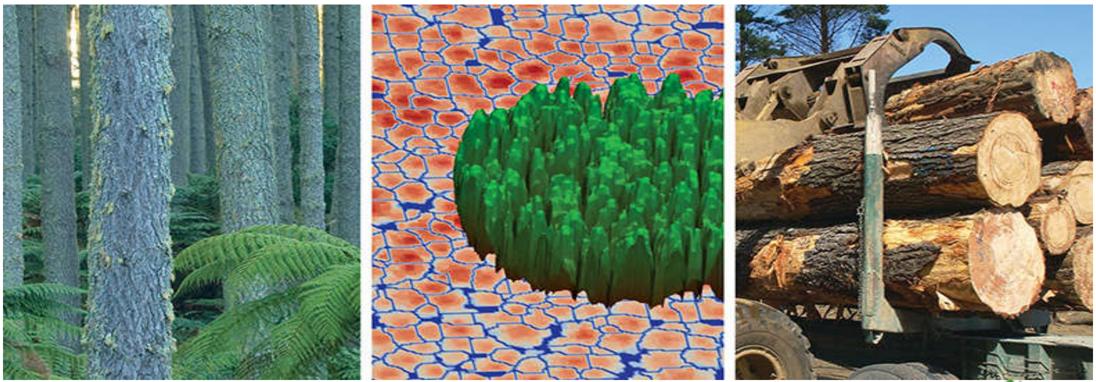
Growing confidence in forestry's future Research Programme

SCION FORESTS • PRODUCTS • INNOVATION

Next generation silviculture

Heidi Dungey, John Moore, Michael Watt



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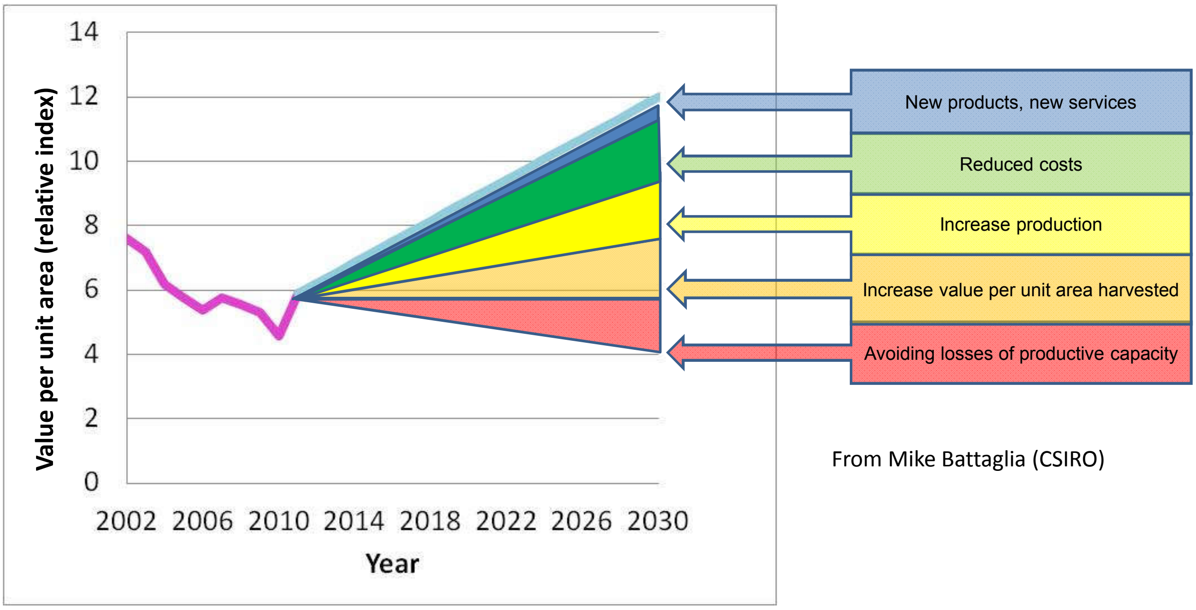
FOREST GROWERS RESEARCH

There are many pathways to increasing productivity

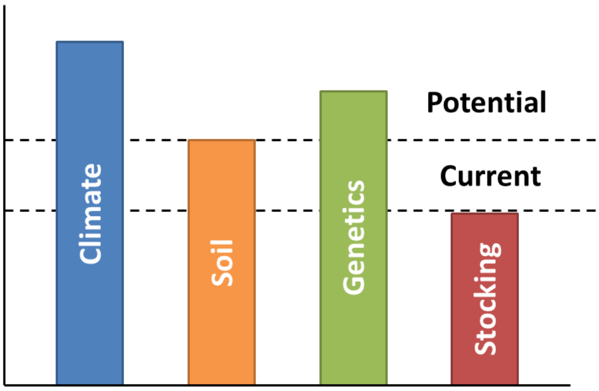


From Mike Battaglia (CSIRO)

Good silviculture is key to increasing productivity

- Practice of controlling different factors to produce a range of different products and services
  - Selection of tree stocks
  - Stand establishment
  - Competition control
  - Maintaining tree health
  - Manipulating wood quality

- A “one size fits all” approach will not maximize productivity
  - Need to develop site-specific prescriptions
  - Requires knowledge of how site, genetics and silviculture combine and interact



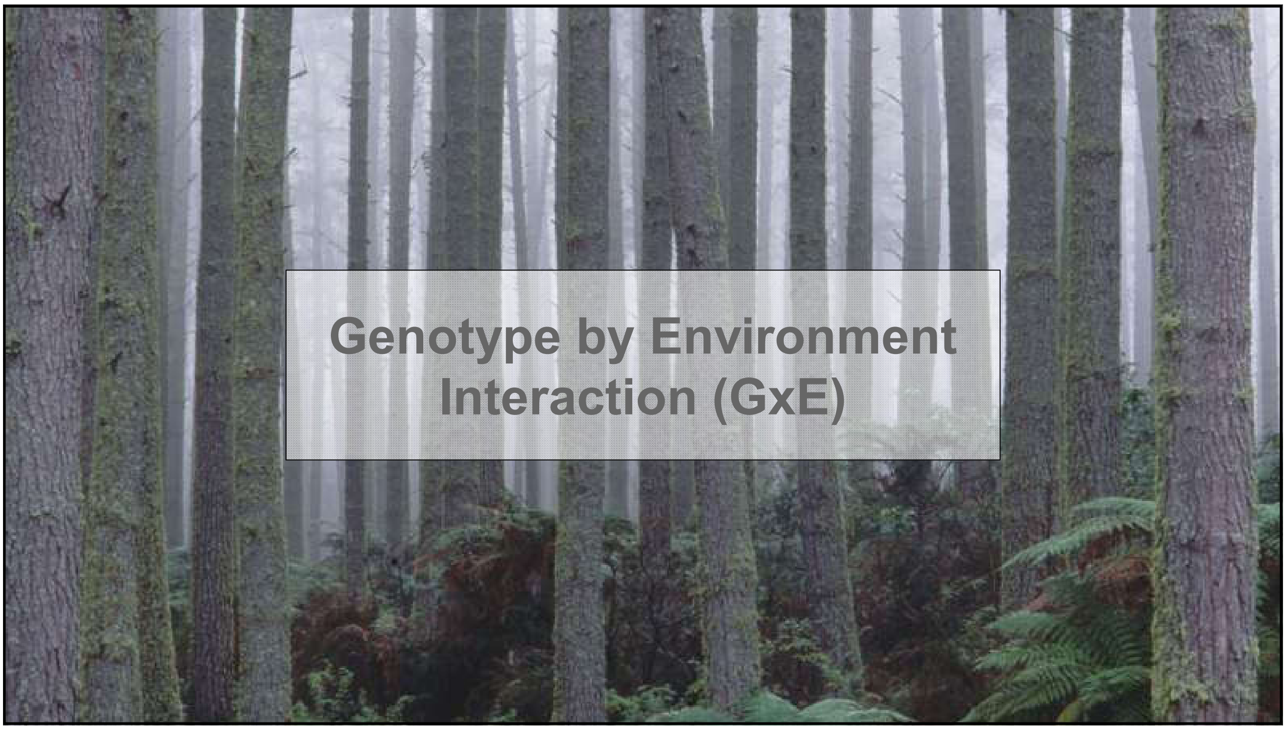
Increasing productivity through exploiting G x E x S

- What is G x E and how can forest managers exploit this for productivity gain?

