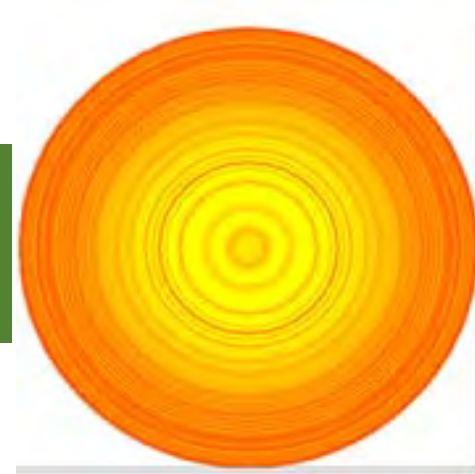


Tools and models for assessing wood quality in Australian radiata pine



Validation and development of
eCambium software tool



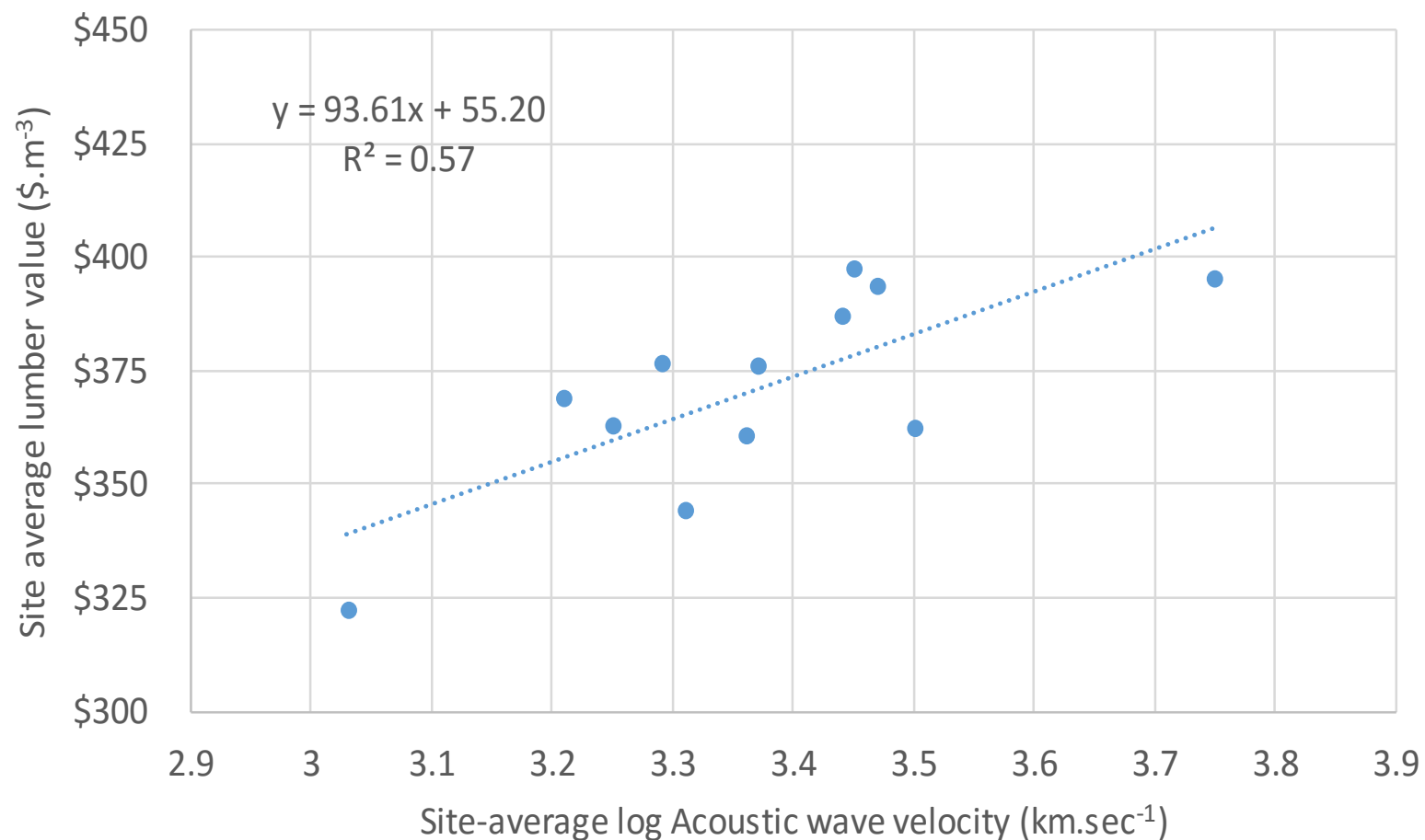
Geoff Downes
Forest Quality Pty. Ltd.

Dave Drew
Forest Forecasting

Forest Quality Pty Ltd

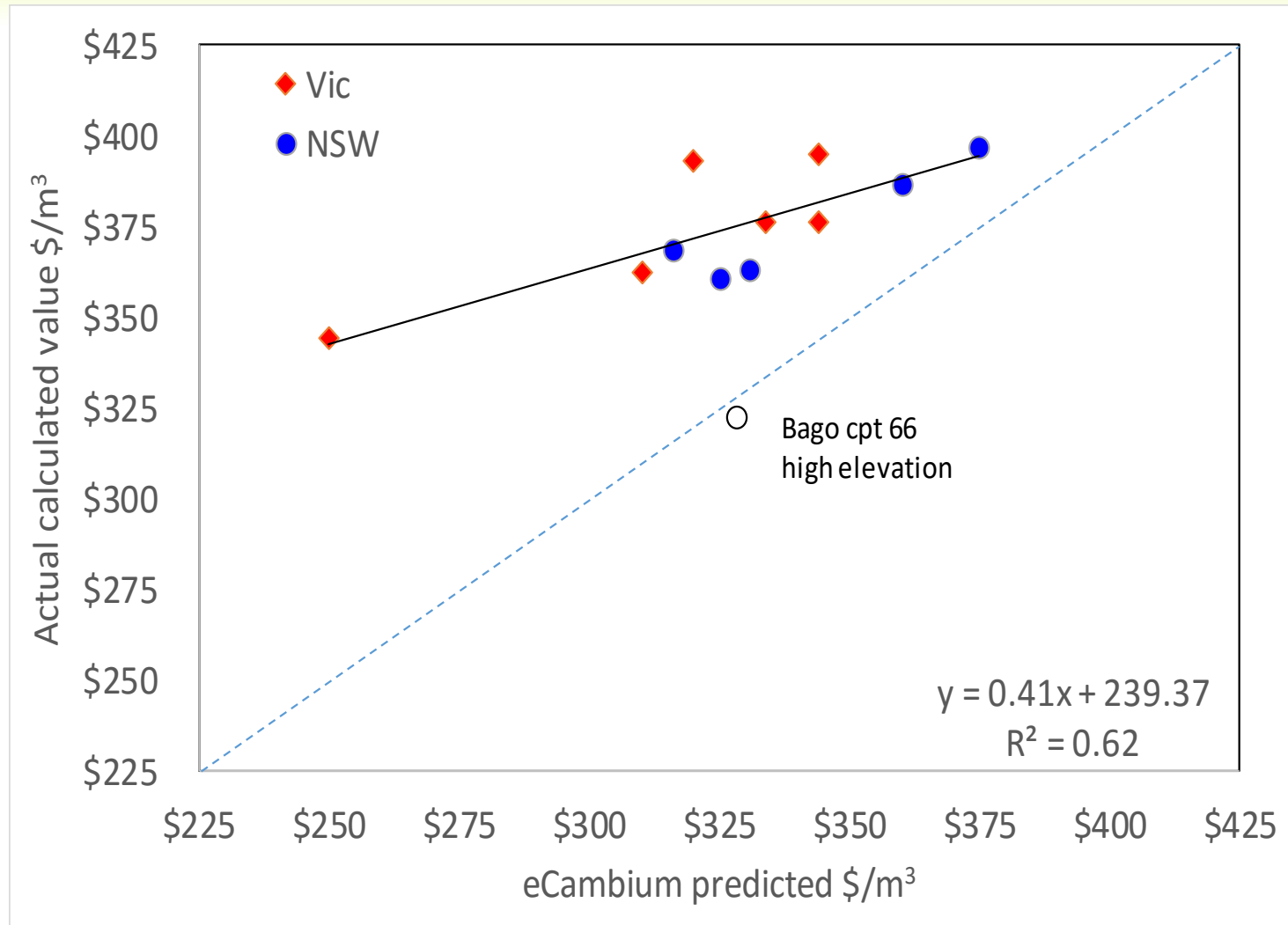
- Applied R&D based in southern Tasmania
 - 20 years working for CSIRO in Forestry and Forest Products
 - CRC Hardwood Fibre and Paper Science (1992 –1999)
 - SilviScan Services (2000-2003)
 - Ensis Joint Venture with Scion (NZ) (2003-2008)
 - CRC Forestry Ltd (2005 – 2012)
- Spin-off company from the CRC Forestry Ltd. (Est. July 2012)
- Focus on wood property assessment and modelling
 1. NIR assessment of Eucalypt pulp properties
 2. In-field assessment of wood properties and training
 - Increment coring | IML Resistograph | Portable NIR
 3. Process-based modelling of wood properties
 - FWPA funded eCambium projects in radiata pine (2010 -2016)

