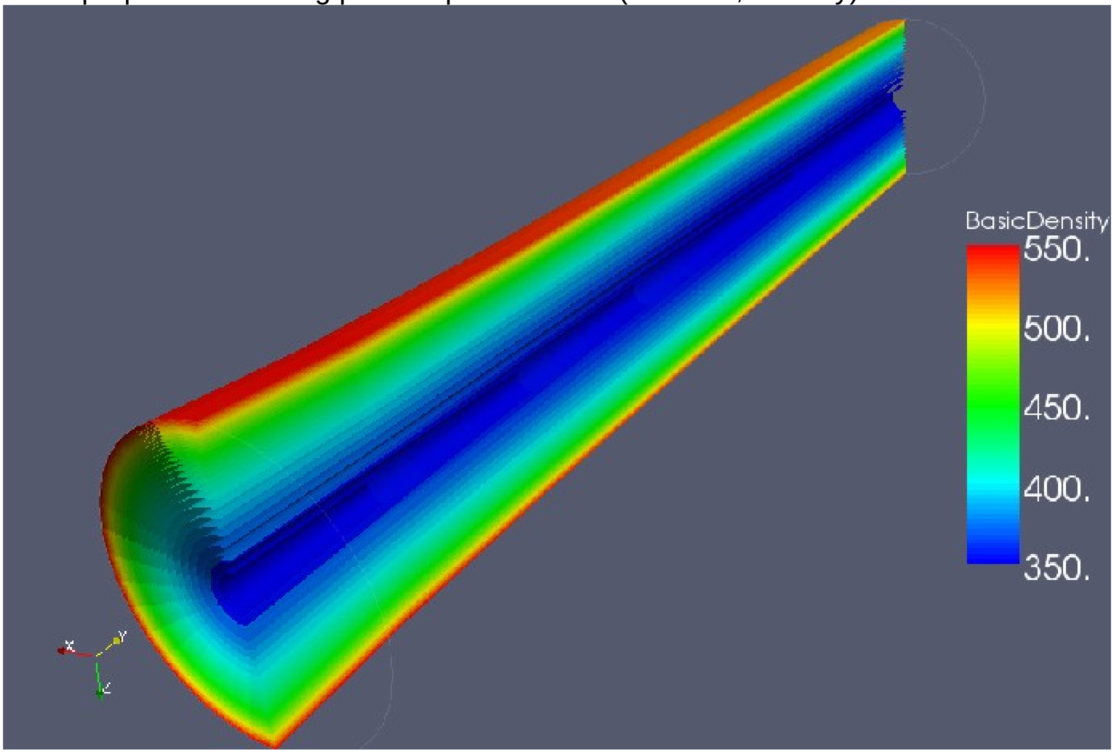


Appendix 4 : Stem Detail

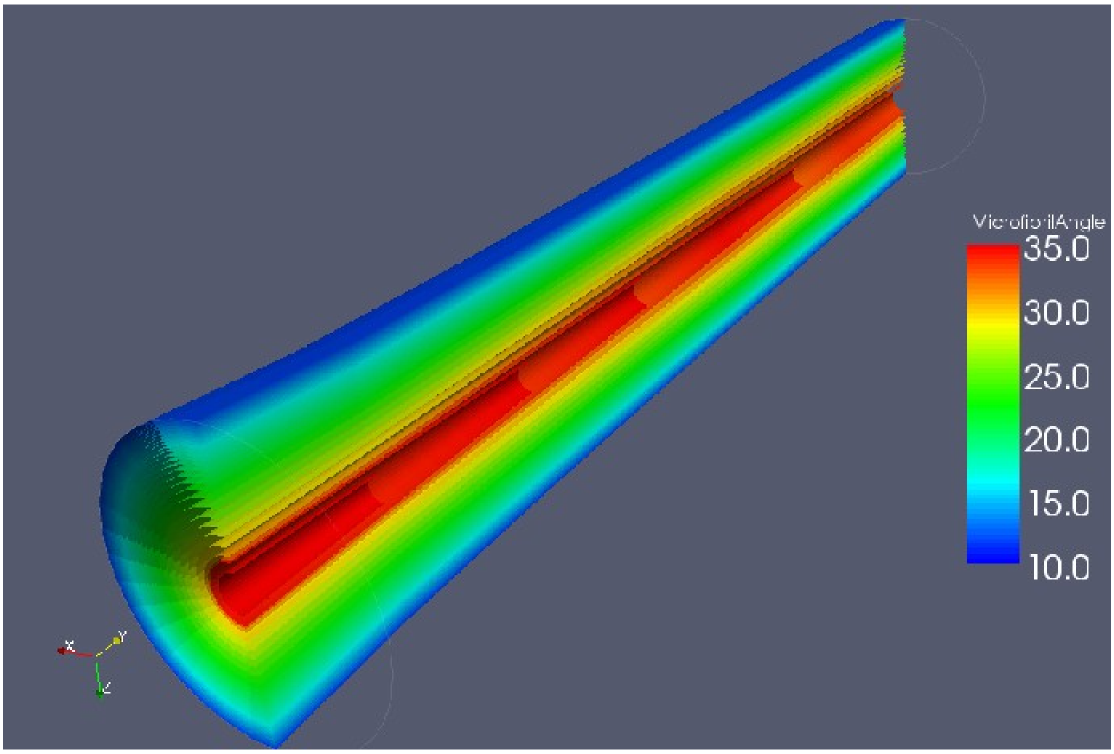


Appendix 5 : Log Detail

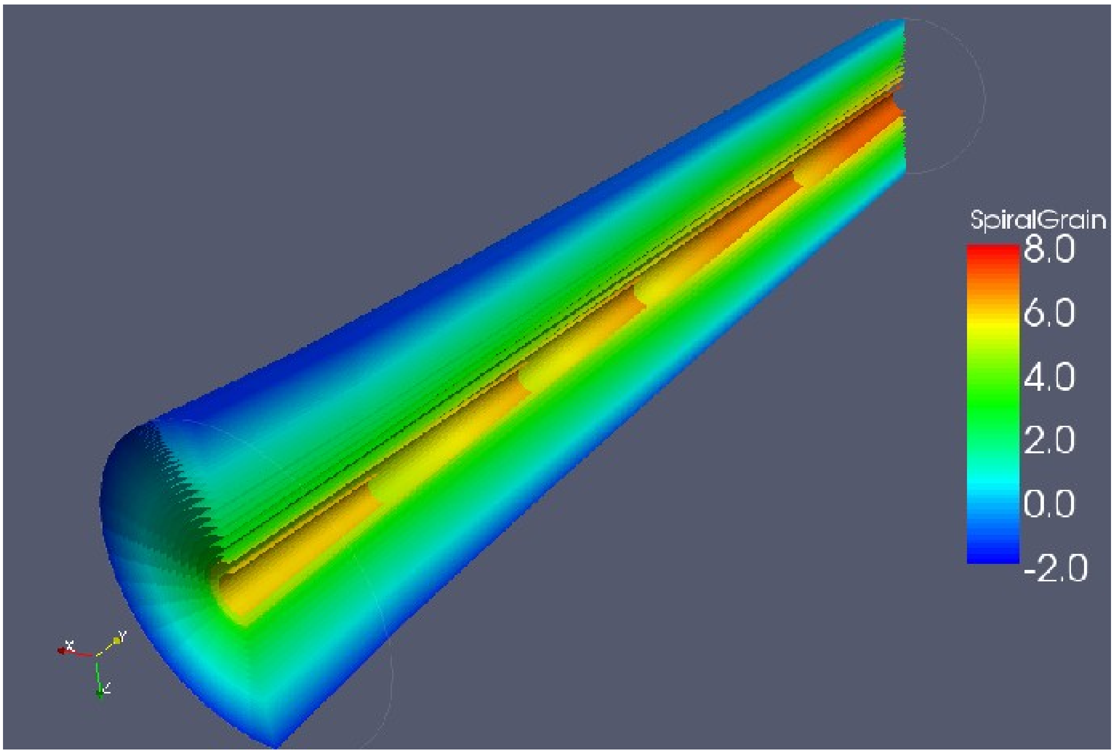
Butt log from the representative stem for Clearwood regime, showing internal distribution of the key wood properties affecting product performance (stiffness, stability).