- What is the “optimum” post-thinning stand density to maximize value?

- What have we learned from long-term experiments?

- Bringing it all together – how to design new silvicultural regimes for specific genotypes (seedlots) on specific sites?



Genotype by Environment Interaction (GxE)

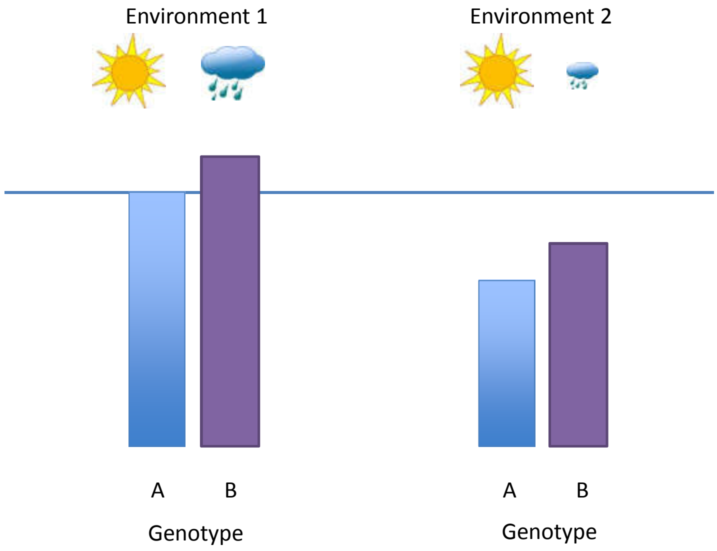
Genotype by environment interaction

Phenotype = Genotype + Environment

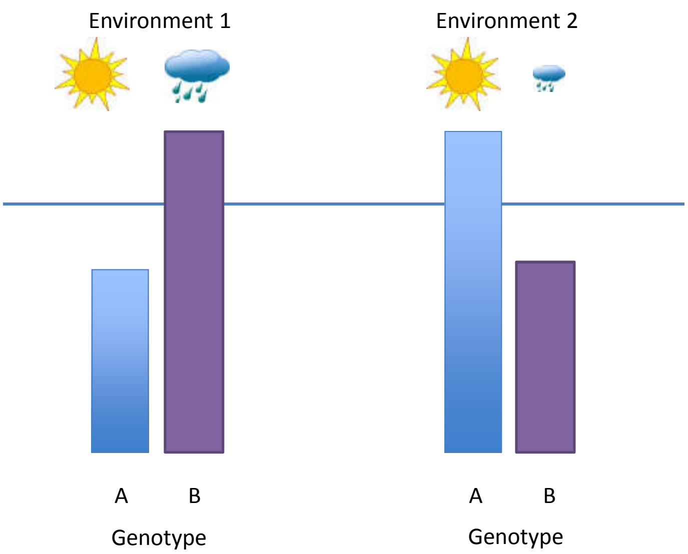
+ Genotype x Environment

$$P = G + E + (G \times E)$$

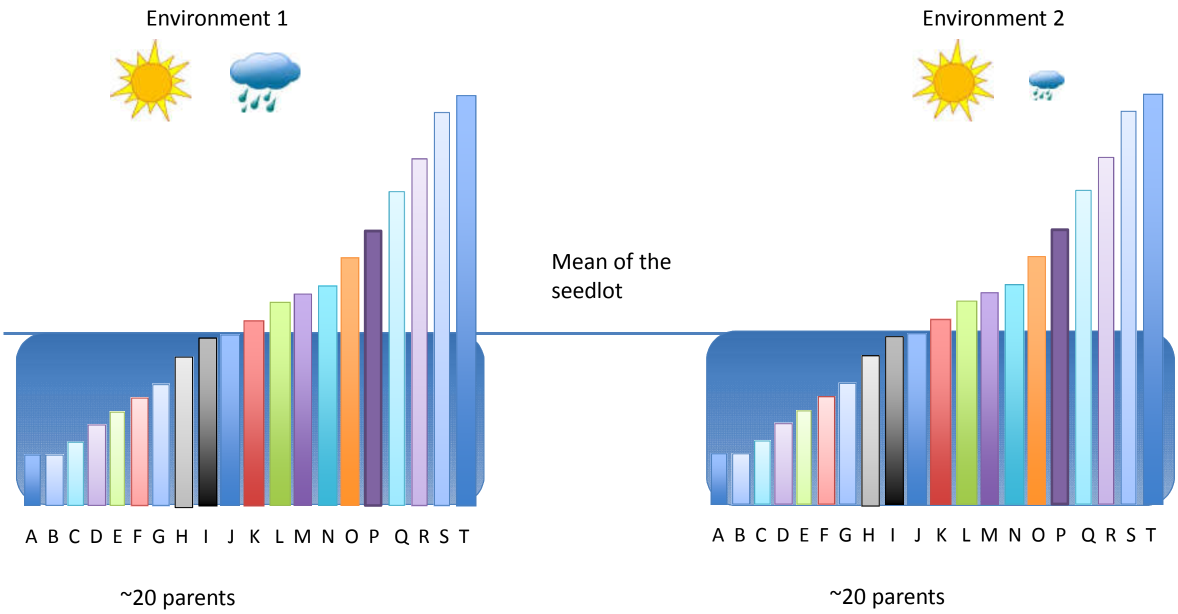
Genotype x Environment



Genotype x Environment

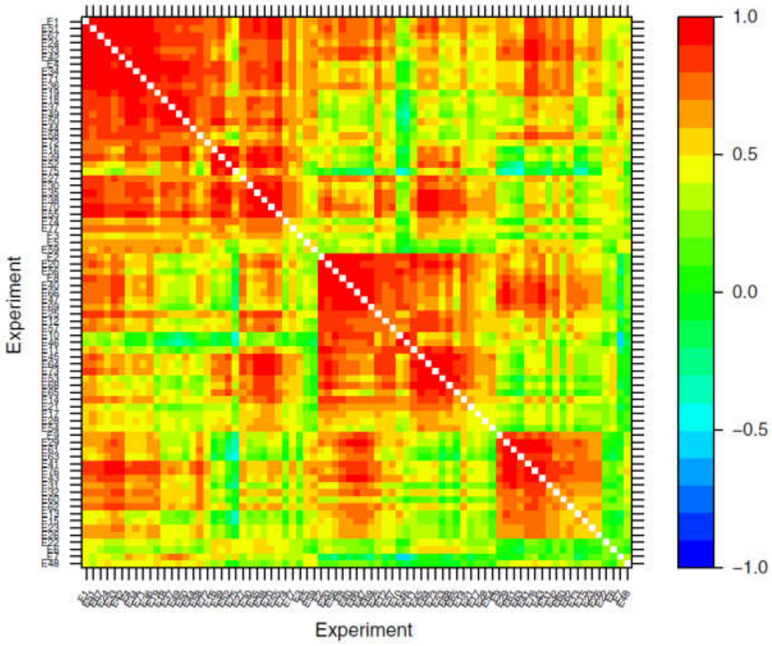


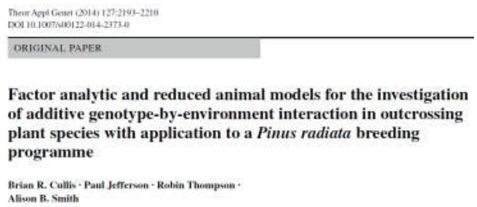
Seedlot (GFPlus) x Environment



So how do you use it?