Wealth generation



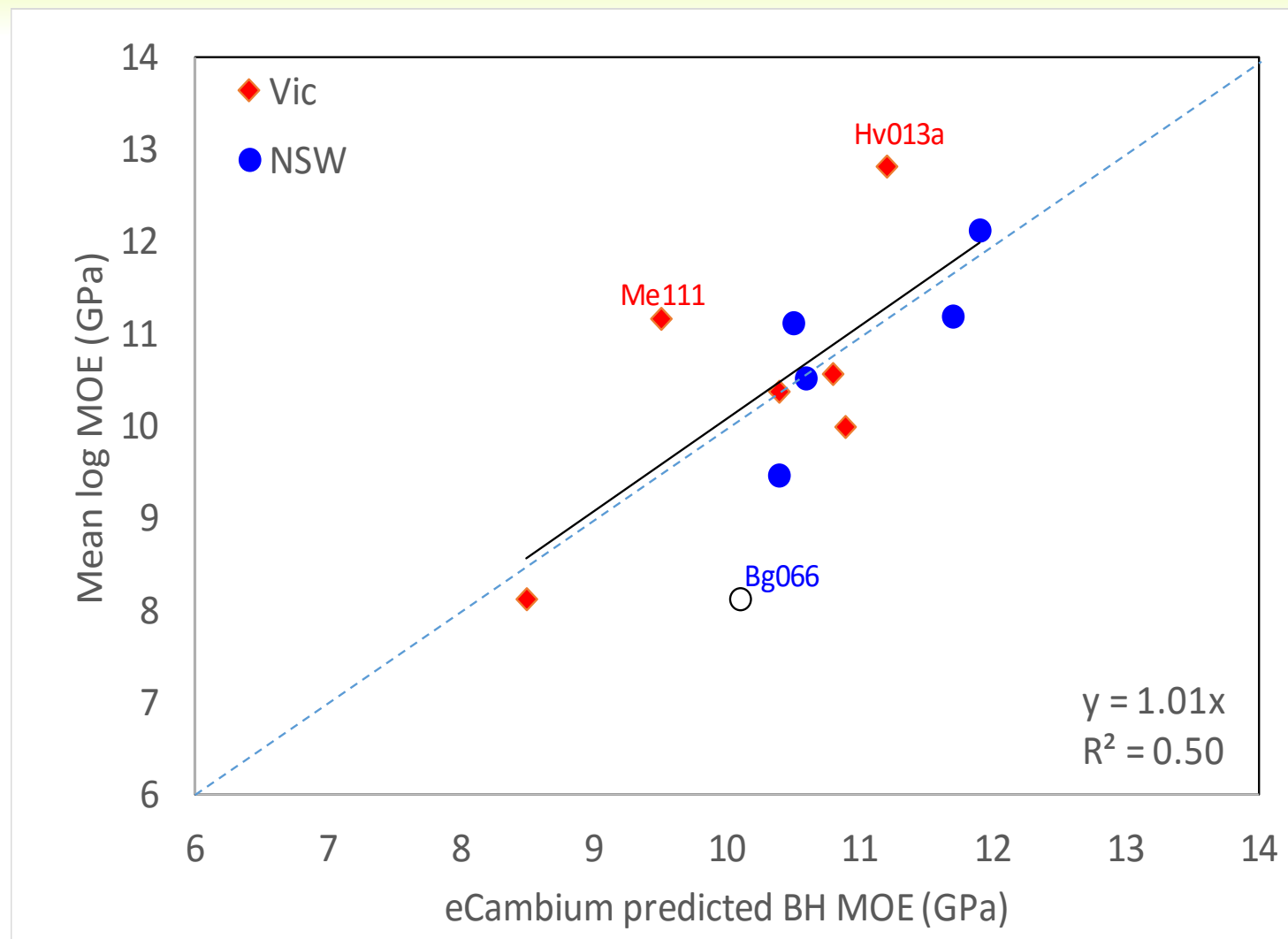
eCambium's prediction of site value

- eCambium predictions made 4 months before logs were harvested



eCambium's prediction of log MOE

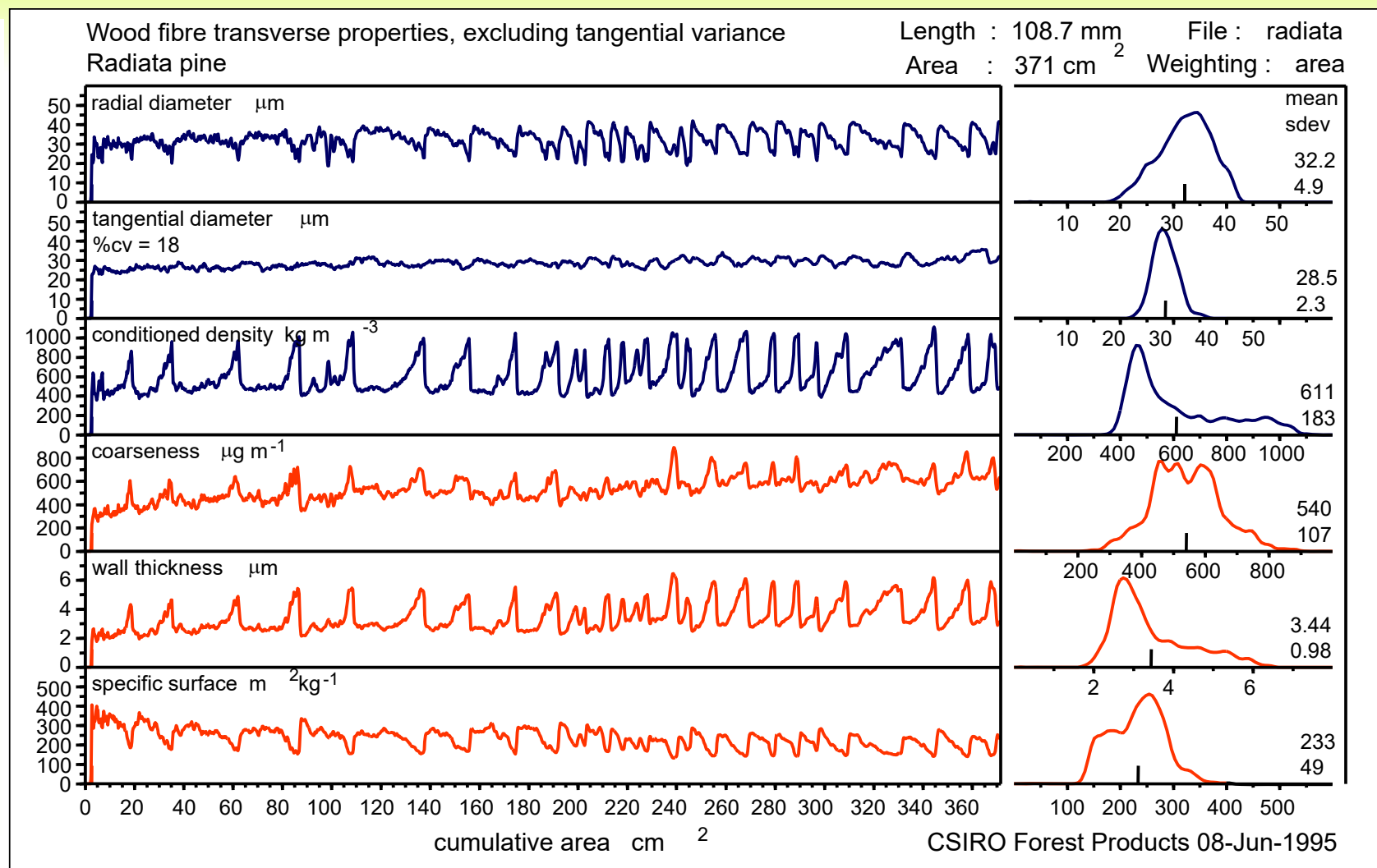
- eCambium predictions made 4 months before logs were harvested



Typical SS-1 Analysis Report (circa 1995)

Cost:

~\$200 per radial core



SilviScan mapping of wood stiffness variation within trees

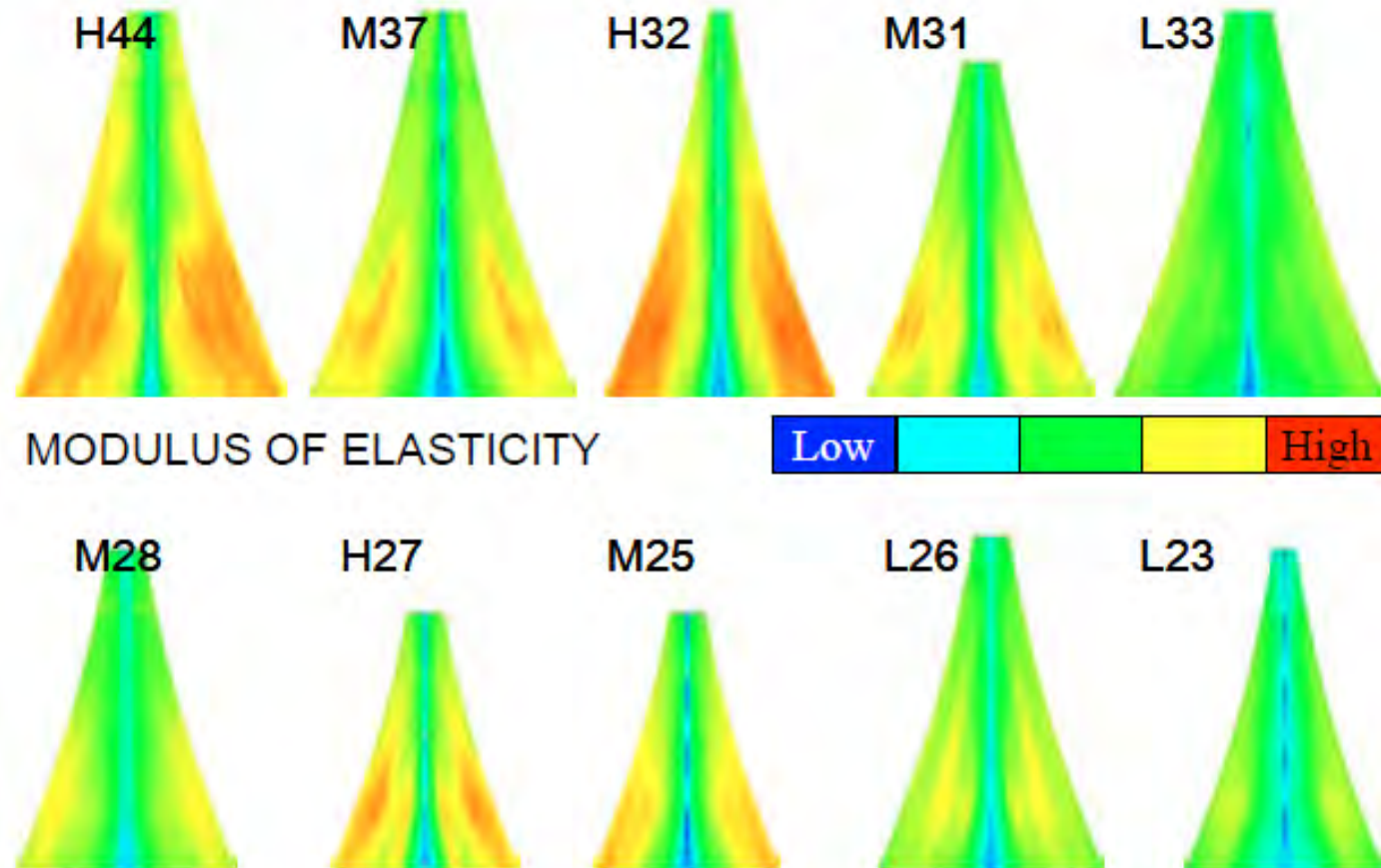
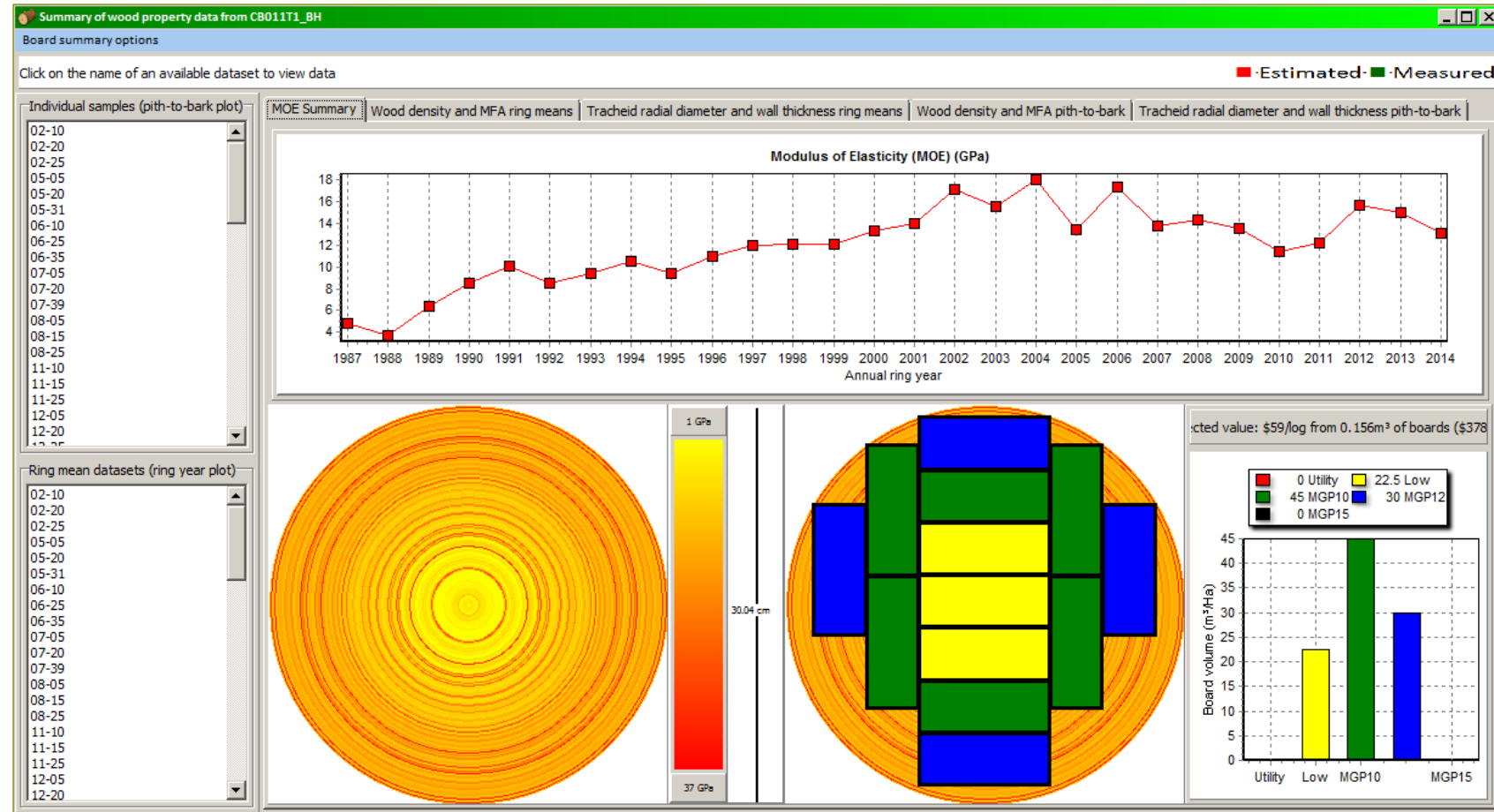


Figure 20: Site average whole-tree maps for SilviScan estimated Modulus of Elasticity

Overview of eCambium (Version 2.1)

- eCambium predictions of wood variation link effects of growth on board volume and quality



eCambium's main user interface

e-Cambium: Murray_Valley_Sites_090516

File Run Boards View Tools About

Project

Create a new project

Open an existing project

Input data and scenarios

Add/edit an input dataset

Add/edit a scenario

Run

Run selected scenario(s)

Outputs

View summary graphs

Export data

Scenario name	Stem position (m)	Diameter UB (cm)	Core mean WD (kg/m ³)	Core mean MOE (GPa)	Tree height (m)	Final stand volume (m ³ /Ha)	Segment (µm)
AR1194_BH	1.3	36.6	343	8.6	30.4	499	100
AR1194_BH_CaBala	1.3						
BG066UT_BH	1.3	30.2	361	9	28.1	675	100
BG582UT_BH	1.3	30	362	9.2	29.1	688	100
BG583T2_BH	1.3	41.8	344	8.9	33.5	352	100
BG587T1_BH	1.3	32.6	349	8.8	28.1	462	100
BI104T1_BH	1.3	33.4	353	9.4	29.8	411	100
BI104T1_BH_CaBala	1.3						
BI133T2_BH	1.3	38.4	343	8.8	32.1	296	100
BR019_BH	1.3	29	348	8.7	27.3	680	100
BU019a_BH	1.3	33	366	9.7	27.3	233	100
BU019b_BH	1.3	26.8	375	9.8	25.8	608	100
CB001T1_BH	1.3	31.6	357	9.2	28	350	100
CB001T1_BH_CaBala	1.3						
CB011T1_BH	1.3	30	364	9.7	27.8	485	100
CB011T1_BH_CaBala	1.3						
CB018T1_BH	1.3	29.8	373	10	29.1	324	100
EV002_BH	1.3	25.4	363	9.2	26.4	610	100
EV002_BH_CaBala	1.3						
GA003_BH	1.3	39.4	337	8	30.9	369	100
GA003_BH_CaBala	1.3						
GC801_BH	1.3	36.4	340	8.5	28.4	461	100
GC801_BH_CaBala	1.3						
GH828T1_BH	1.3	32.2	366	9.7	28.5	511	100
GH828UT_BH	1.3	29.2	356	8.7	28.1	677	100
GH845T1_BH	1.3	37.2	340	8.3	29.4	627	100
GH845T2_BH	1.3	35.6	342	8.3	29.3	374	100
GH845T2_BH_CaBala	1.3						
GH849T1_BH	1.3	34.6	348	8.4	29.2	439	100