Basic density



Microfibril angle

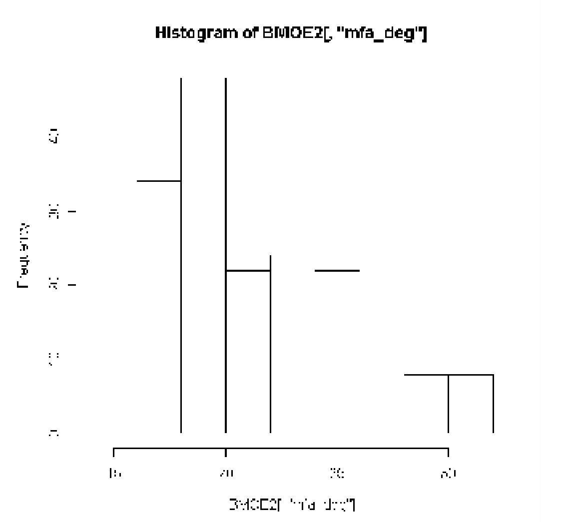


Spiral grain

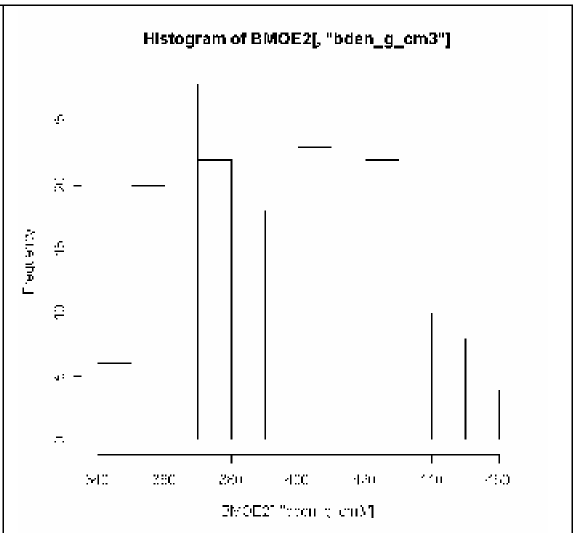
Appendix 6 : Board Detail

Framing Product Results

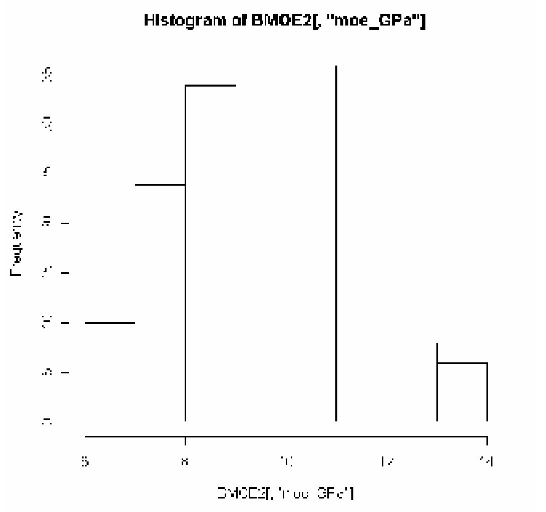
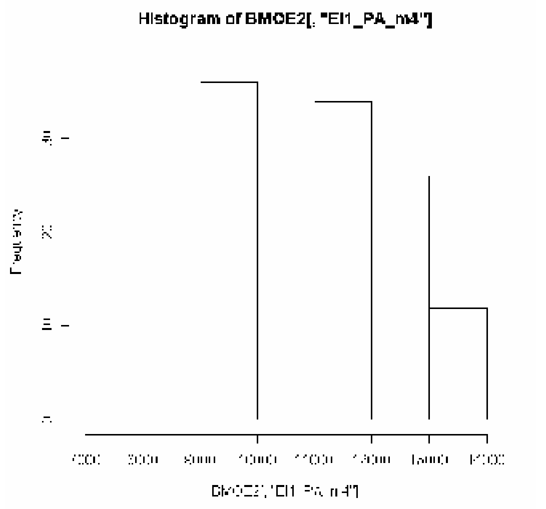
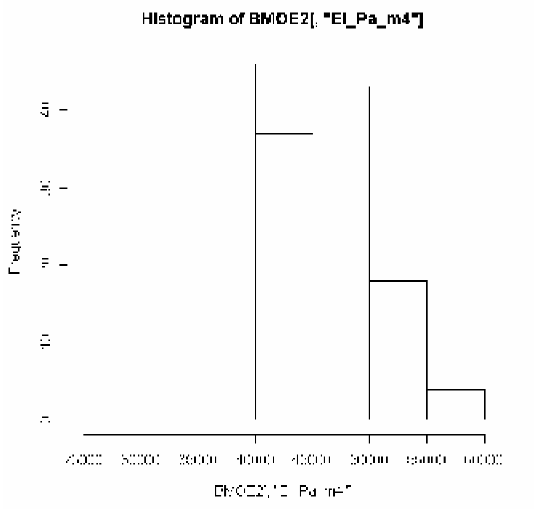
The representative Framing stem was cut into 5 logs, all 4.9m in length. These logs were all sawn into 100x50mm boards with the same sawing pattern, and evaluated for mean flexural stiffness.



MFA (degrees)

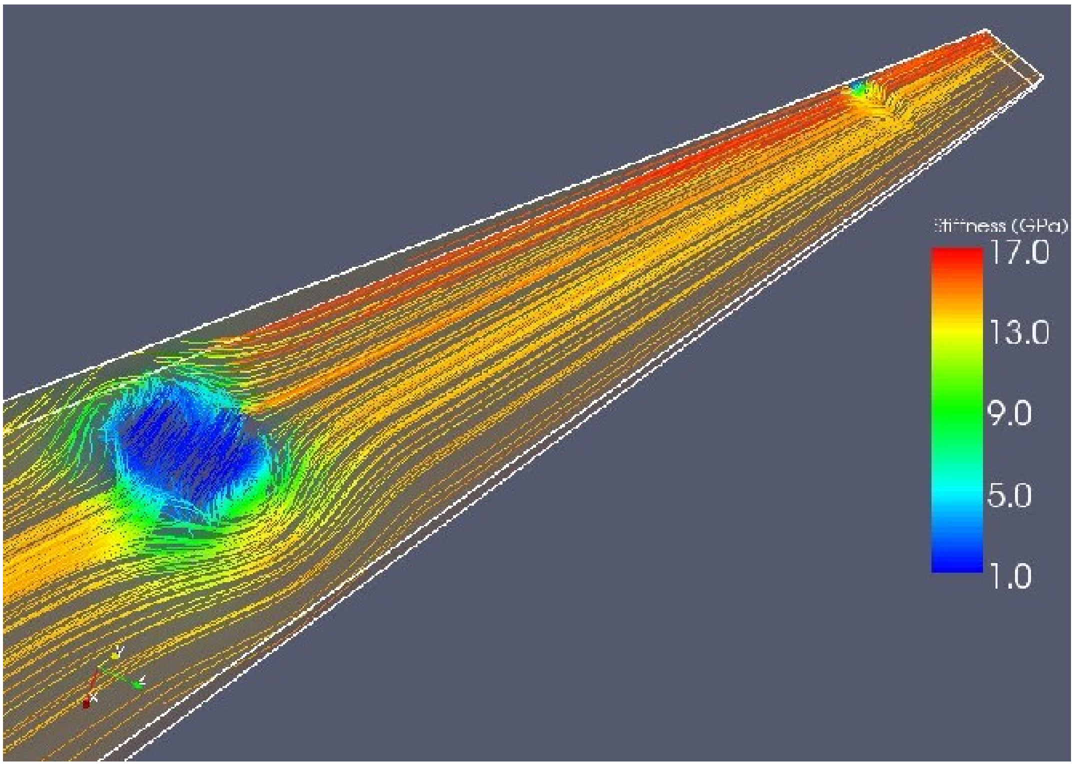


Basic density (kgm^3)