- Breeding values estimated on average across all trial sites in NZ
- GFPlus estimated from breeding values
- Higher GFPlus – better 'on average' performance
- GFPlus value for key traits – DBH, wood density, wood stiffness





Theor Appl Genet (2014) 127:2193–2210
DOI 10.1007/s00122-014-2373-0

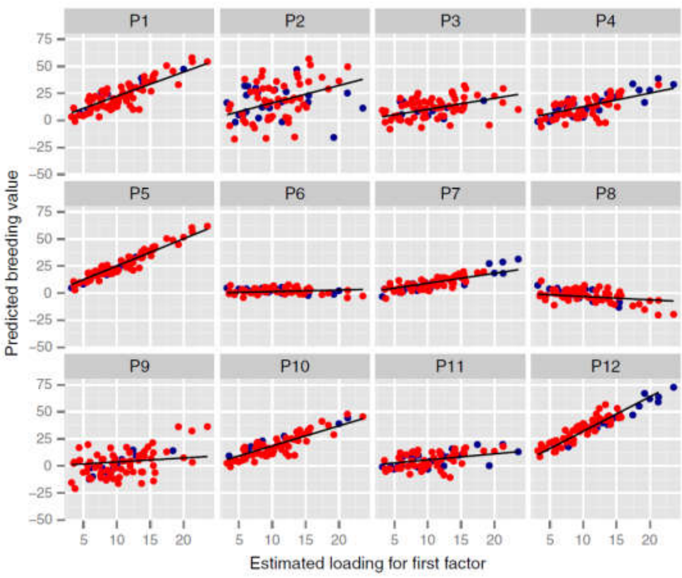
ORIGINAL PAPER

Factor analytic and reduced animal models for the investigation of additive genotype-by-environment interaction in outcrossing plant species with application to a *Pinus radiata* breeding programme

Brian R. Cullis · Paul Jefferson · Robin Thompson · Alison B. Smith

77 single-tree plot trials, 312,848 trees, 2733 parents

Trials designed to test the relative performance of different families



Some parents show a lot of change across sites

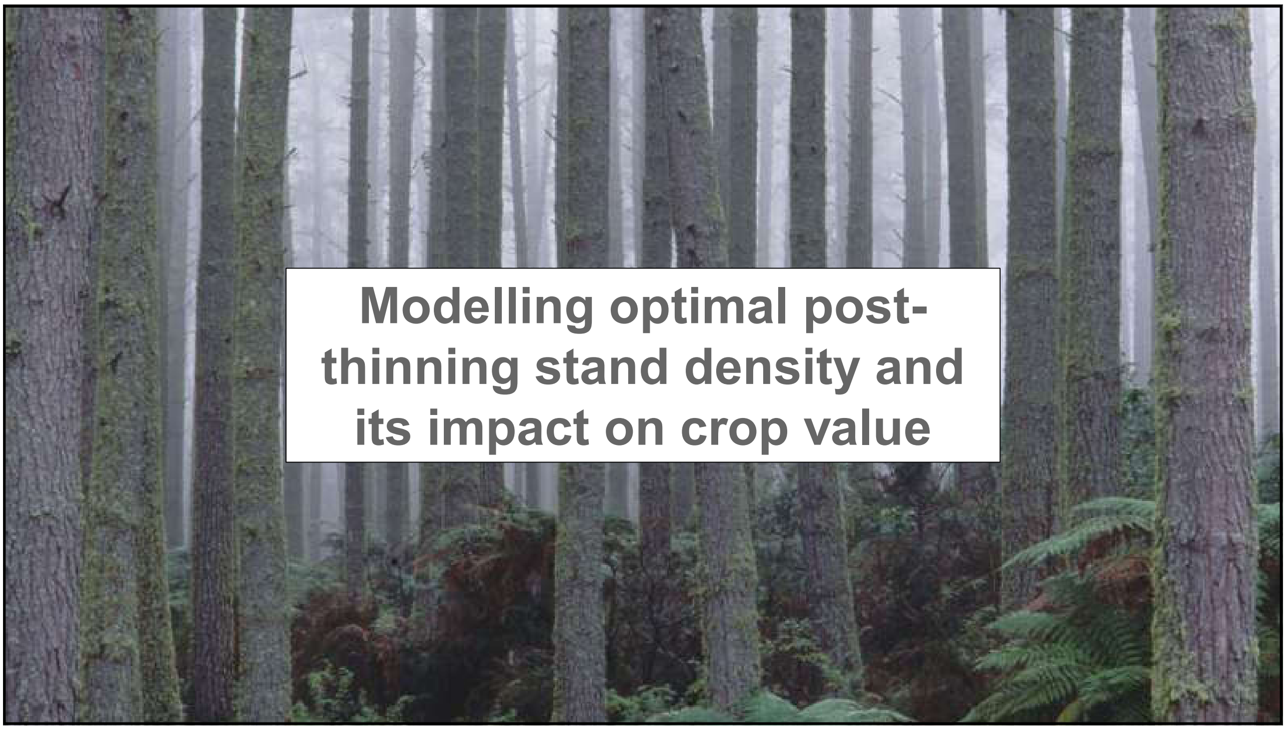
Some parents are stable

How much extra might be available by taking advantage of this difference?

Key message

- GFPlus can be used to get the most out of genetics (on average)
- Better sites will get better expression
- GFPlus is a mix of seedlots to buffer individual family changes

- The future is – taking advantage of the additional gain available
- Single families and even clone matching to site
- Optimising silviculture for growing families and clones



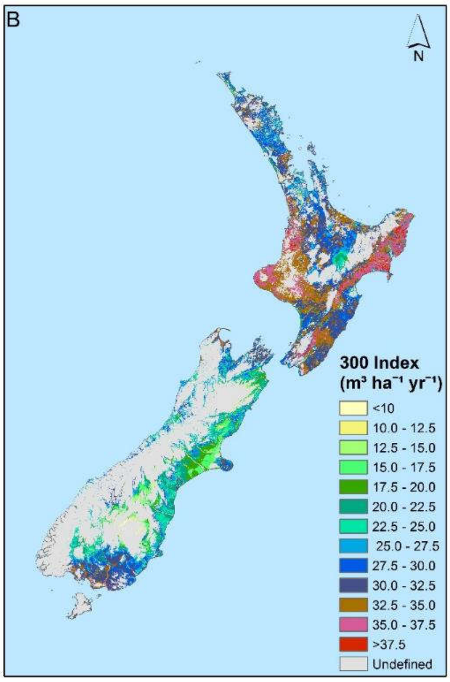
Modelling optimal post-thinning stand density and its impact on crop value

Introduction

- Final stand density is an important determinant of crop volume and value
- Empirical models included within Forecaster widely used to predict optimal stand density at stand level
- Large scale spatial surfaces of optimal stand density could be useful for forest managers

Introduction

- 300 Index and Site Index used to determine final stand density
- Spatial surfaces of these indices available
- Potential to use these for developing surfaces describing optimal stand density