Defining site

Add or edit input datasets

Import

Site information | Regime information | Weather data | Modelling parameters

Site information

AR 1194_Dr2.51
BG066_Gn2.4
BG582
BG583
BG587
BI104
BI133
BR019
BU019a
BU019b
CB001_Gn2.1
CB011
CB018
EV002
GA003
GC801_Um6.1
GH828_Dr2.2
GH845_Dr2.2
GH849_Dr2.2
GO024
HC427
HL224
HV013
HV013a
JN058
KO057
LV015

Create a new site
Delete selected site
Save changes

Soil characteristics and water availability

Site latitude (deg):
-35

Site longitude (deg):
0

Soil texture
'Dominant' soil texture:
☒ Modify 'dominant' texture
Clay loam

Sand % in the top 0.6m
0

Clay % in the top 0.6m
0

Silt % in the top 0.6m
0

Soil depth
Effective rooting depth (m):
1.1

Depth to water table (m)
999

Site fertility
Site fertility rating
0.30

☐ Modify FR with CN ratio

Total N (%) in top 0.6m
0

Organic C (%) in top 0.6m
0

Soil water
Proportion of rock present (%)
0

Max soil porosity (mm/m)
420

Effective field capacity (mm/m)
399

Permanent wilting point (mm/m)
247

Initial available soil water (mm/m)
399

Site Index
Dominant height (m)
0 ☐ Use SI

SI base age (y)
0

Notes

Defining regime

Add or edit input datasets

Import

Site information | Regime information | Weather data | Modelling parameters

AR1194_Fert
ARtest
BG066_UT
BG582UT
BG583_T2
BG587_T1
BI104_Alt
BI104_T1
BI133_T3
BR019
BU019a
BU019b
CB001_T1
CB011_T1
CB018_T1
EV002_Fert
GA003_Fert

Establishment date:
7/ 1/1987

Harvest date:
10/ 7/2014

Rotation length:
27.27 years

Initial stand density
1100 stems/Ha

Event type	Event age (y)	Event date	Event description
Establishment	0	7/1/1987	Initial stand density of 1100 stems/Ha
Fertilization	0.1000000000000004	8/6/1987	Fertilization to increase site FR by 0.29
Pruning	8	7/1/1995	Pruning with intensity of 0.1
Thinning	17	6/30/2004	Residual stand density of 400 stems/Ha
Harvest	27.2689938398357	10/7/2014	Clearfell

Regime

Create a new regime

Copy selected regime

Delete selected regime

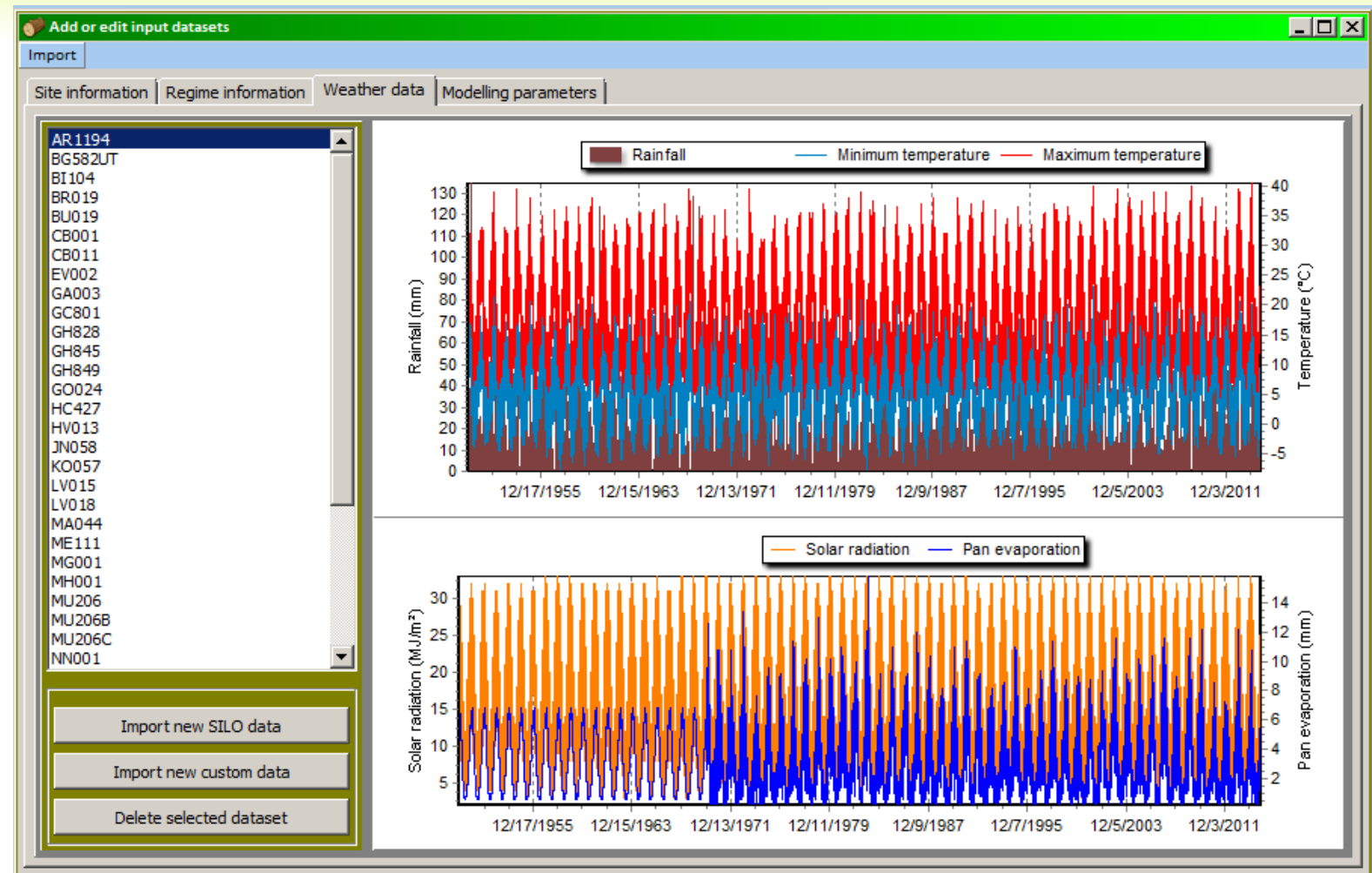
Event

Add a new event

Delete selected event

Save changes

Defining weather



Building a “scenario”

e-Cambium: Murray_Valley_Sites_090516

File Run Boards View Tools About

Project

- Create a new project
- Open an existing project

Input data and scenarios

- Add/edit an input dataset
- Add/edit a scenario**

Run

- Run selected scenario(s)

Outputs

- View summary graphs
- Export data

Scenario name	Stem position (m)	Diameter UB (cm)	Core mean WD (kg/m³)	Core mean MOE (GPa)	Tree height (m)	Final stand volume (m³/ha)	Segment (µm)
AAATestCaseBH	1.3	38.2	337	8.9	28.9	509	100
AR1194_BH	1.3	36.6	343	8.6	30.4	499	100
AR1194_BH_CaBala	1.3						
BG066UT_BH	1.3	30.2	361	9	27.1	658	100
BG582UT_BH	1.3	30	362	9.2	29.1	688	100
BG583T2_BH				8.9	33.5	352	100
BG587T1_BH				8.8	28.1	462	100
BI104T1_BH				9.4	29.8	411	100
BI104T1_BH_CaBala							
BI133T2_BH				8.8	32.1	296	100
BR019_BH				8.7	27.3	680	100
BU019a_BH				9.7	27.3	233	100
BU019b_BH				9.8	25.8	608	100
CB001T1_BH				9.2	28	350	100
CB001T1_BH_CaBala							
CB011T1_BH				9.7	27.8	485	100
CB011T1_BH_CaBala							
CB018T1_BH				10	29.1	324	100
EV002_BH				9.2	26.4	610	100
EV002_BH_CaBala							
GA003_BH				8	30.9	369	100
GA003_BH_CaBala							
GC801_BH				8.5	28.4	461	100
GC801_BH_CaBala							
GH828T1_BH	1.3	32.2	360	9.7	28.5	511	100
GH828UT_BH	1.3	29.2	356	8.7	28.1	677	100
GH845T1_BH	1.3	37.2	340	8.3	29.4	627	100
GH845T2_BH	1.3	35.6	342	8.3	29.3	374	100
GH845T2_BH_CaBala	1.3						

