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Matching Genotypes to Current and Future Production Environments to Maximise Radiata Pine Productivity and Profitability

Milos Ivković[1], Greg Dutkowski[2], Paul Jefferson[4], Washington Gapare[1], Harry Wu[1], Tom Jovanovic[1] and Tony McRae[3]

[1] CSIRO Plant Industry, Canberra ACT 2601, Australia
[2] Plant Plan Genetics, PO Box 1811, Mount Gambier, SA 5290, Australia
[3] Southern Tree Breeding Association Inc. PO Box 1811, Mount Gambier, SA 5290, Australia
[4] Radiata Pine Breeding Company Ltd., PO 1127, Rotorua, New Zealand

Email: Milosh.Ivkovich@csiro.au

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Radiata pine (*Pinus radiata* D. Don) is the most important commercial conifer species in Australia and New Zealand. Significant progress has been made in the improvement of growth, form and wood quality traits through the understanding of their genetic control. However, the benefits of these long-term investments in genetic tree improvement have not been fully realised, as improved genotypes must be matched to their specific growing environments and production systems to fully realize their genetic potential.

Current radiata pine breeding and deployment in Australia and New Zealand is based largely on state and regional boundaries or forest inventory zones rather than on rigorously mapped climatic and physiographic parameters. Current zones cannot deliver optimal genetic gains across the whole estate. To further improve radiata pine plantation productivity and to maximize realised genetic gain from breeding and deployment populations under current and future climates, it is necessary to: (*i*) delineate breeding and deployment zones based on site and climatic factors, and (*ii*) match genotypes with current and future production environments considering multiple objectives, such as maximizing growth, improving form, branching and wood quality.

Optimal breeding and deployment zones must consider genotypic responses together with physiographic and climatic information. Genetic information on breeding stock was combined with soil and climatic data of more than 300 test sites to pinpoint environmental factors affecting the response of radiata pine to environmental variation, and to provide a better understanding of the factors contributing to the observed genotype x environment interaction (GxE). An analysis of GxE was performed using multivariate analytical techniques and mapped using geographic information system (GIS) tools.

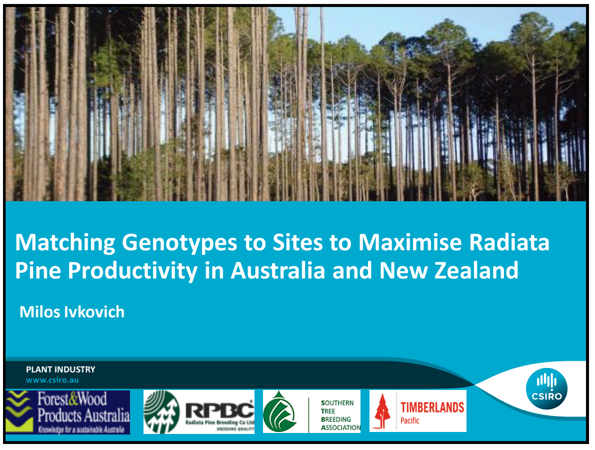
We explored different methodologies to account for GxE. In practice, the Radiata Pine Breeding Company (RPBC) in New Zealand prefers clustering of sites based on a factor analytic model involving a G×E term. To explain the clustering of sites in New Zealand based on geo-climatic variables we used several analytical techniques including visualisation based on Random Forest Classification and Multi Dimensional Scaling, Multiple Regression on Distance Matrices and Multiple Regression Trees.

The Southern Tree Breeding Association (STBA) in Australia prefers site classification based on modelling of genetic correlations. For the trials in Australia, we created a database of genetic parameters as a basis for the modelling of genetic correlations. Site classification involved grouping trials into site types based on certain goodness of fit criteria to reduce the so called residual G×E, or minimise G×E within site types. Genetic evaluations with the TREEPLAN system, incorporating the new site classification will demonstrate the genetic gain resulting from the improved classification.

The environmental variables determining the G×E patterns or, so called, "drivers of GxE" were identified, and at the broadest, trans-continental scale, climatic variables such as temperature and rainfall were the most significant. However, at a local regional scale soils and topographical factors were of more significance. New site classification will be defined across Australia and New Zealand, and genetic gains that can potentially be obtained by accounting for genotype by environment interaction (G×E) evaluated.