Objective

- Develop a model that can predict optimal stand density and value for unpruned, pruned regimes
- Determine the relative value of pruned vs unpruned regimes
- Output optimal stand density and relative value for NZ plantations under varying input conditions
- Determine value of optimising stand density for unpruned regimes

Model development

- Three regimes defined
  - Structural : S30, min sed 27 cm, max branch 7 cm
  - Small log pruned : P30, min sed 30 cm
  - Large log pruned : P40, min sed 40 cm
- Use Forecaster to predict volumes by regime for a range of sites, stand densities, ages

Model development

- Fit quadratic regression model predicting volume for each of the three regimes from age, 300 Index, Site Index and stand density
- Derive optimum stand density using simple calculus from predicted volumes, costs and values

Model requirements

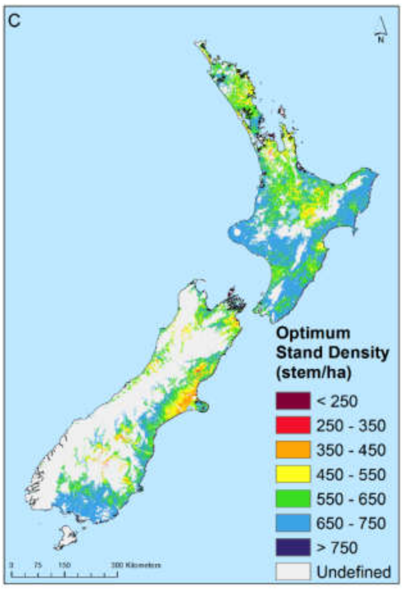
- Rotation age
- Site Index
- 300 Index
- Net value of S30 logs (value-harvest cost) ($/m3)
- Premium for pruned logs over S30 logs ($/m3)
- Cost of pruning ($/stem at harvest age)

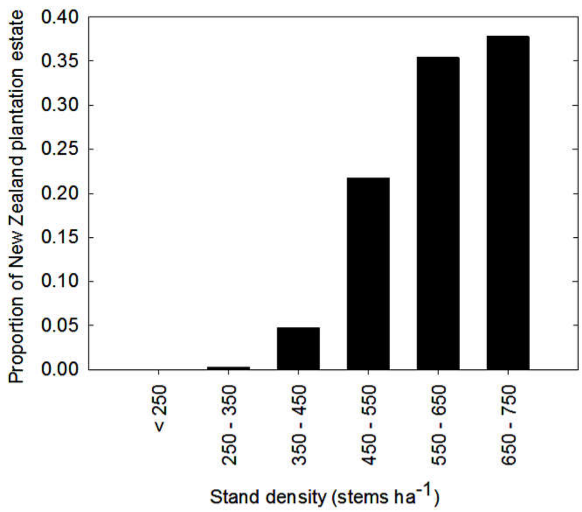
Model outputs

- Optimal stand density, by regime
- Stand value, by regime ($/ha)
- Relative value of pruning (%) for P30 and P40 regimes

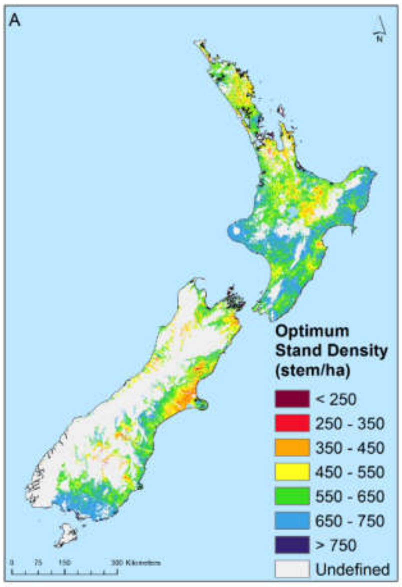
  = (Pruned value - Unpruned value)/Unpruned value x 100