Add or edit an e-Cambium scenario

Scenario name: BG066UT_BH thinned

Site: BG066_Gn2.4

Weather dataset: BG582UT

Genotype: Prad_030315_B

Rotation regime: BG066_UT

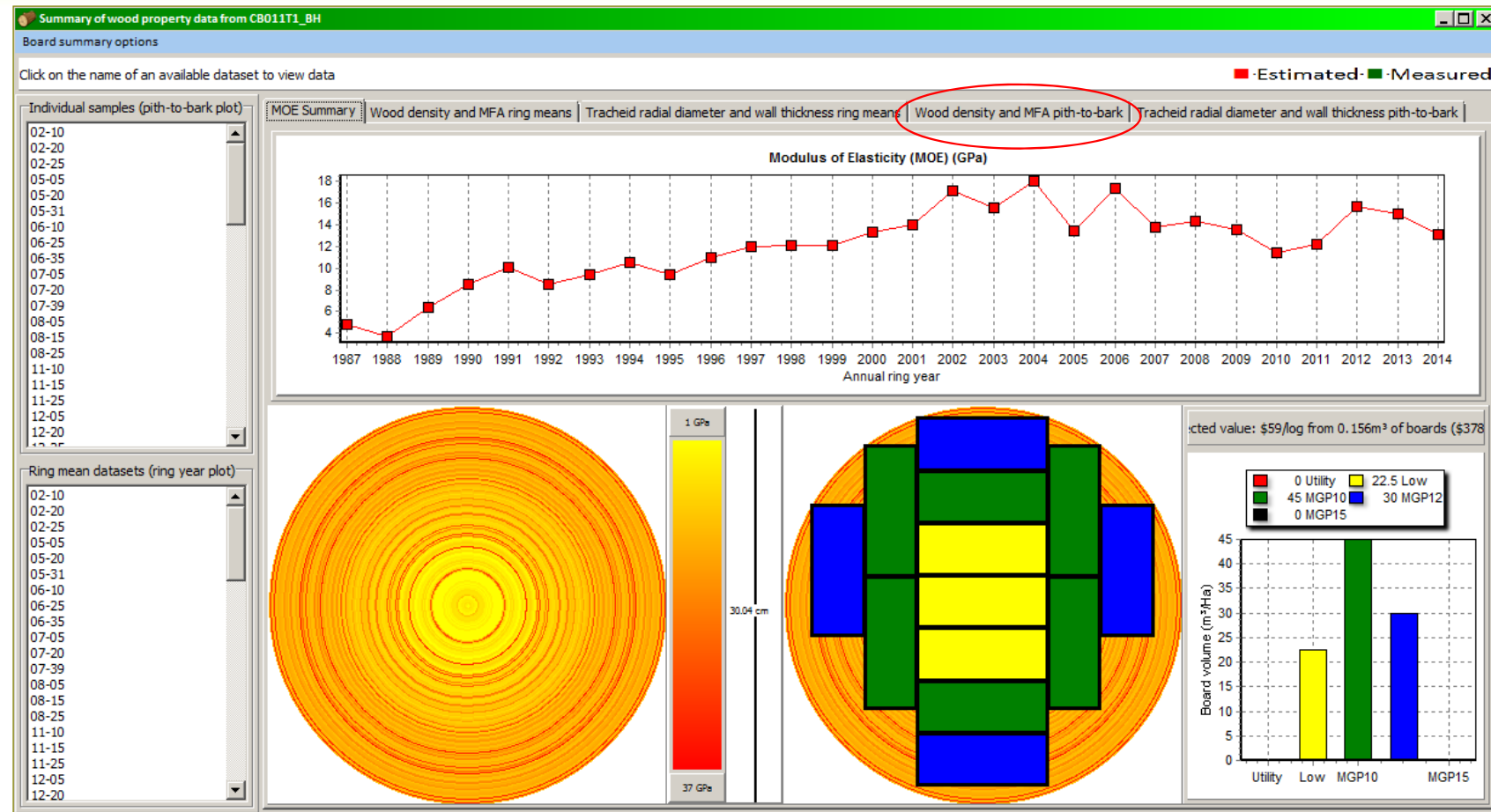
Tree type: Average

Stem position (m): 1.3

OK Cancel

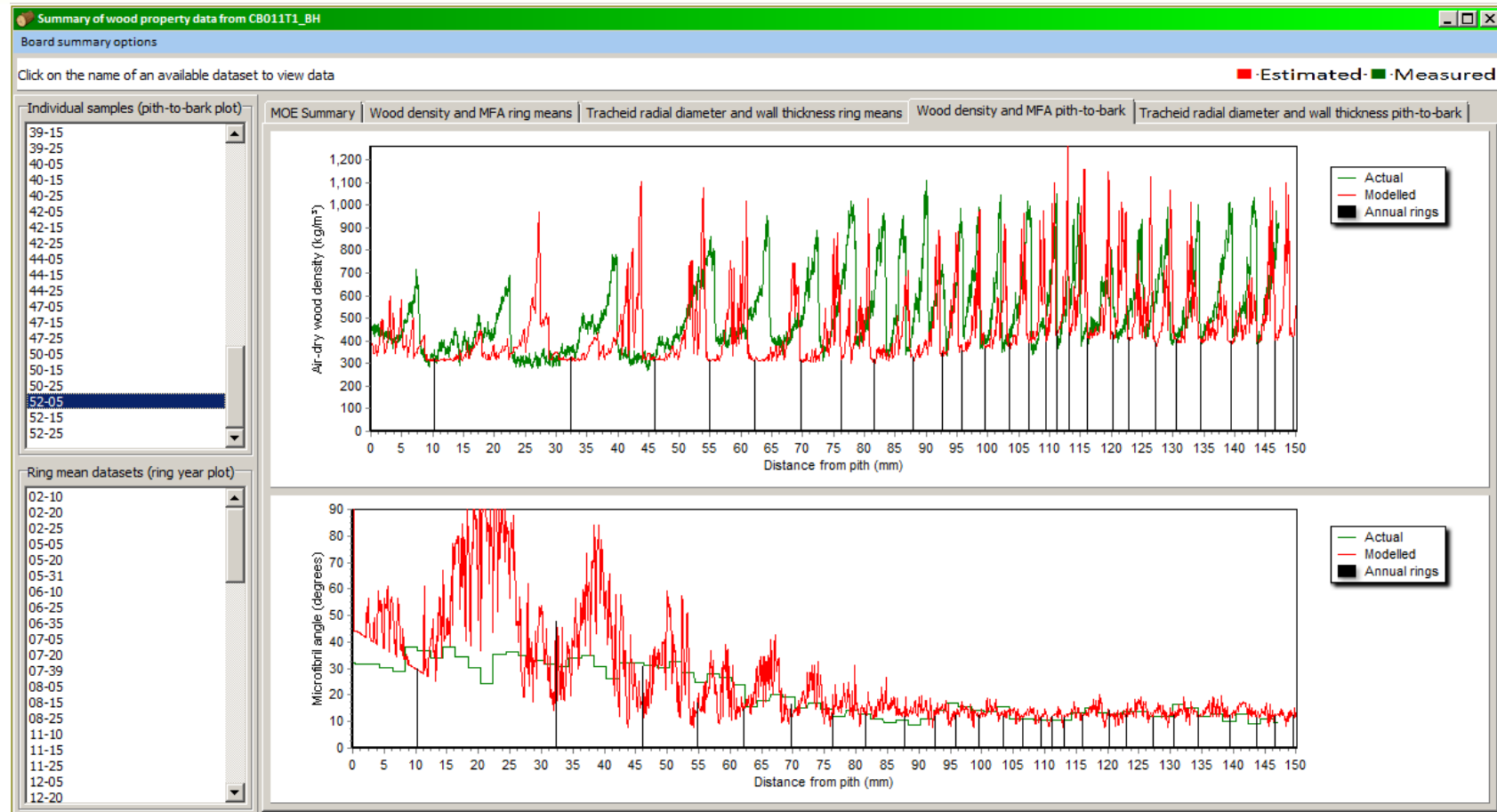
Overview of eCambium (Version 2.1)

- eCambium predictions of wood variation link effects of growth on board volume and quality



Drilling down into the lower level values

- Daily predictions of
- Wood density
- MFA
- Fibre diameter
- Fibre wall thickness





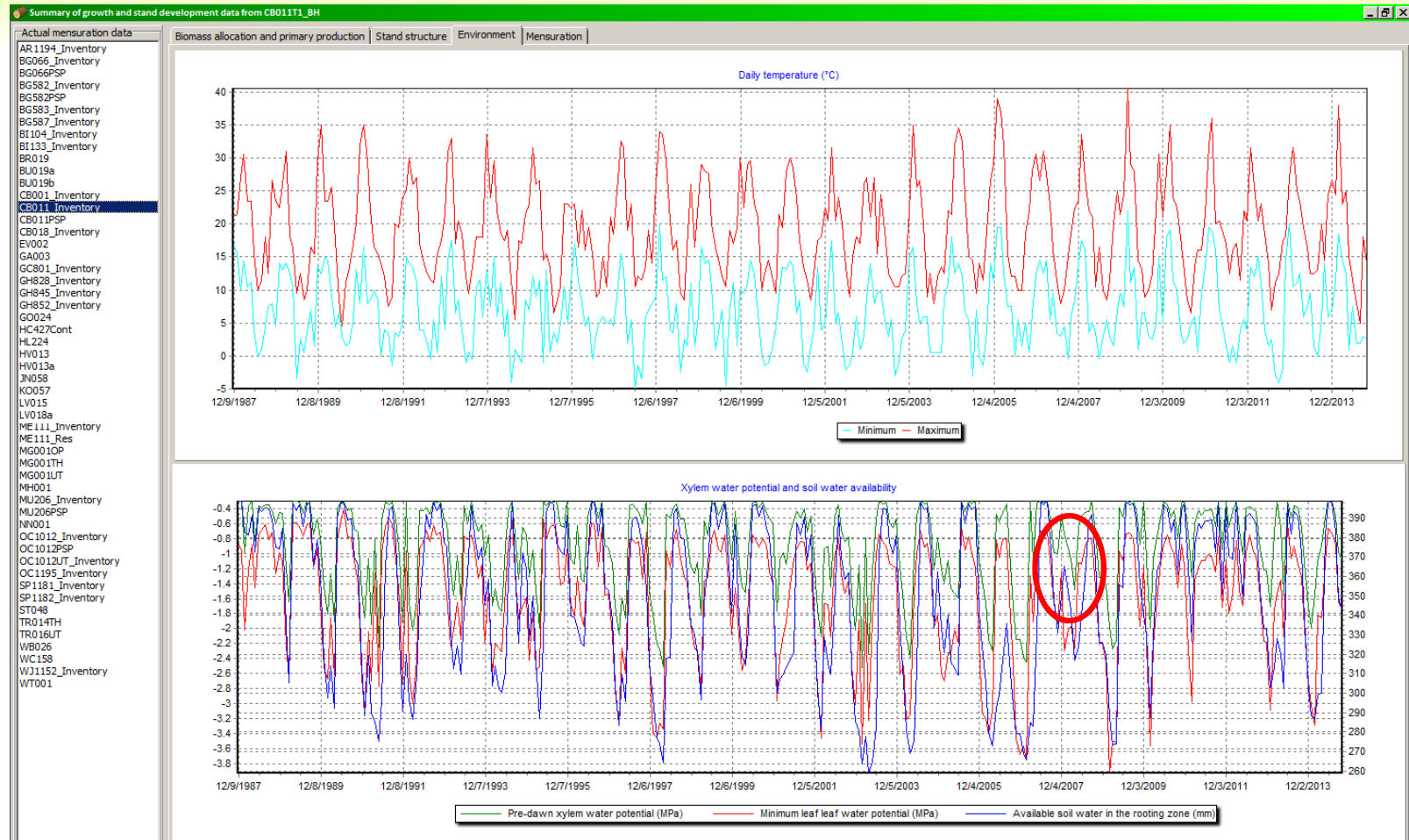
Forest Quality

MORE VALUABLE TREES

Tree growth predictions

Predictions of

- Height
- DBH
- Stand Volume
- Soil water availability
- Predawn water potential



Forest & Wood
Products Australia



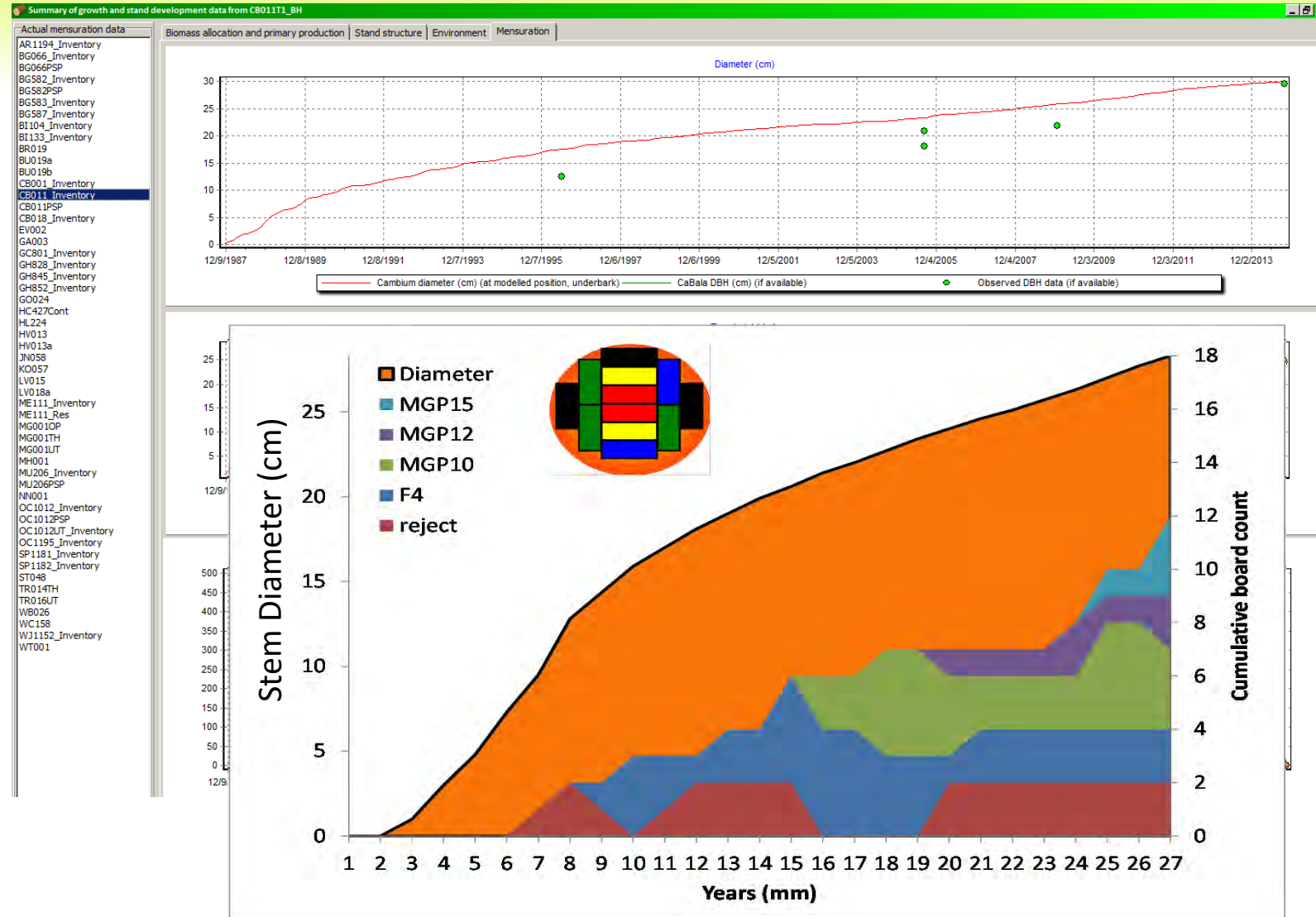
Forest Quality

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Tree growth predictions

Predictions of

- Height
- DBH
- Stand Volume
- Soil water availability
- Predawn water potential