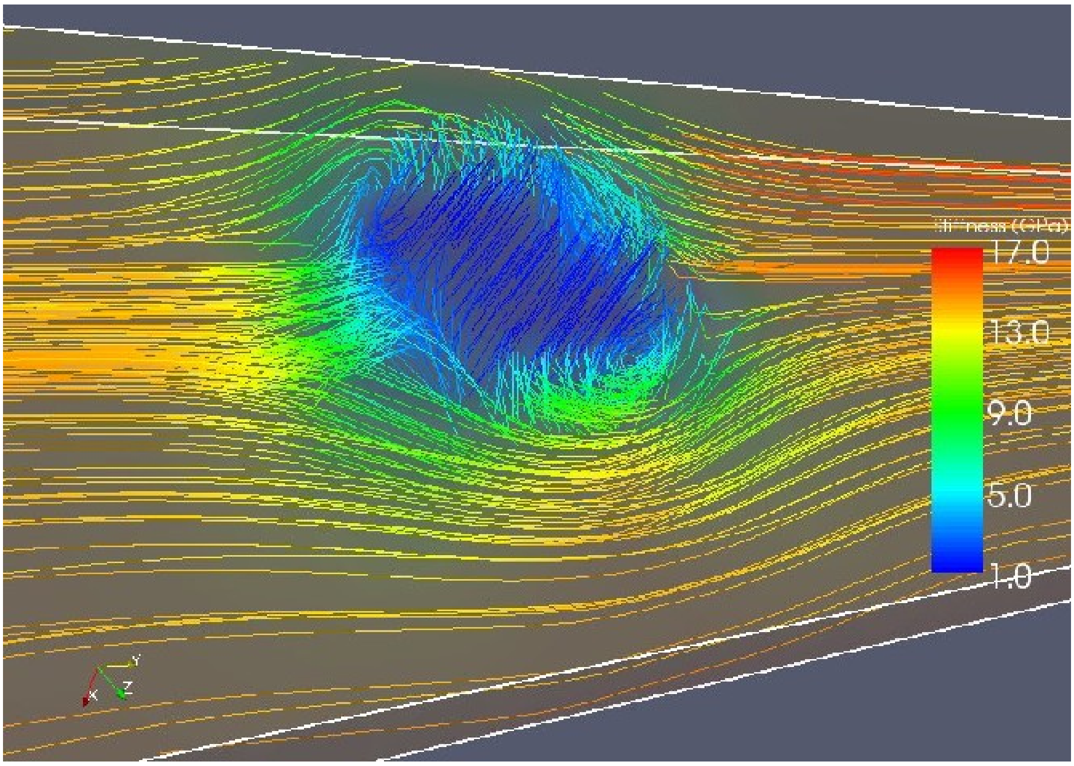
 MOE (GPa)	
 Flexural stiffness across board thickness (Pa/m^4)	 Flexural stiffness across board width (Pa/m^4)

Distributions for key input variables (MFA, density) and calculated longitudinal (MOE) and flexural stiffnesses (EI, across the thickness and the width of the board).

The MFA, density and MOE values presented above are volume-weighted averages. The flexural stiffness values (EI) are volume weighted but also take into account position in the board. Regions near the edges of the board have a greater influence on flexural stiffness than regions near the centre. For this reason a knot (a region of very low stiffness) will reduce local stiffness much more if it is at the edge of a board rather than in the centre. However, because knots occupy such a small proportion of the total board, their volume-weighted contribution to overall board stiffness is low.



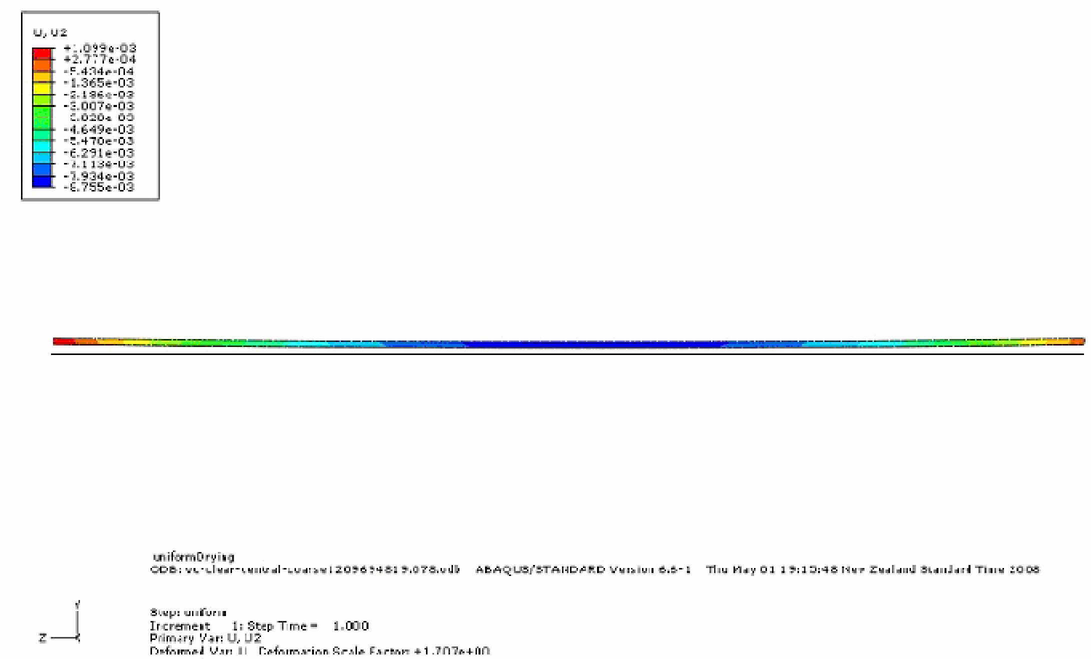
Board showing longitudinal stiffness (MOE). Gradual variation in stiffness occurs due to changes in key wood properties (density, spiral grain and MFA). Within- and near-knots changes in fibre orientation greatly reduce stiffness locally.