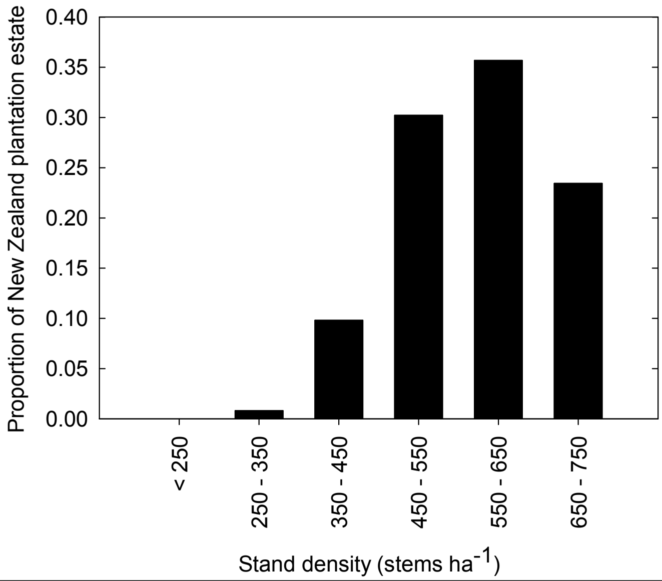
Stand density – S30



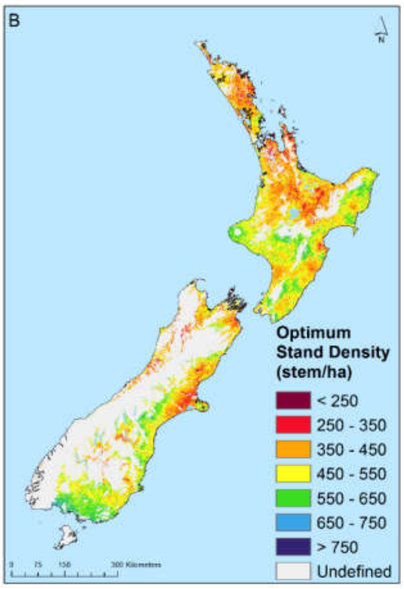


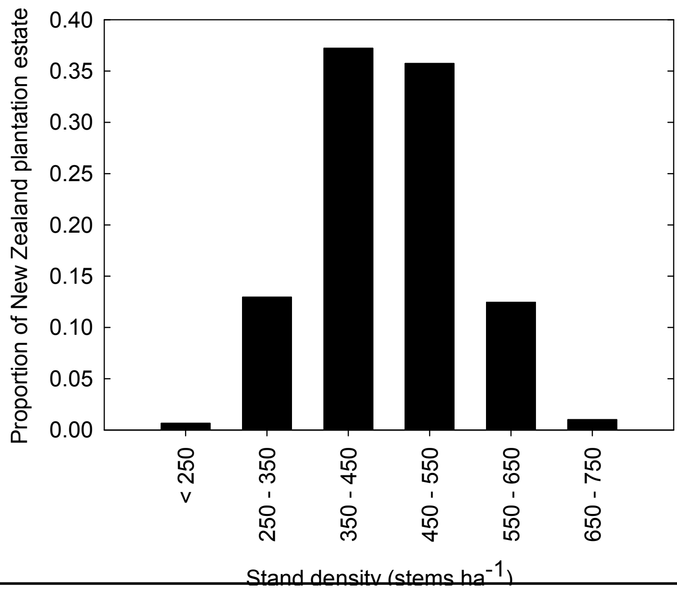
Stand density – P30





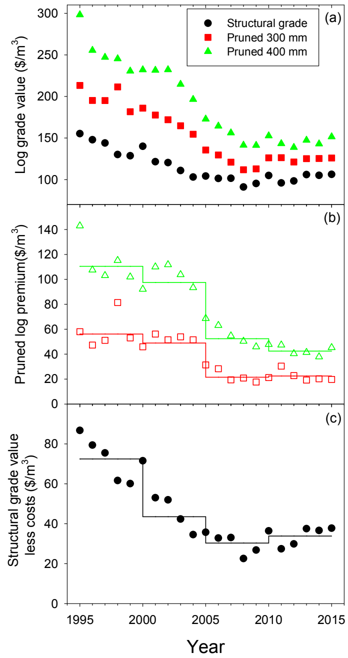
Stand density – P40



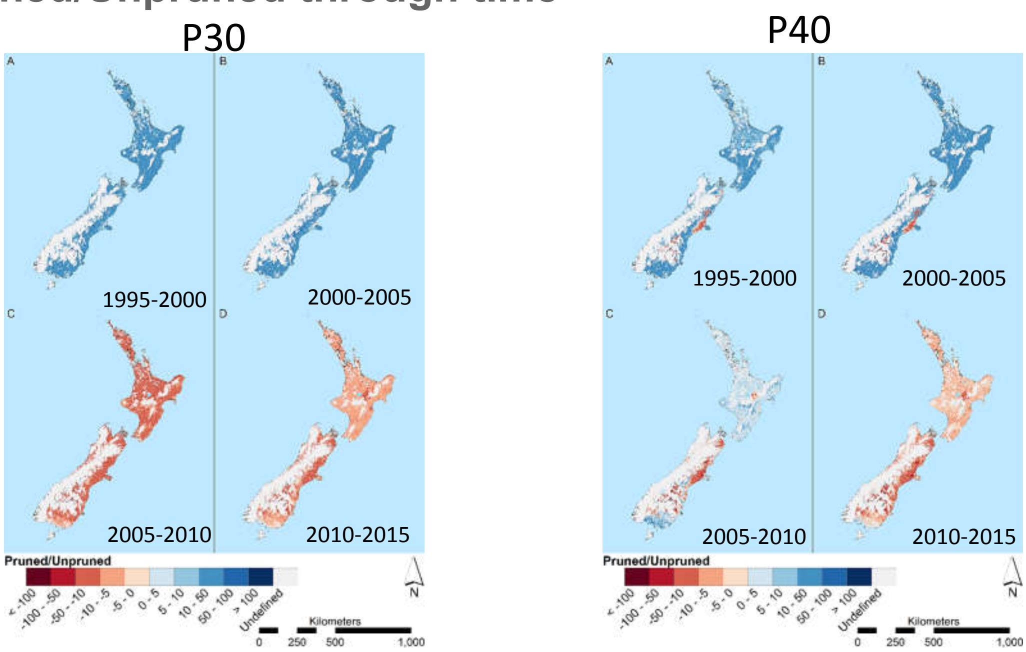


Inputs to model

- Five year means used as model input
  - 1995 – 2000
  - 2000 – 2005
  - 2005 – 2010
  - 2010 - 2015

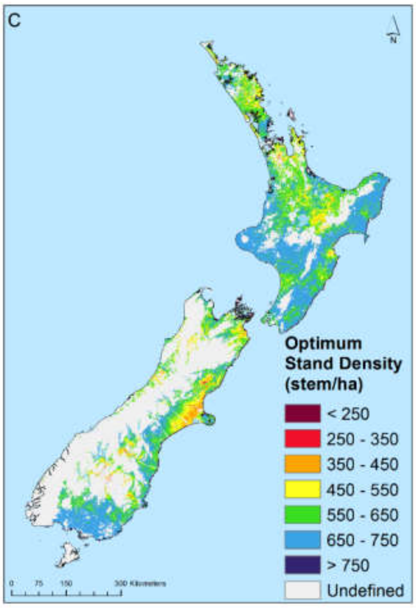


Pruned/Unpruned through time



Economics of structural grade regimes

- Model predicts mean stocking of 614 stems ha^{-1} > than actual stocking of ca. 500 stems ha^{-1}
- Model predicts 88% of stands with stocking > 500 stems ha^{-1}
- This disparity of ca. 100 stems ha^{-1} suggests that greater value could be obtained from structural grade regimes

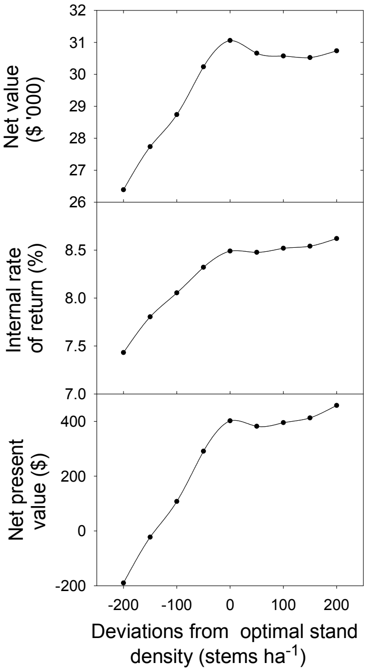


Methods

- Forecaster runs undertaken for 15 combinations of SI and 300 Index covering productivity range
- Each run undertaken using optimal stocking and eight stockings below and above optimal stocking (range -200 to +200)
- Used current log prices and costs, benchmarked from several sources

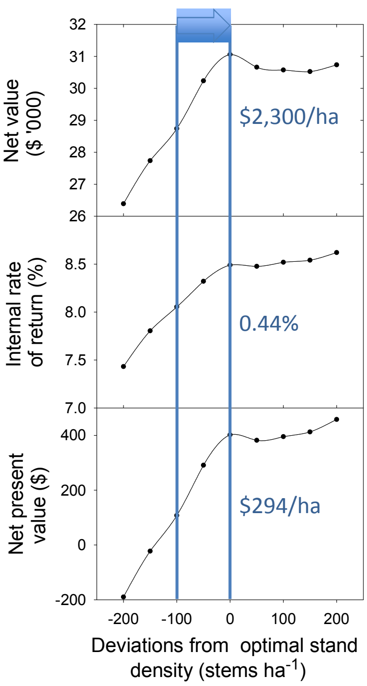
300 Index	Site Index	S_{opt}
(m^3 ha^{-1})	(m)	(stems ha^{-1})
10	18	290
10	22	200
10	26	200
17.5	19	700
17.5	26	434
17.5	33	253
25	23	700
25	30	526
25	37	319
32.5	26	700
32.5	33	647
32.5	40	398
40	30	700
40	37	700
40	44	451

Economics of structural grade regimes



- Increases in all metrics to optimum
- Marginal increases/reductions after optimum

Economics of structural grade regimes

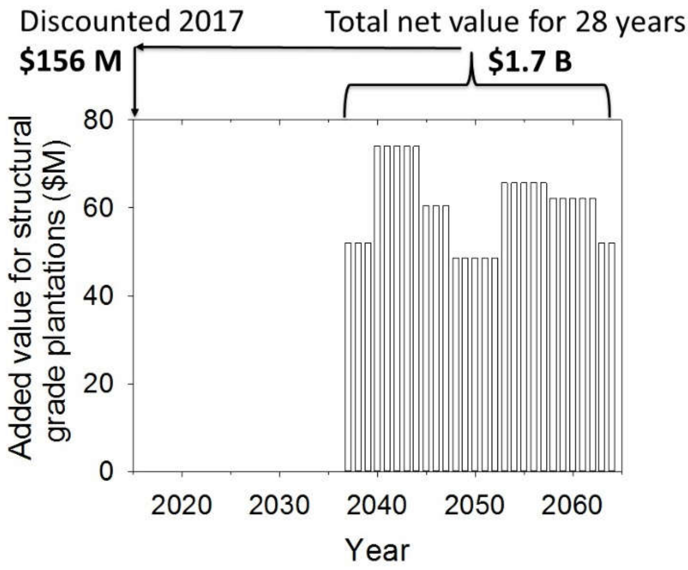


- Increases in all metrics to optimum
- Marginal increases/reductions after optimum