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Products Australia

Murray Valley Basin Validation

Project Objectives

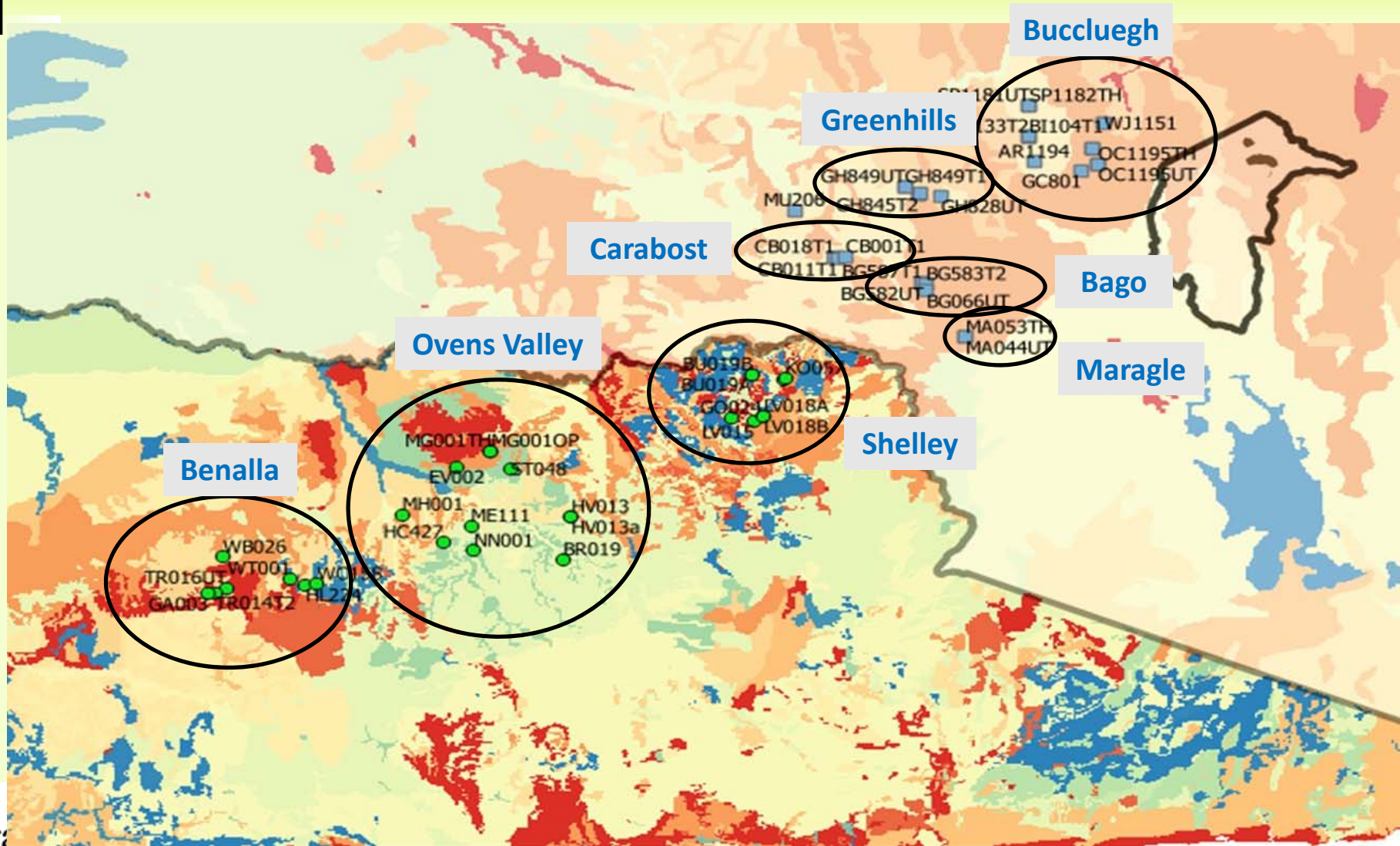
- Regional assessment of wood property variation from *P. radiata* sites in the Murray Valley Basin
 - close to harvest
 - represent wide range of resource variability
- Obtain a representative data set describing site average and variance data of tree and wood properties as a basis for evaluating the performance of the eCambium modelling tool
- Produce a “commercially-ready” version of eCambium



Forest Quality

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Site Selection



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Stage 1: NDE Resource Evaluation

- 53 sites
- 30 trees per site
 - DBH
 - Outerwood density cores
 - Standing tree acoustic velocity (ST300)
- 6 trees per site
 - Tree height
 - Branch diameter
 - Bark thickness

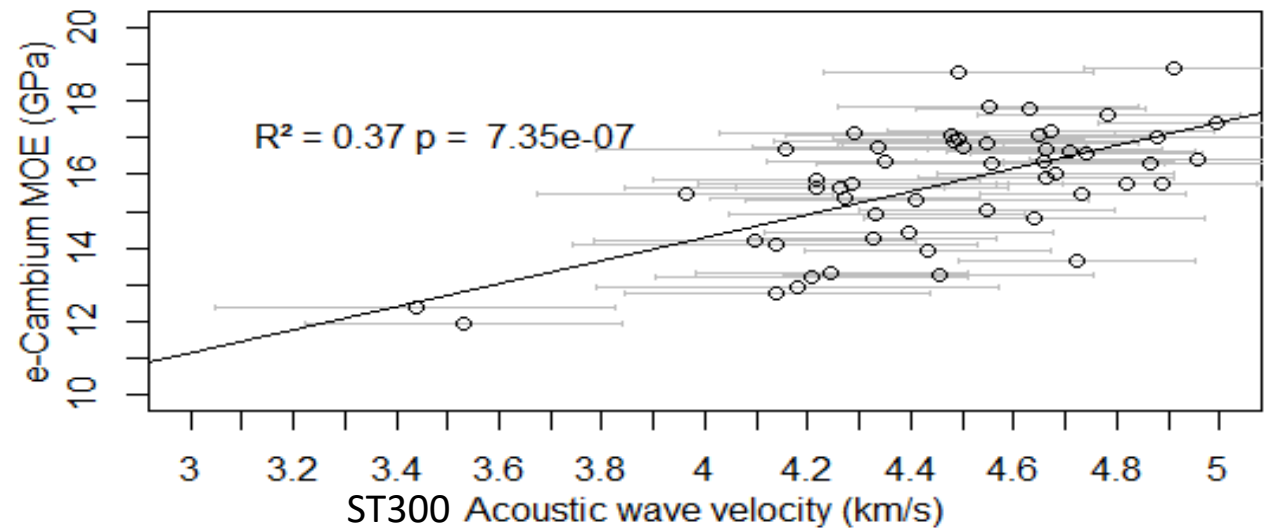
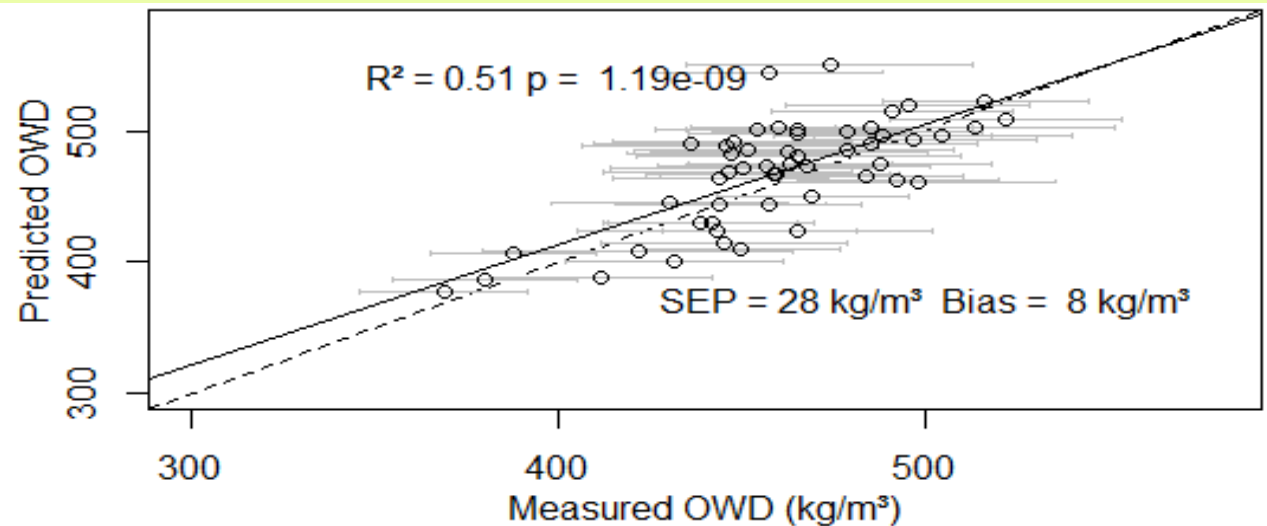


Forest Quality

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eCambium prediction of outerwood density

50% of the variation in site mean OWD was predicted by eCambium



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Fitted Empirical models of outerwood density

$$OWD = 396.6 - 1.93(\text{Branch Diameter}) + 0.174(\text{Spring Rainfall}) + 2.43(\text{Age})$$

- 38% variance explained

$$UT_OWD = 392 - 2.36(\text{Branch Diameter}) + 0.63(\text{Autumn Rainfall}) + 4.64(\text{Max. Autumn T}) + 2.45(\text{Age})$$

- 55% variance explained

$$T1_OWD = 1187 - 2.26(\text{Branch Diameter}) - 0.476(\text{DBHOB}) - 0.066(\text{Annual Rainfall}) - 21.55(\text{Ave Temp}) - 0.07(\text{Annual Radiation}) + 10.1(\text{Age})$$