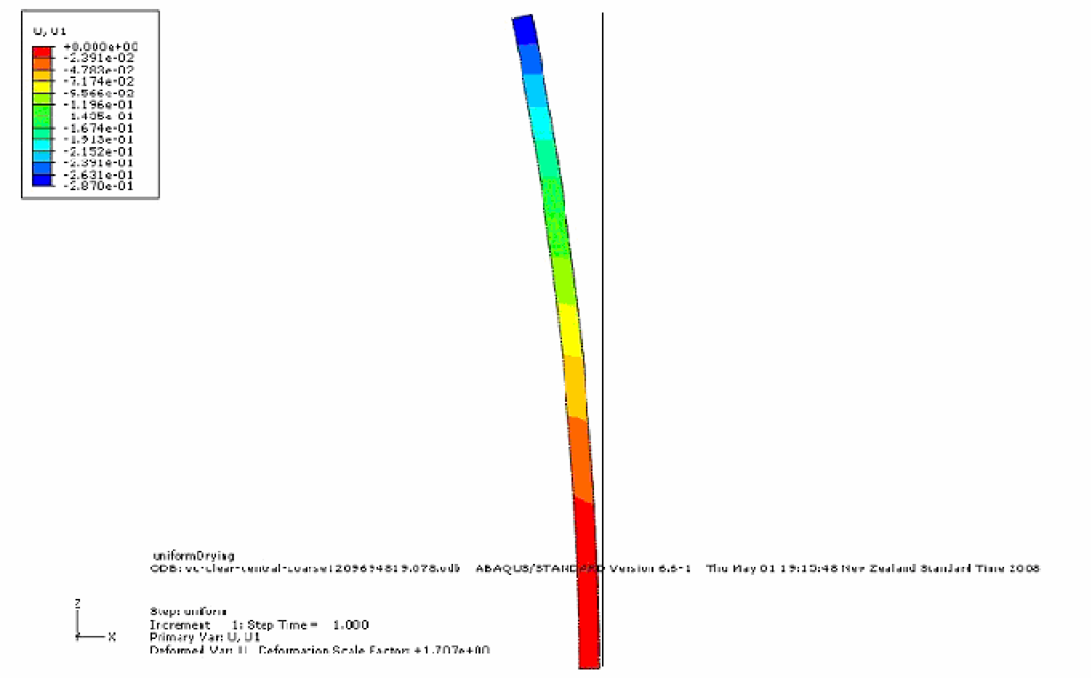
Close-up view of fibre orientation and low stiffness in association with a large knot. Within the knot fibres are aligned at right angles to the usual longitudinal direction, resulting in very low longitudinal stiffness. A region of reduced stiffness due to disturbed fibre orientation also extends around the knot.

Clearwood Product Results

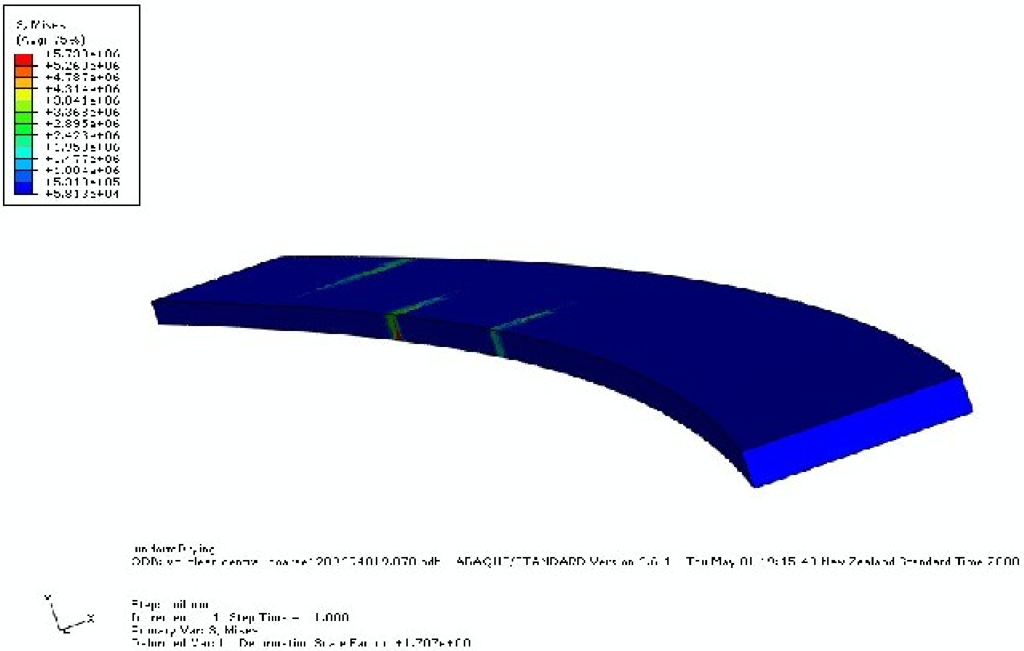
The representative clearwood stem was cut into 6 logs, all 4.9m in length. These logs were all sawn into 150x25mm boards with the same sawing pattern, and evaluated for drying warp.