Total potential increase in value to NZ plantation estate

- Net value $1.7 B
  - Discounted $156 M

- Gross value $3.8 B
  - Discounted $349 M



Conclusions

- Model demonstrates strong reduction in pruning profitability over last 10 years

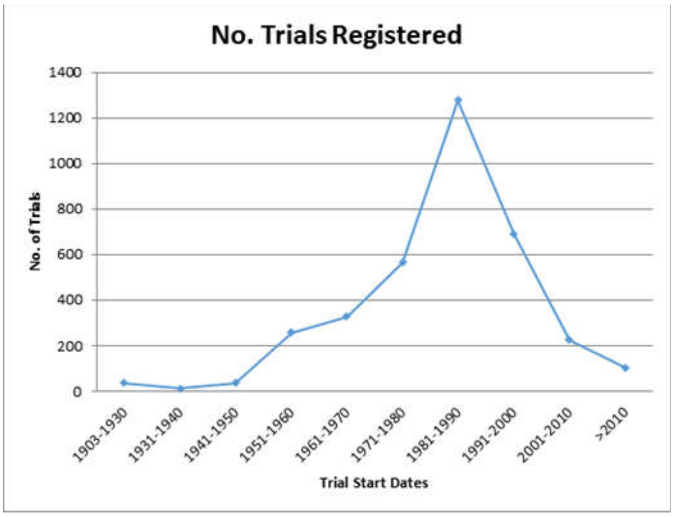
- Optimal stand densities for both pruned and unpruned regimes considerably exceed current stand densities

Conclusion

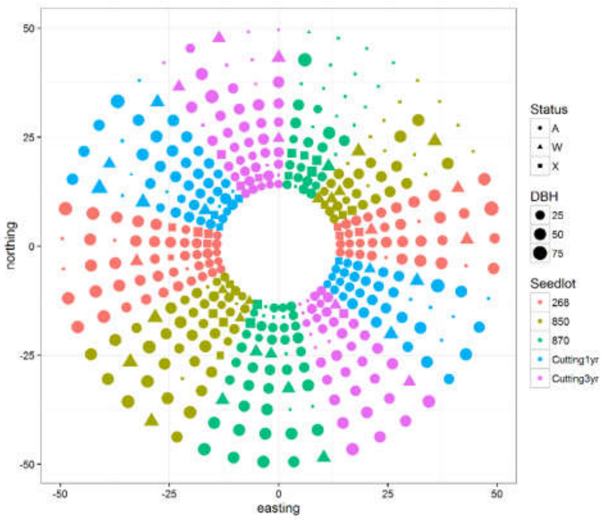
- Increasing stocking by 100 stems ha^{-1} should result in increases of ca. \$5,200 ha^{-1}, \$2,300 ha^{-1}, 0.44%, \$294 ha^{-1}, respectively, for gross value, net value, IRR and NPV
- These equate to percentage increases of 6.6% and 8.0%, respectively, for Gross and Net Value
- Increasing stocking across the plantation estate by 100 stems ha^{-1} could result in discounted gross and net increases of 349M and \$156M over 28 year period

NZ has a large network of long term trials

- ~ 3200 trials registered in Scion's trial database
  - 2310 active
  - 833 inactive
  - 97 unknown
- Many of these trials were established in the 1980s
  - Have been or will be harvested in the next 5 years
- Provide valuable data for answering key questions about forest growth and the response to silviculture



We have a wide variety of trials and demonstrations



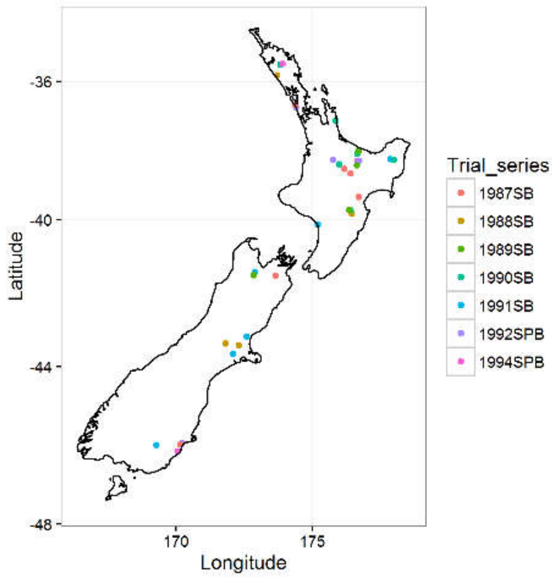
Euan Mason experimental trial, Rolleston

How can long-term trials inform silviculture?

- Forest managers need to answer a range of questions to develop regimes
  - What is the appropriate density to grow stands at?
  - How much extra value will I get from using improved tree stocks?
  - Should I prune? If so,
    - How many trees should I prune per hectare?
    - What height should I prune to?
    - How many followers (unpruned trees) should I leave before final thinning?
    - How long should I wait to thin the stand?
- Long-term trials not only provide data to support these decisions, but also provide practical demonstrations

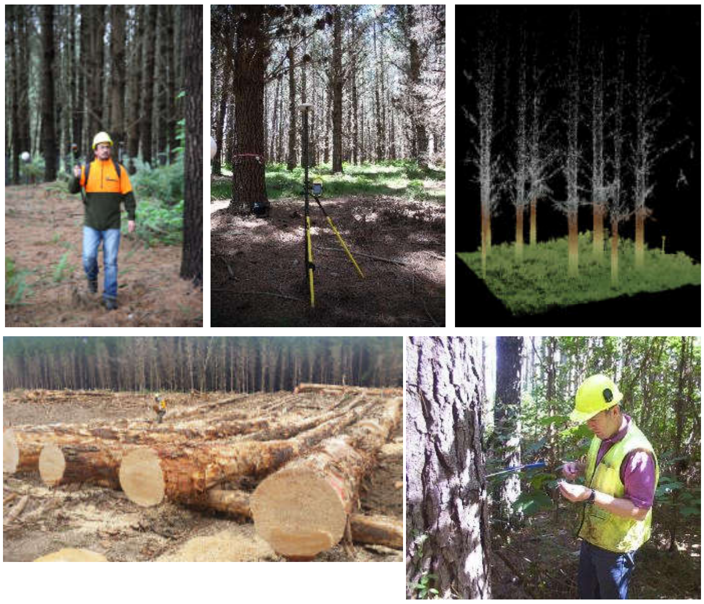
Silviculture & tree breeds trials

- Installed at 35 sites throughout NZ
- Examine the interaction between silviculture and genetics on growth and wood properties
- Genetic material ranges from unimproved to highly improved
- Stand density after thinning ranges from 100 stems/ha up to 1000 stems/ha