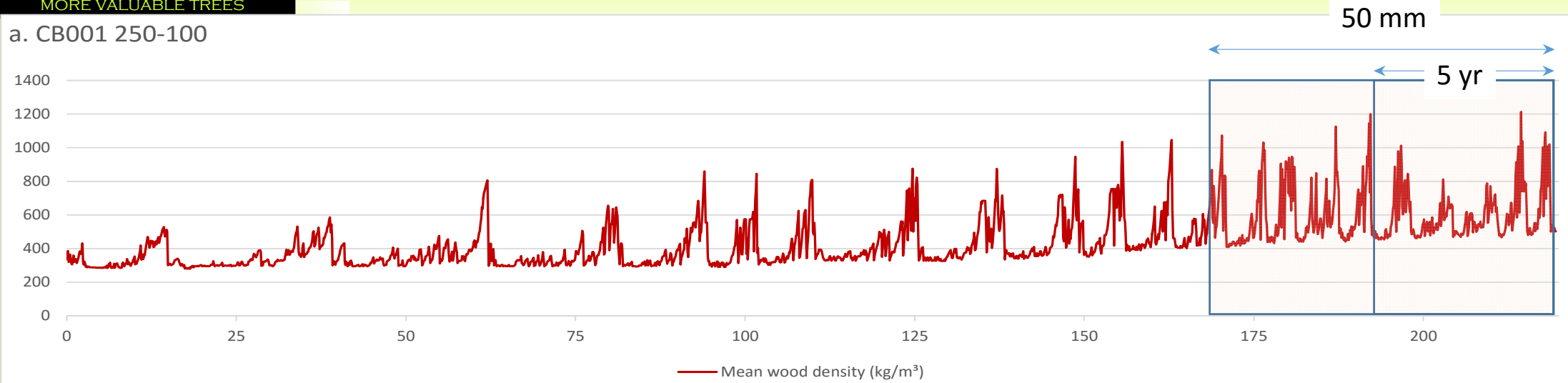
- 71% variance explained



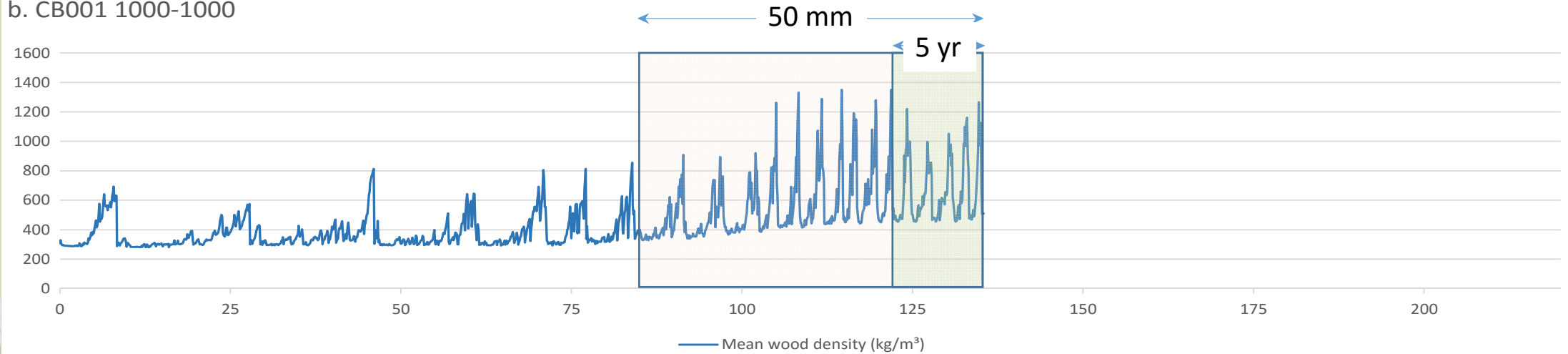
Forest Quality
MORE VALUABLE TREES

Problem of 50mm outerwood cores

a. CB001 250-100

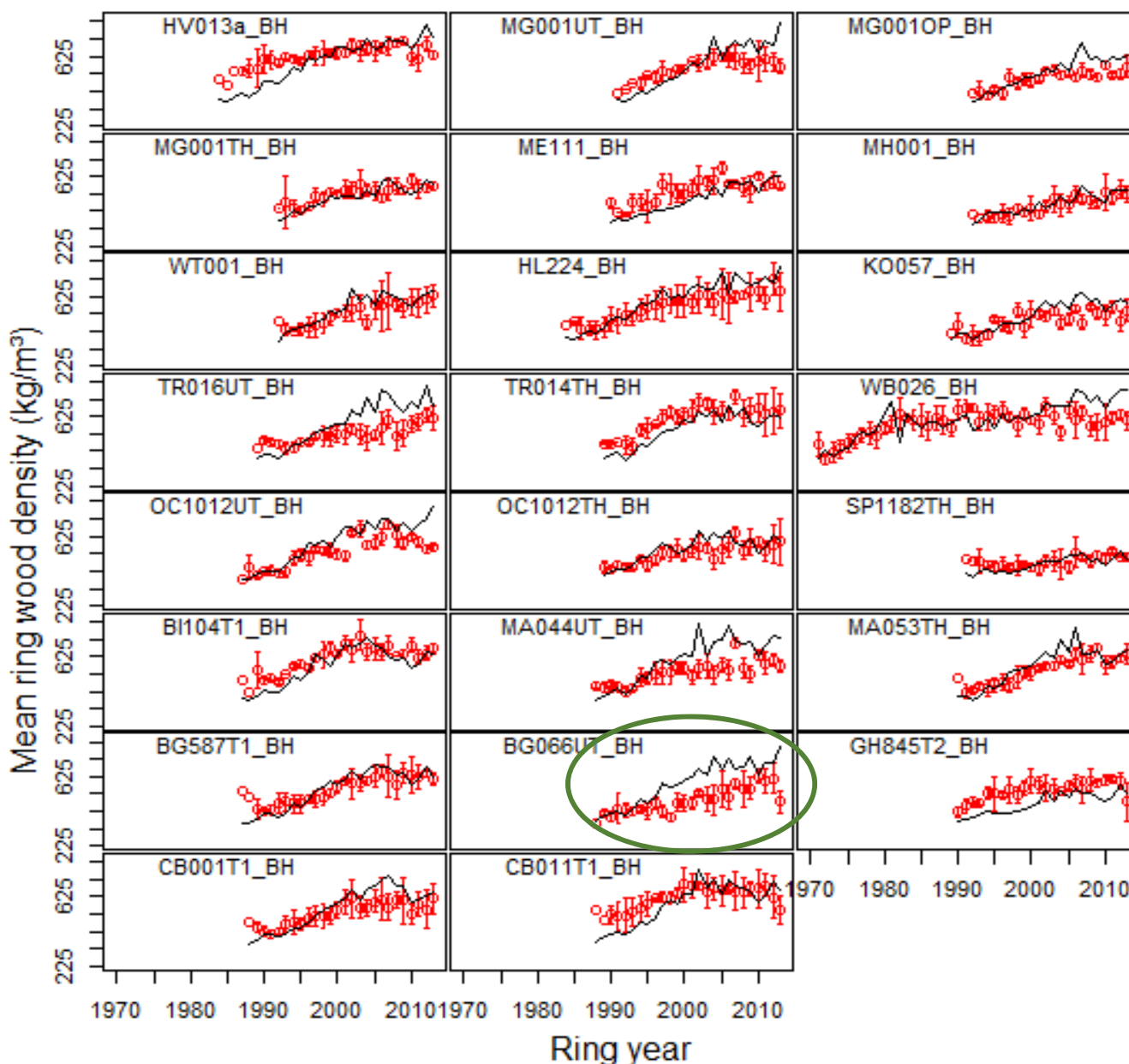


b. CB001 1000-1000



Radial trends

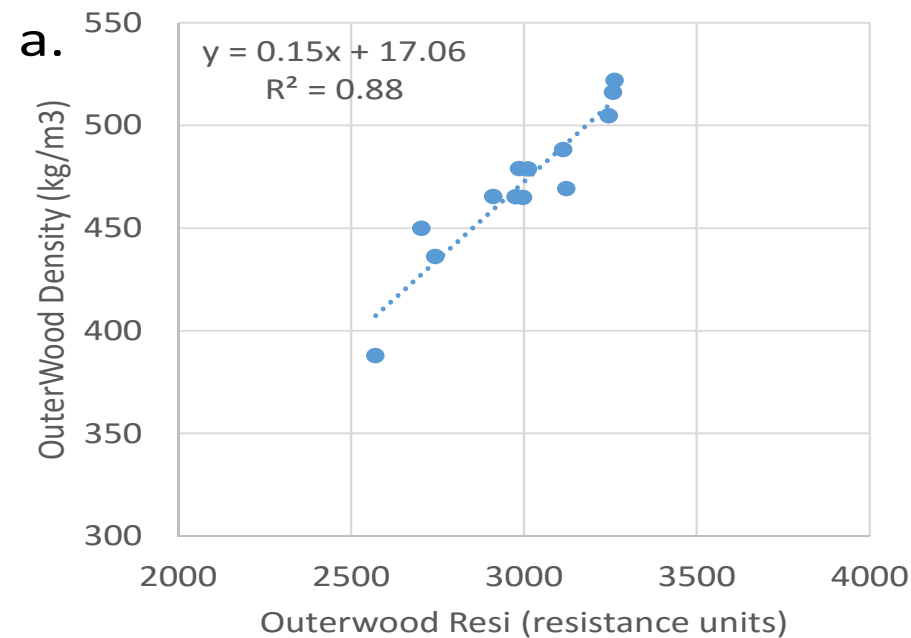
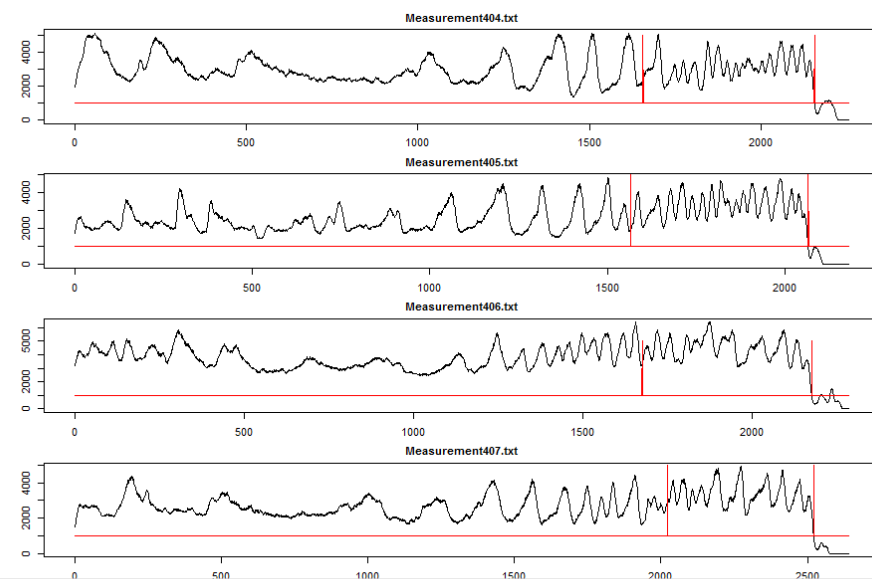
Comparison with actual Silviscan data allowed eCambium to be evaluated at the annual ring level to assess whether the model was predicting radial trends accurately.





IML Resistograph

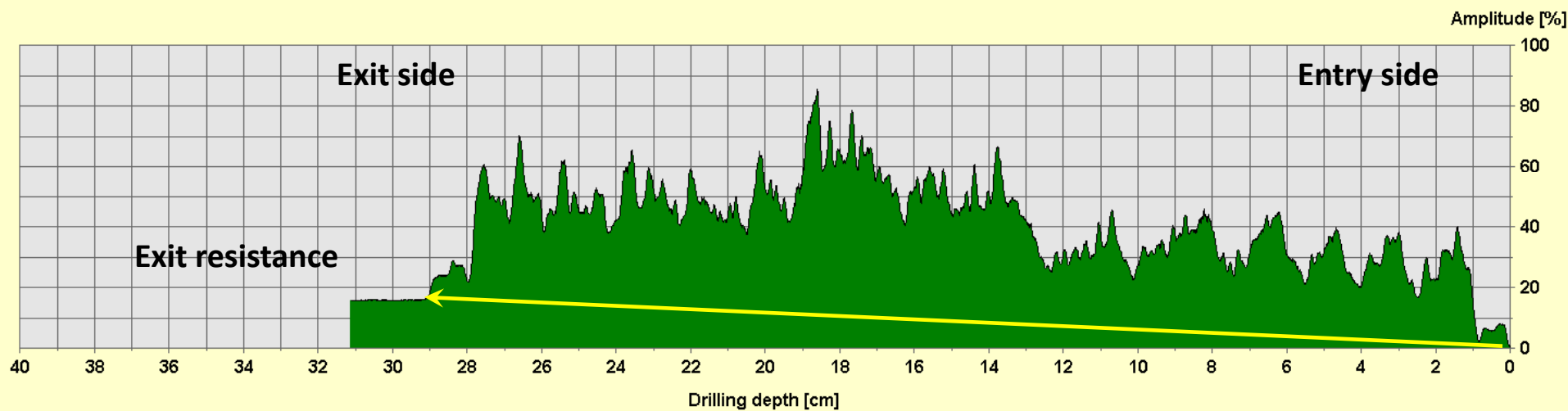
- < 30 secs per tree
- Provides radial variation
- No Laboratory work
- Easy –to-use





Measuring / object data

Measurement no. :	161	Needle speed :	2500 r/min	Diameter :	
ID number :	05/25/04	Needle state :	---	Level :	
Drilling depth :	31,15 cm	Tilt :	---	Direction :	
Date :	03.11.2016	Offset :	88/300	Species :	
Time :	12:14:56	Avg. curve :	off	Location :	
Feed speed :	150 cm/min			Name :	



Assessment

☐	From 0,0 cm to 0,0 cm :
☐	From 0,0 cm to 0,0 cm :
☐	From 0,0 cm to 0,0 cm :
☐	From 0,0 cm to 0,0 cm :
☐	From 0,0 cm to 0,0 cm :
☐	From 0,0 cm to 0,0 cm :

**70% of exit resistance explained by diameter
(~50%) and density (~20%)**

Comment

FORICO N KING05

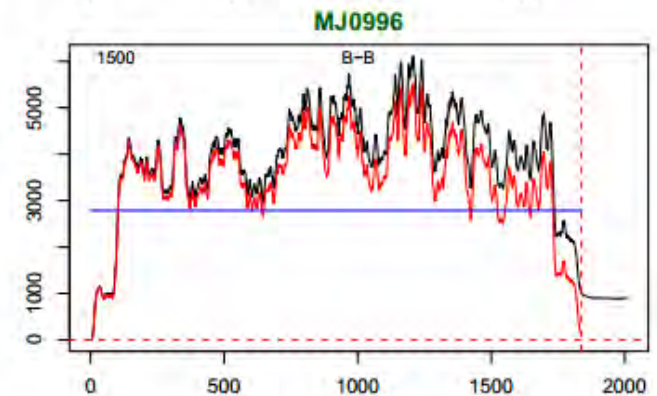
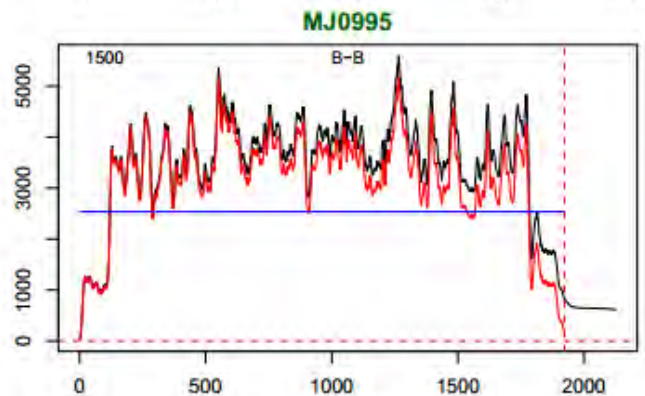
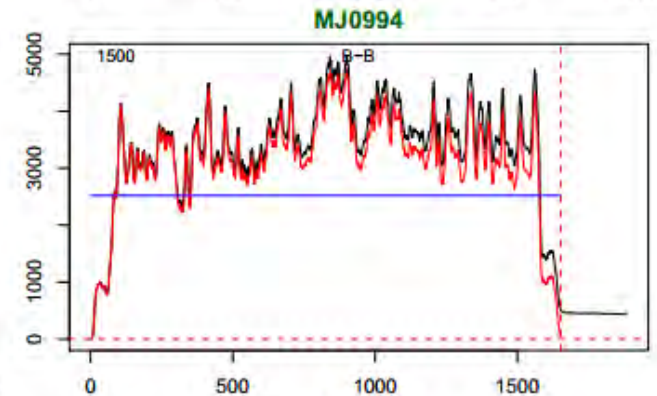
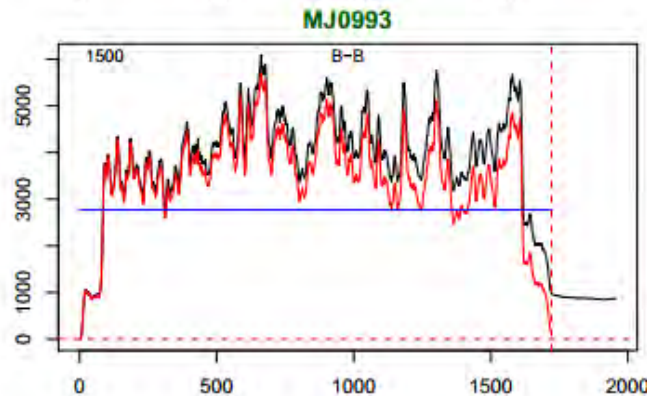
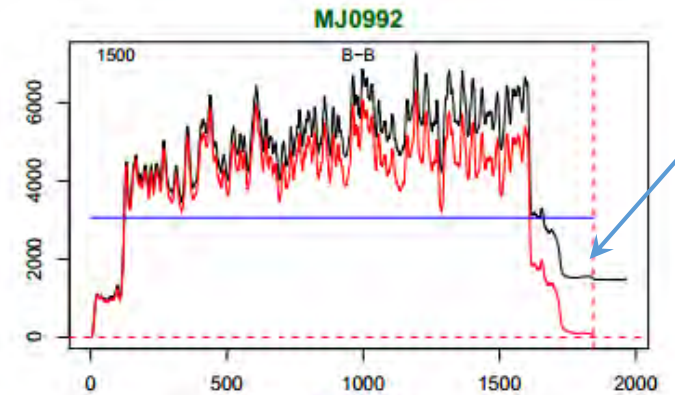
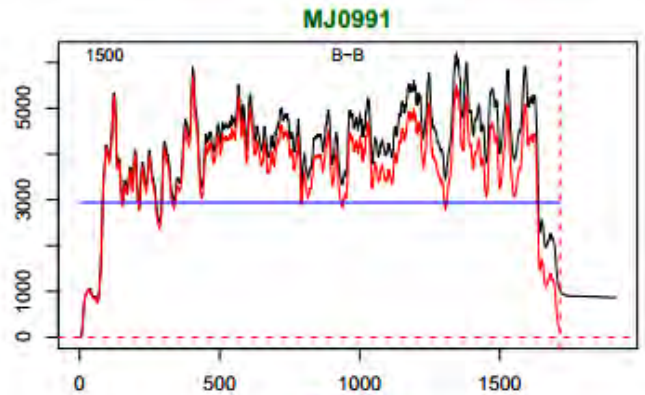