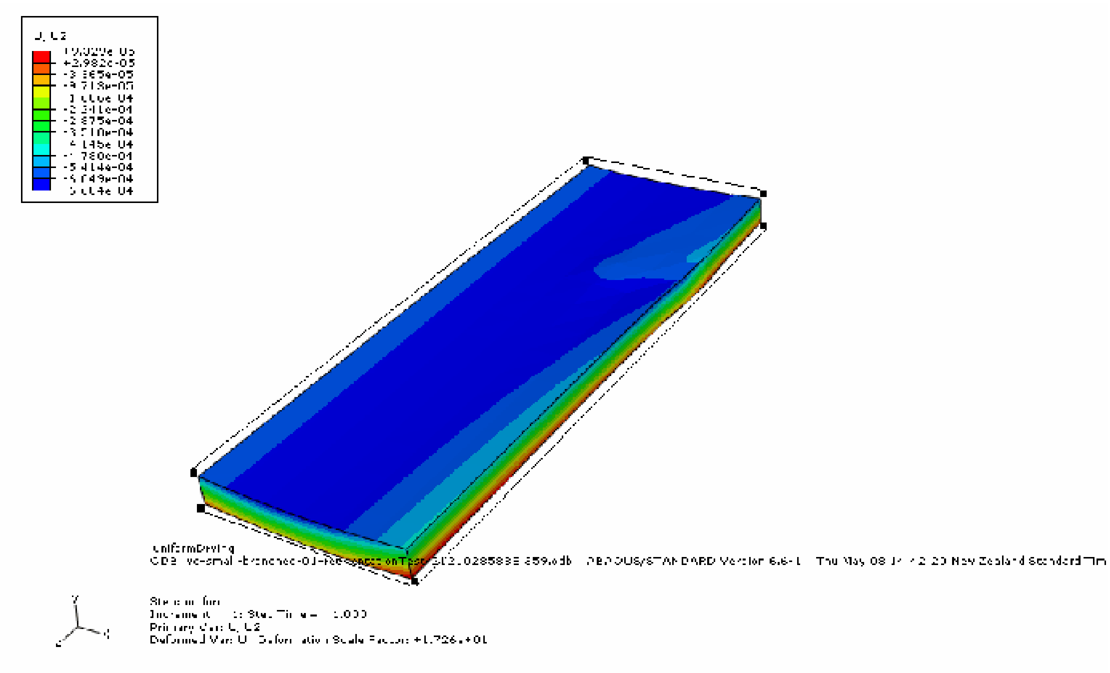
Drying distortion in 125x25mm board from clearwood regime: bow.



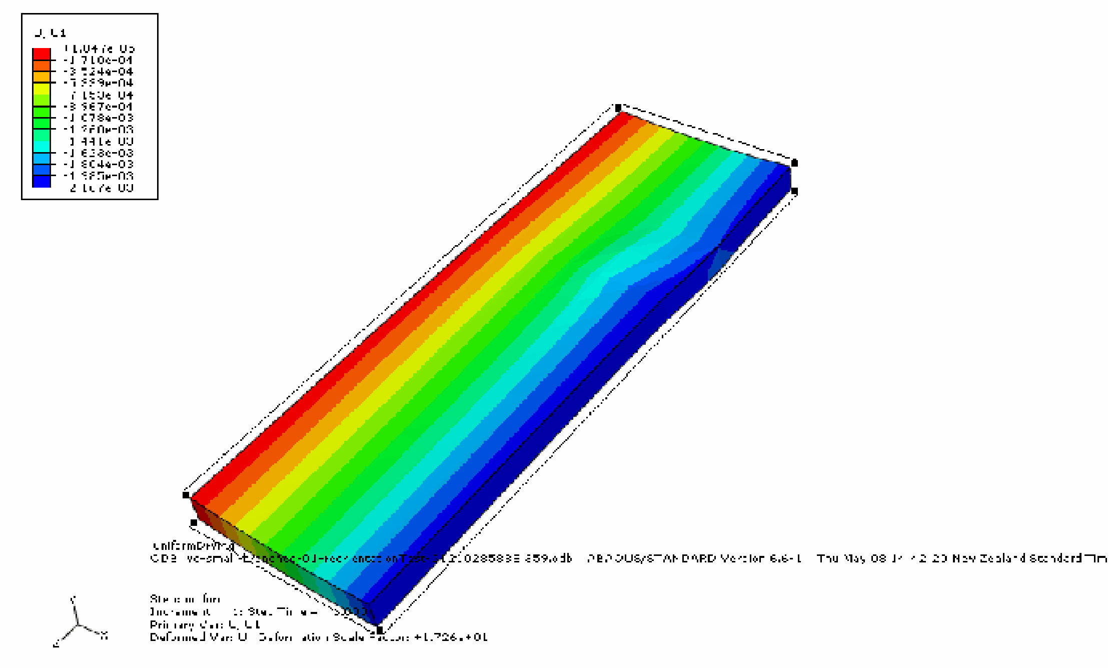
Drying distortion in 125x25mm board from clearwood regime: crook (exaggerated)