Our ultimate goal is to recommend best strategies to maximise genetic gain by matching genotypes with production environments and ensure immediate adoption of results into selection and deployment programs of the radiata pine industry. We also expect the risk of plantation failure or suboptimal performance due to changed site conditions as a result of climate change will also be reduced, however, such benefits are more difficult to quantify at this stage.

Predictions of plantation yield at different plantation locations based on future climate forecasts typically do not consider potential for adaptation by using genetic selection. Climate change scenarios will be the superimposed on the "response functions" or "norms of reaction" models developed in this study, and responses of different genotypes will be extrapolated beyond current climatic conditions. Trials at the extremes of the radiata pine climate envelope will be particularly valuable to assess the effects of future climate change on growth and form traits. Climate change impacts on deployment zones will then be evaluated using (GIS) tools that we are currently developing. This study will determine the extent to which we can use genetic selection to mitigate some of the predicted negative effects of climate change on timber supply from the radiata pine plantation estate in Australia and New Zealand.


Matching Genotypes to Sites to Maximise Radiata Pine Productivity in Australia and New Zealand
Milos Ivkovich
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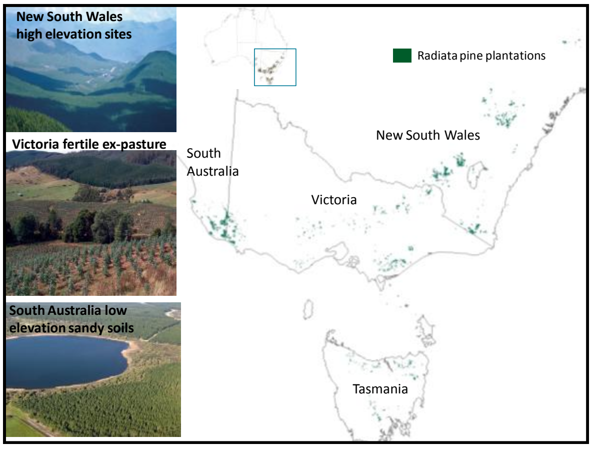
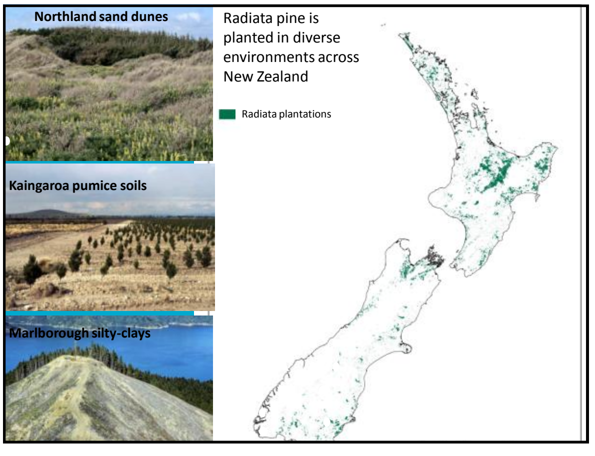
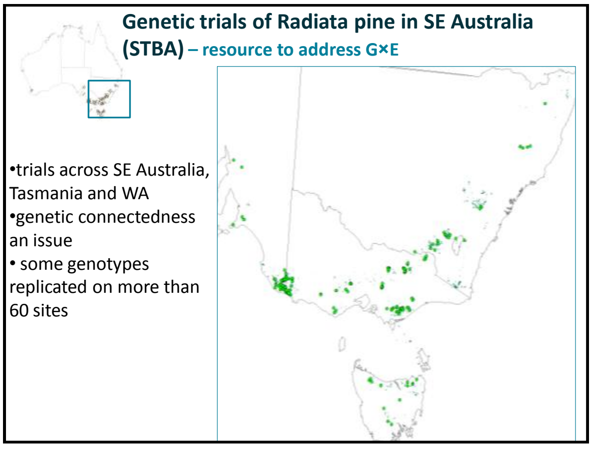
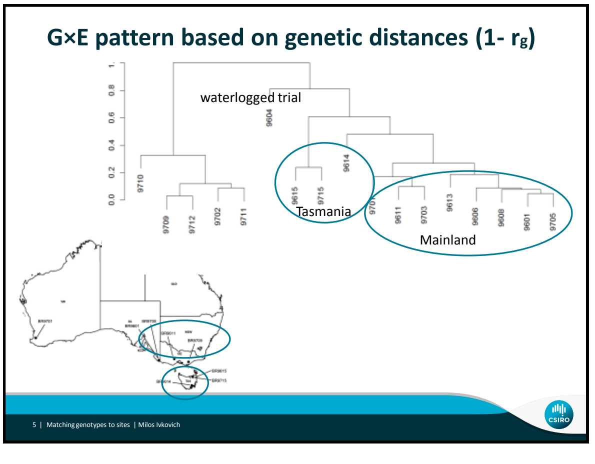