Forest Quality

MORE VALUABLE TREES

Properties obtained

- Overbark diameter
- Underbark diameter
- Bark thickness
- Average underbark density
- Outerwood averages
- Radial average



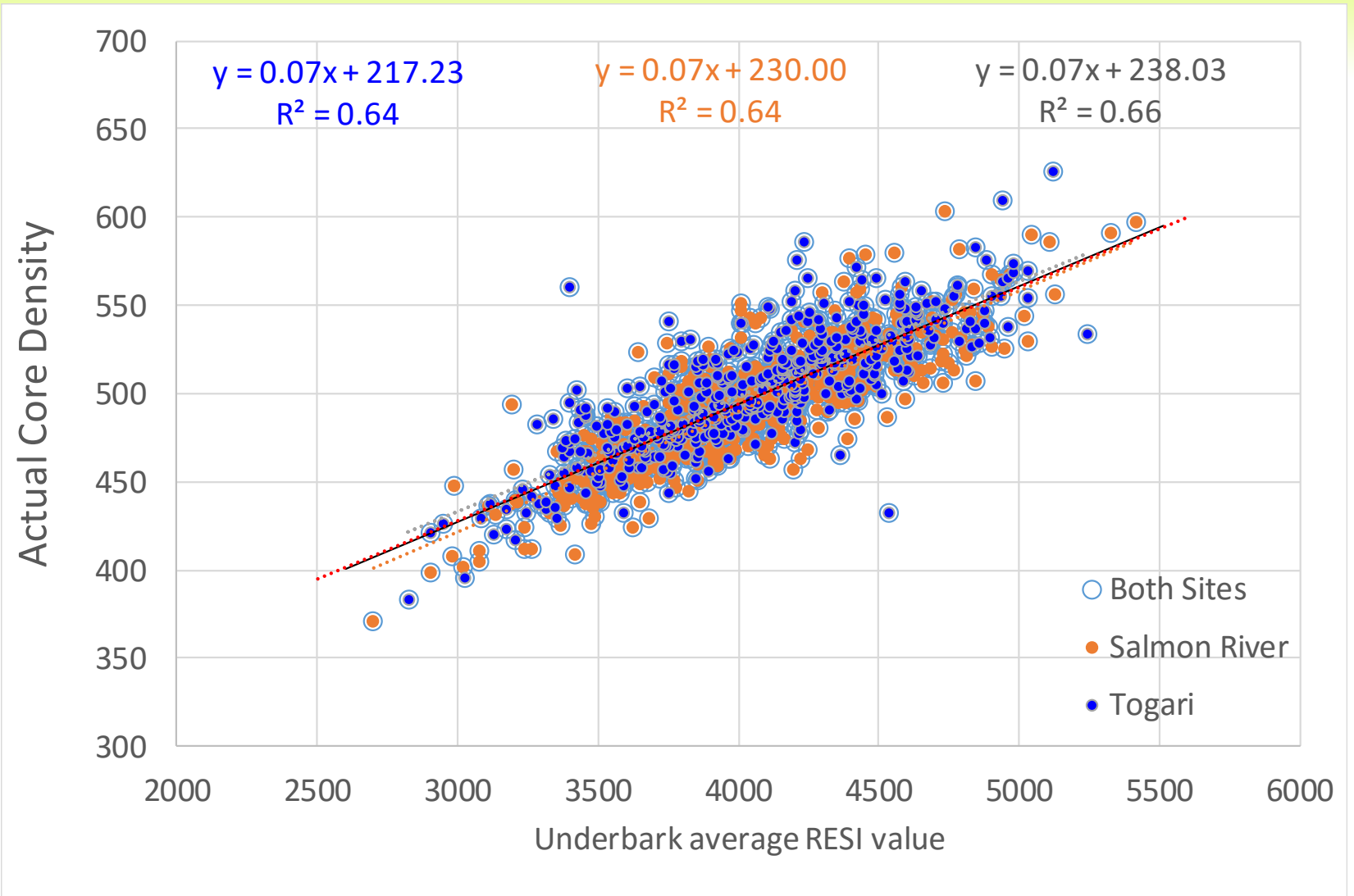
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Forest Quality

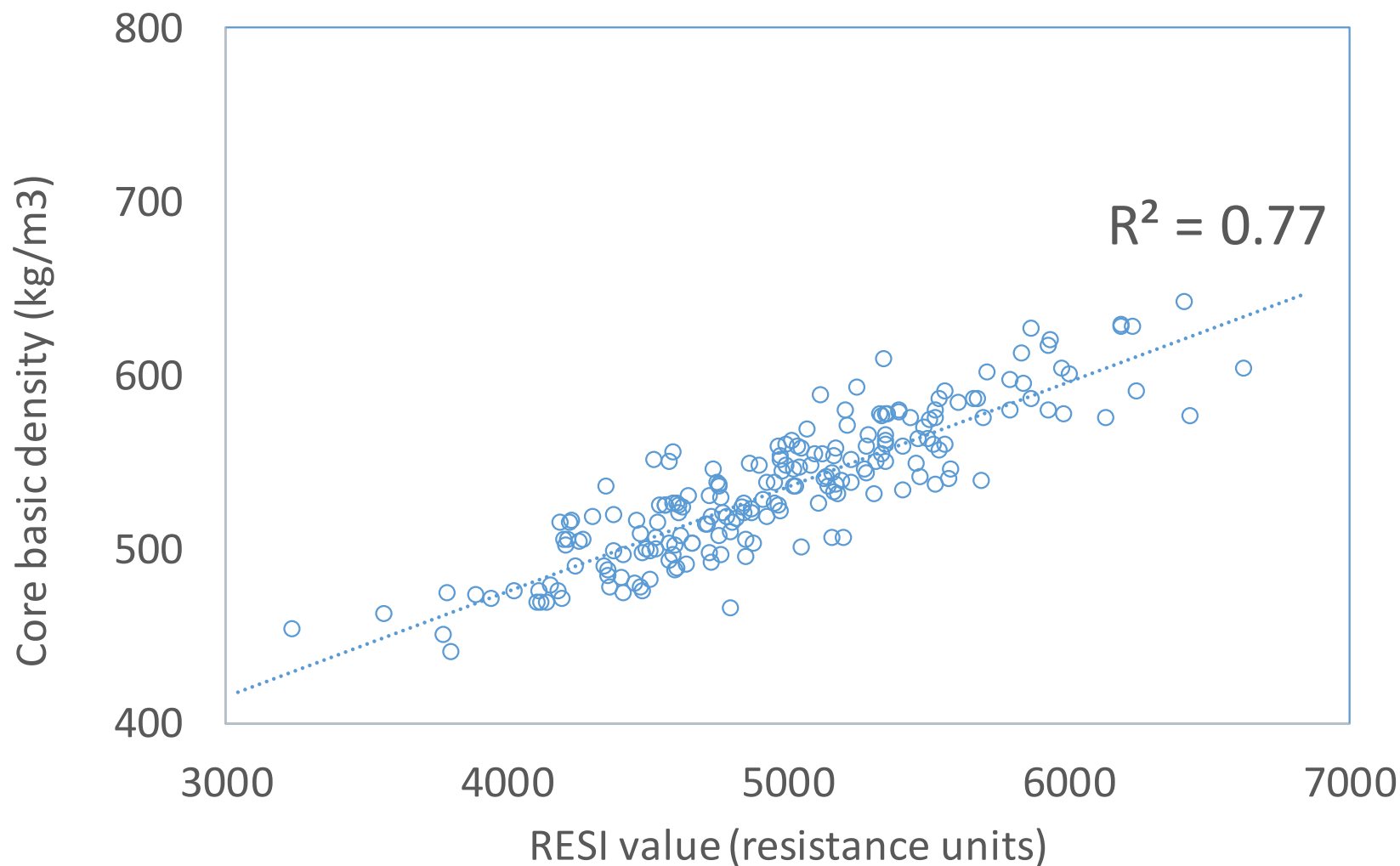
MORE VALUABLE TREES

ARC study: University of Tasmania (Prof Brad Potts)



Forest & Wood
Products Australia

Manjimup, WA Resi Validation



Projects and Data Input

- Create a new project
- Open an existing project
- Import Resi data files
- Add or edit sample info

Sample name	PrHM200 (km/s)	PrDensity (kg/m)	PrMOE (GPa)	Parameter Set	Sample posi	Tree ID	Tree type	DBH (cm)	Site name	Resi speed (r)	Resi feed rate
1_1-11-7	3.72	526.5	14.6	Default							
1_1-12-6	4.04	510.9	16.7	Default							
1_1-1-6	3.75	504.5	14.2	Default							
1_1-2-6	3.82	488.5	14.3	Default							
1_1-4-6	3.48	494.2	12	Default							
1_1-6-6	3.72	511.6	14.1	Default							
1_1-8-6	3.69	547.8	14.9	Default							
1_1-10-6	3.99	583.5	18.6	Default							

Data

Allocate pith, cambial position and annual rings

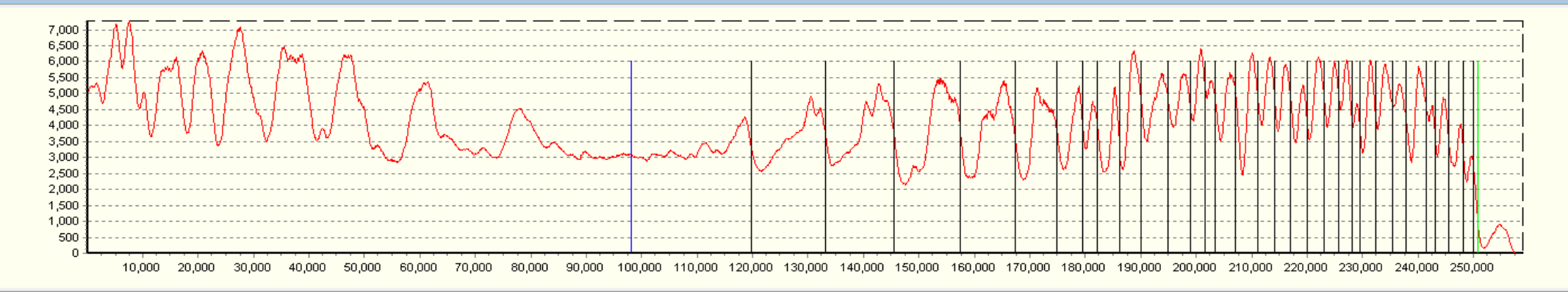
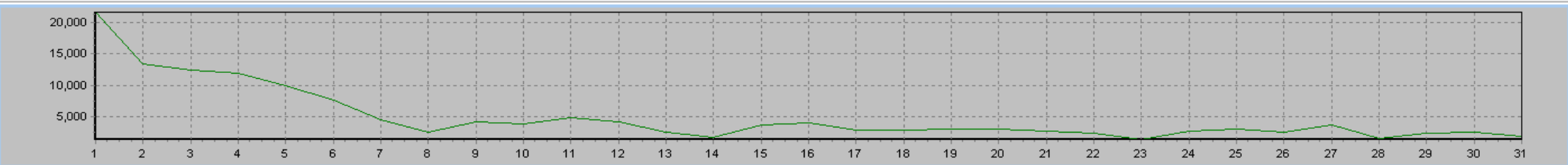
Manually select:

☐ Pith
 ☒ Rings
 ☐ CZone

Select a Resi sample: 34_1-11-7
 Select a parameter set: Default
 Calculate HM200 value
 Delete Sample

Last Sample...34_1-13-6
 ☐ Select to use existing rings

Select a sample to compare:



11_2-11-6	3.37	430	9.0	Default							
11_2-11-6	4.03	504.6	16.4	Default							
11_2-12-6	3.38	449.5	10.3	Default							
11_2-13-6	3.69	500.3	13.6	Default							
11_2-14-6	3.5	450.8	11.1	Default							