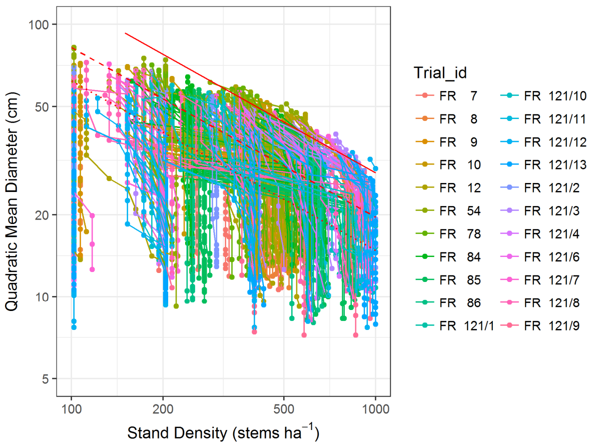


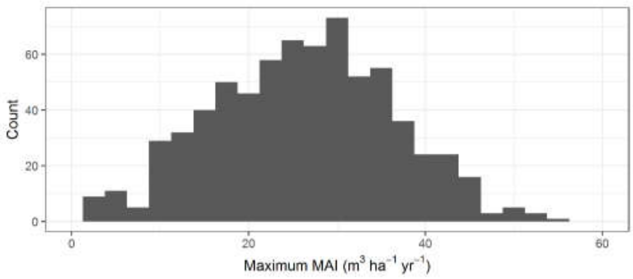
End-of-rotation assessment of these trials

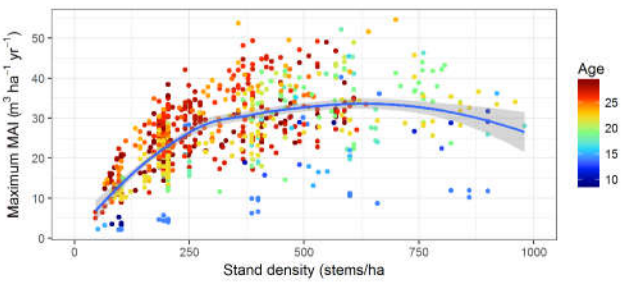
- Unique opportunity to quantify effects of genetics, silviculture and site on log product assortments, wood properties and total value
- Standing tree assessment
  - Tree size
  - Pre-harvest inventory
  - Wood density
  - Acoustic velocity (ST-300)
  - IML-Resistograph



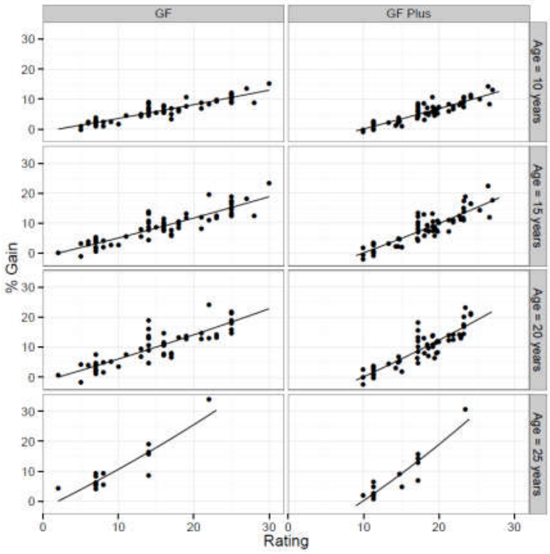
Large range in tree growth conditions in these trials







Long-term large plot trials have been key to quantifying realized genetic gain for growth

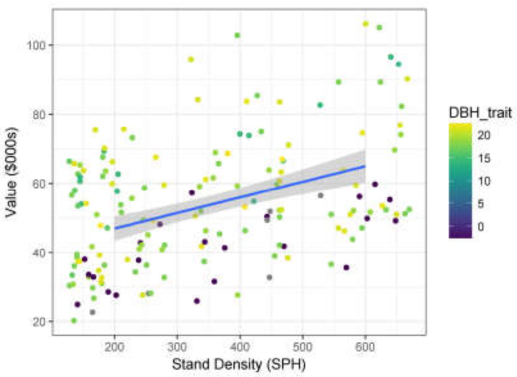


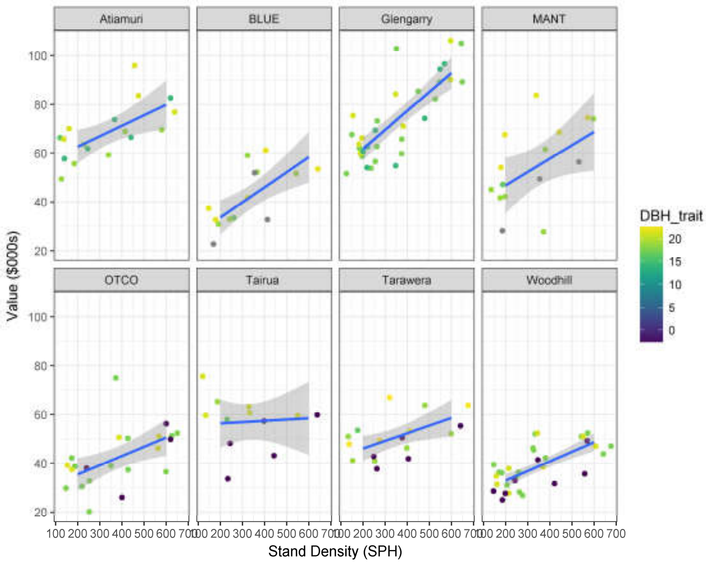
- 300 Index increases by:
  - 1.59% per unit of GF Plus growth
- Site Index increases by:
  - 0.36% per unit of GF Plus growth
- Each unit of GF Plus growth =
  - 1.51% increase in volume
  - 1.91% increase in stumpage value
- Highly improved vs unimproved
  - 33% greater stumpage value
  - $8.5 B increase in value of national estate

Stem is merchandised into log grades to maximise value

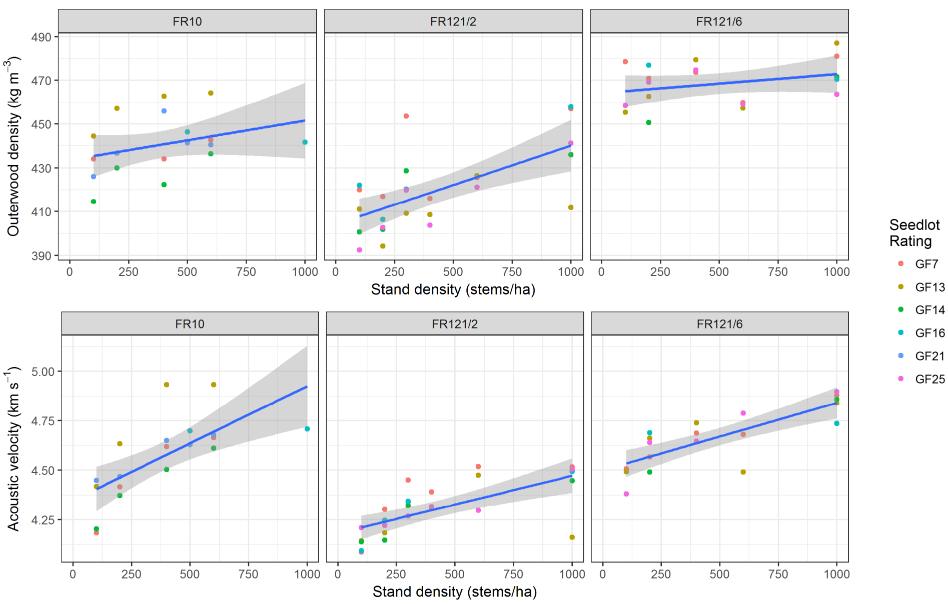
Grade	Value ($/m^3)	Minimum small end diameter (cm)	Maximum allowable branch size (cm)	Maximum allowable sweep (proportion of SED)
S40	108.50	40	7	0.25
S30	100.00	30	7	0.25
S20	80.00	20	7	0.25
A	88.00	30	12	0.25
K	70.00	22	12	0.25
Industrial	50.00	30	25	0.31
Pulp	45.00	10	-	1.00