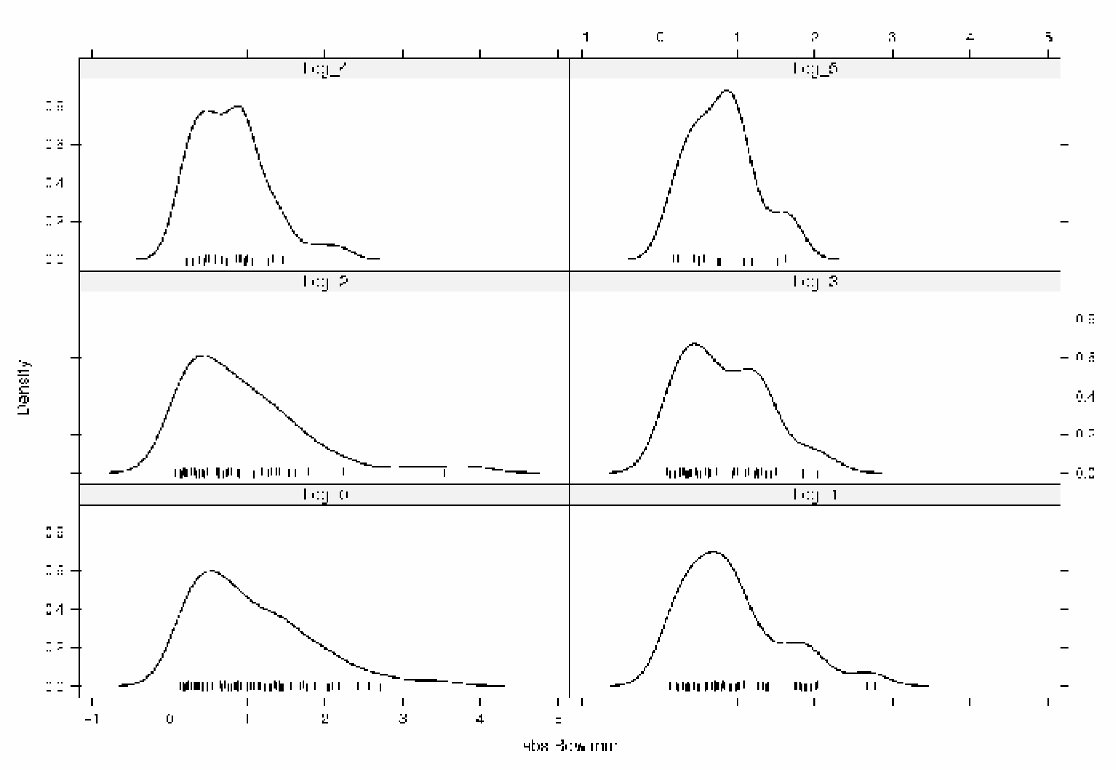
Drying distortion in 125x25mm board from clearwood regime: general view of distortion (exaggerated) looking from board end showing crook and slight twist. Three knots evident as patches of different colour (representing higher local stress).