Check parameters

Clear the log

Compact Database

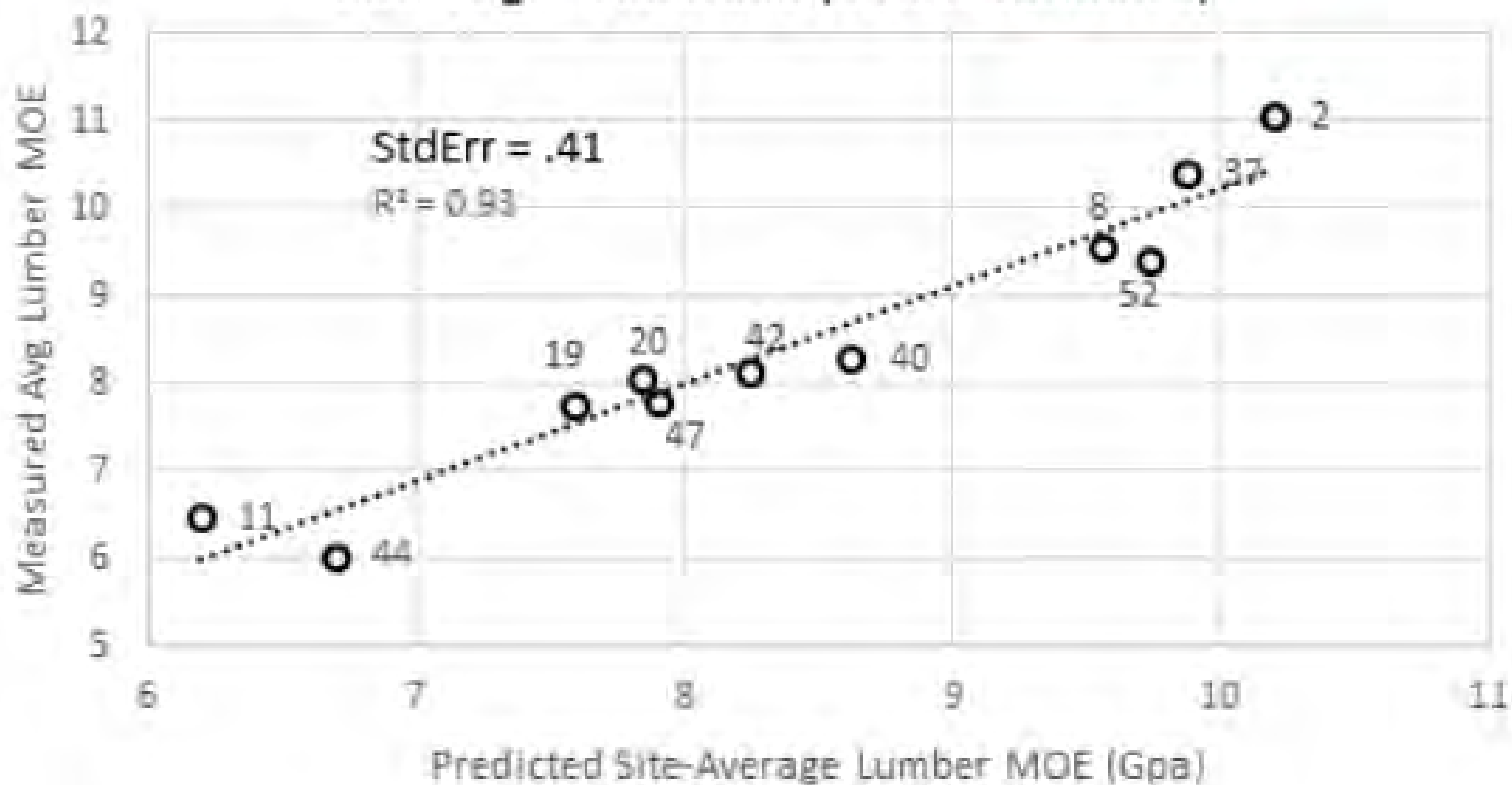
1/18/2017 8:30:37 PM: Calculations for 34_1-13-6 completed. PrHM200 = 4.13409617750339
 1/18/2017 8:30:35 PM: Calculations for 34_1-1-6 completed. PrHM200 = 3.92390776035512
 1/18/2017 8:30:29 PM: Calculations for 34_1-13-6 completed. PrHM200 = 4.13409617750339
 1/18/2017 8:30:27 PM: Calculations for 34_1-11-7 completed. PrHM200 = 3.97928336378193
 1/18/2017 8:30:25 PM: Calculations for 1_1-11-7 completed. PrHM200 = 3.72100179283597



Forest Quality

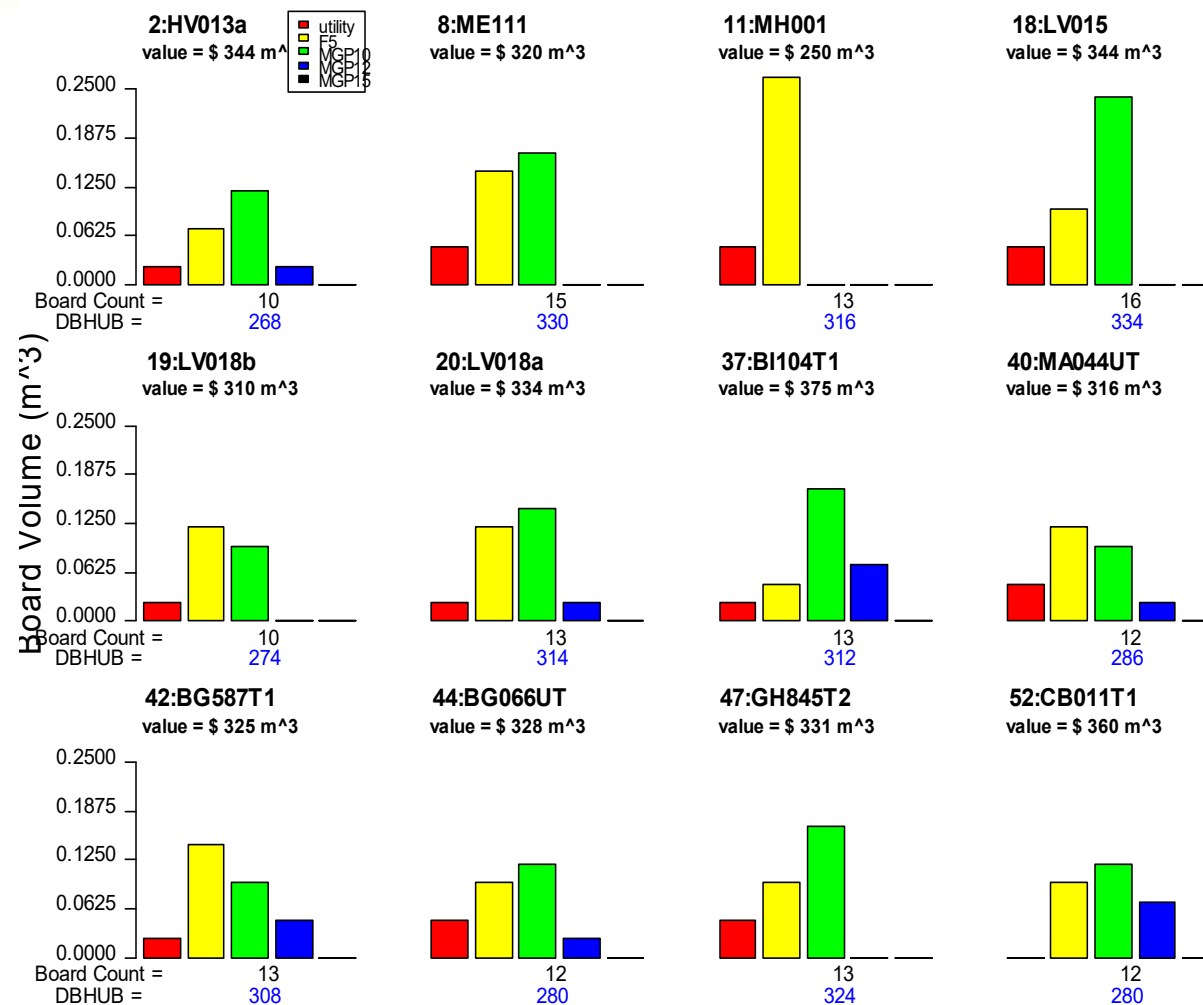
MORE VALUABLE TREES

Prediction of Site Avg MOE Using Resi Data & DBH Butt Logs - Australia (3 Resi Variables)



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Sawmill study sites value predictions





Forest Quality

MORE VALUABLE TREES

Log Preparation





Logs weighed for green density calculation



Logs loaded into mill infeed





Forest Quality

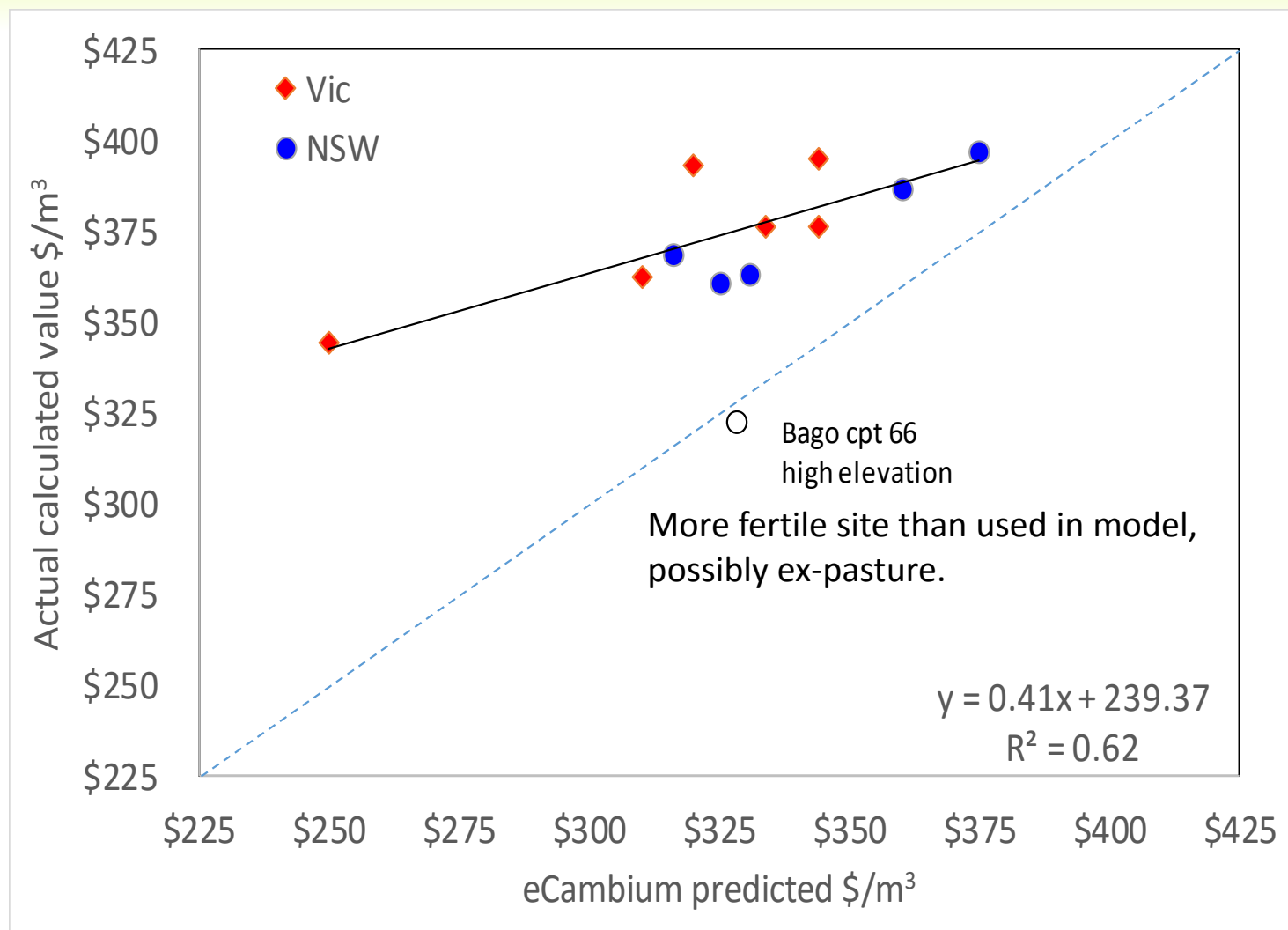
MORE VALUABLE TREES

Resultant boards imaged



eCambium's prediction of site value

- eCambium predictions made 4 months before logs were harvested
- Partly dependent on grade thresholds for converting MOE into grade



Conclusions

- eCambium explained similar OWD variance to empirical models
 - eCambium predictions in range using general inputs for site descriptions
 - publically available database values
 - FR constant at 0.3,
 - rock content constant at zero
 - Parameter optimization, across Tasmania, Green Triangle, Victoria and NSW yielded calibration $r^2 > 60\%$
- eCambium explained 50-60% of the site average sawlog value and log MOE
 - Low-cost way to get broad-scale insights into estate-level wood variation and value
- Model setup and operation relatively simple
 - Ready for commercial application
 - Development for operational functionality needed (industry input required)

e-Cambium: options for the future