Total value strongly related to stand density

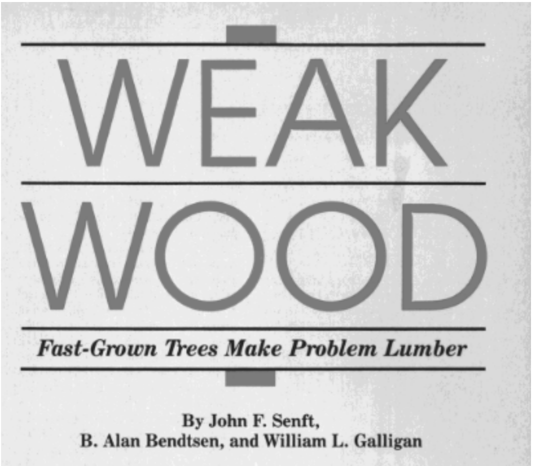




Preliminary results on wood property assessment



A cautionary note on wood quality

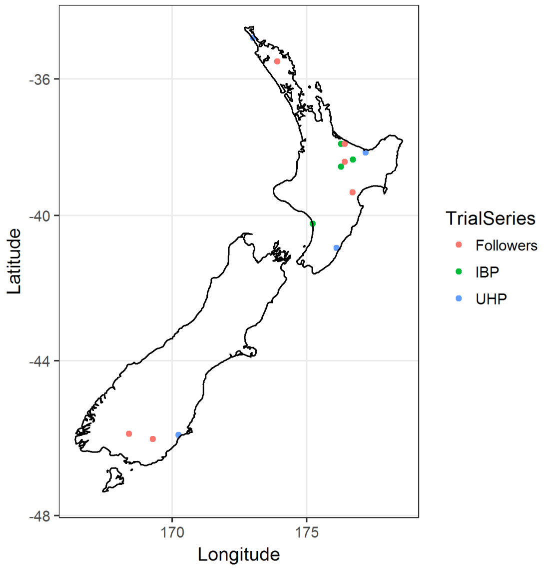

WEAK WOOD

Fast-Grown Trees Make Problem Lumber

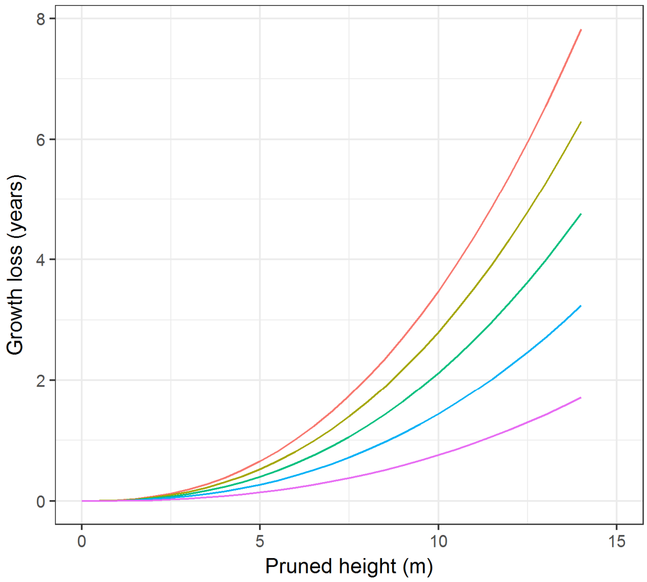
By John F. Senft,
B. Alan Bendtsen, and William L. Galligan

We want more wood, not corewood!

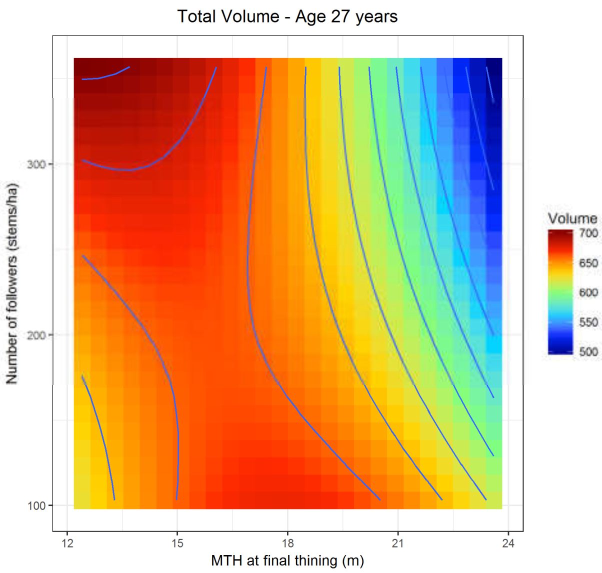
Trials to examine aspects of pruning

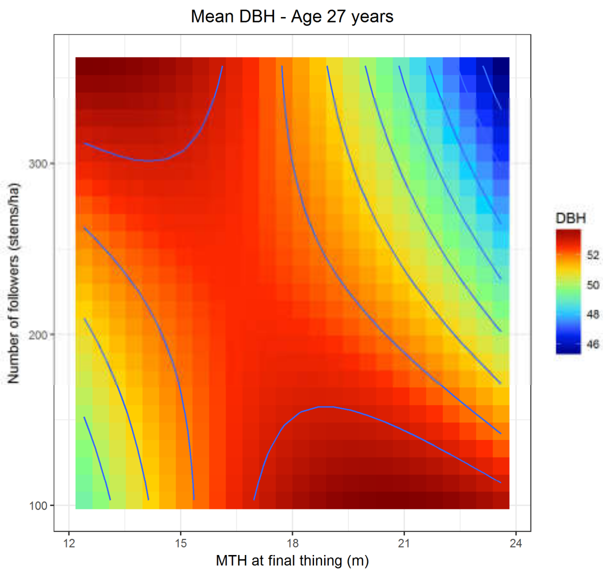


Quantifying growth loss with different pruning severity



Impacts of followers and timing of thinning on yield





Summary of what we've learned from trials

- Trials provide important information on the drivers of tree growth, wood properties and economic value
- As expected stand density is a major determinant of yield
- High pruning does reduce yield
  - Yield reduction is greatest when it is combined with low green crown retention
- There does not appear to be any significant growth loss from retaining followers, but delayed thinning can impact yields
- There is still much to be learned from these trials, so maintaining ongoing measurements is important (and challenging)

Acknowledgments

- Scion field crew for assessment of standing and felled trees
- RPBC and the GCFF programme for financial support
- FGLT for additional funding to support end-of-rotation assessment of the silviculture-breeds trials
- The forest companies who host these trials and provide considerable in-kind support for data collection

supported by forestgrowers commodity levy

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Key take-home messages

- Our models and trial data enable us to optimize our silvicultural prescriptions to achieve a particular end goal
  - e.g. to maximize return from growing structural grade logs
- The financial benefits of these changes are considerable – e.g. $2300/ha increase in net revenue at harvest from 100 stems/ha increase in stand density
- Large plot trials have enabled the quantification of realized gain for growth and more recently value.
  - Again the benefits are large, e.g. ~30% increase in stumpage vs unimproved seedlots
- G x E is complex, but has the potential to offer further gains from correctly matching genotypes (seedlots) to a particular site

Next generation silvicultural regimes

- Next generation silvicultural regimes will need to balance a range of considerations
  - Financial returns
  - Market requirements and risk
  - Biotic and abiotic risk
- Models and trials have informed our past and current thinking
  - Can guide future thinking by helping us to understand key principles and processes
  - Future trials will be needed to support future silvicultural regimes
  - Trial design needs to be carefully considered to allow for changing circumstances
- ***Developing seedlot and site-specific silvicultural regimes will be the key to maximizing productivity***

Growing confidence in forestry's future Research Programme

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