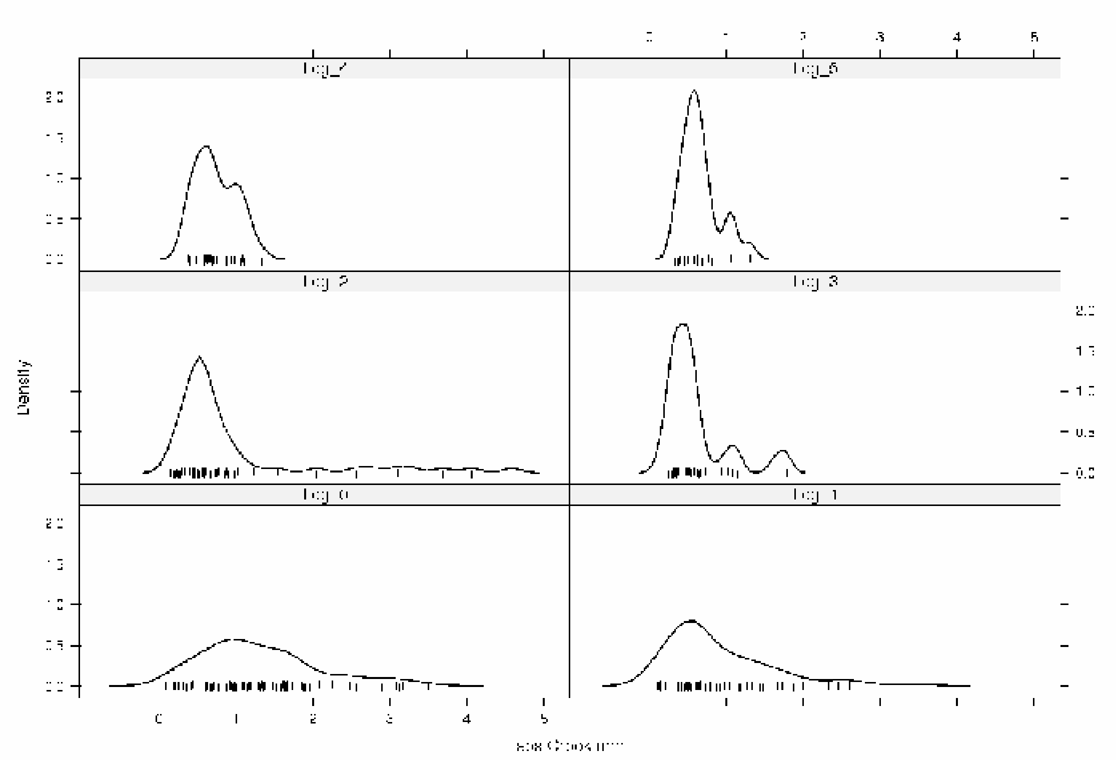
Drying distortion in a 125x25mm board section containing a knot (upper right). Colours represent amount of bow, low on the upper face and increasing towards the lower face. The knot is affecting the amount of distortion locally.



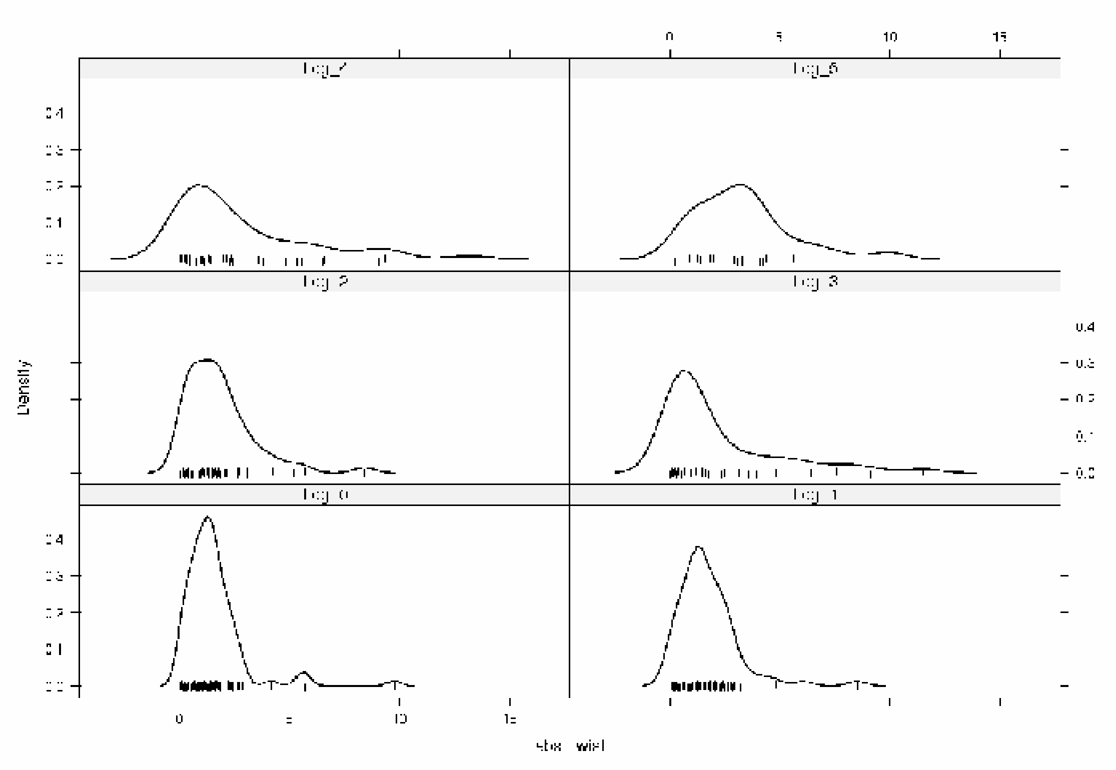
Drying distortion in a 125x25mm board section containing a knot (upper right). Colours represent amount of crook, low on the right-hand edge and increasing towards the left-hand edge. The knot is affecting the amount of distortion locally.



Distributions for bow in all boards by log (0=butt log, 5=top log). In all logs there is an approximately normal distribution of bow values from 0 to 2mm (over the 4.9m board length) and a few boards with higher values (up to 4mm), decreasing at higher log positions.



Distributions for crook in all boards by log (0=butt log, 5=top log). In all logs there is an approximately normal distribution of crook values from 0 to 2mm (over the 4.9m board length) and a few boards with higher values (up to 4mm), decreasing at higher log positions.



Distributions for twist in all boards by log (0=butt log, 5=top log). In all logs there is an approximately normal distribution of twist values from 0 to 4mm (over the 4.9m board length), and a few boards with higher values (up to 10mm). Higher log positions have more high twist values, probably due in part to a higher proportion of boards cut near the pith.