New South Wales high elevation sites
Victoria fertile ex-pasture
South Australia low elevation sandy soils
Radiata pine plantations
New South Wales
South Australia
Victoria
Tasmania


Northland sand dunes
Kaingaroa pumice soils
Marlborough silty-clays
Radiata pine is planted in diverse environments across New Zealand
Radiata plantations


Genetic trials of Radiata pine in SE Australia (STBA) – resource to address G×E
•trials across SE Australia, Tasmania and WA
•genetic connectedness an issue
• some genotypes replicated on more than 60 sites


G×E pattern based on genetic distances (1- rg)
waterlogged trial
Tasmania
Mainland
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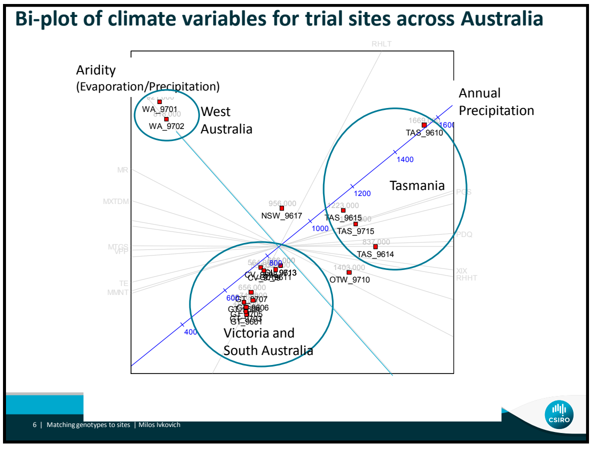
Bi-plot of climate variables for trial sites across Australia
Aridity
(Evaporation/Precipitation)
West Australia
WA_9701
WA_9702
Annual Precipitation
TAS_9610
Tasmania
NSW_9617
TAS_9615
TAS_9715
TAS_9614
OTW_9710
Victoria and South Australia
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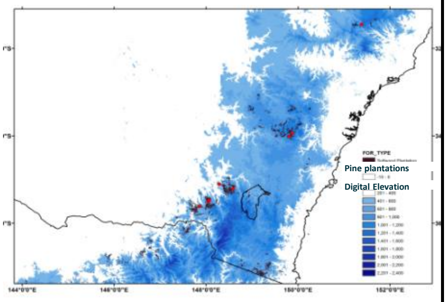
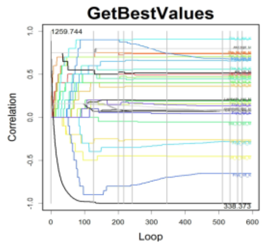
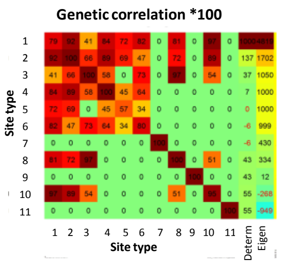
In New South Wales and NE Victoria G×E is driven mostly by elevation, parent rock, and previous land use (e.g. Wu and Matheson 2005, Raymond 2011)



Current deployment of radiata pine is based on National Plantation Inventory zones - not on G×E patterns!

Modelling genetic correlations for DBH across and within site types -deployment zones in Australia (Southern Tree Breeding Association)

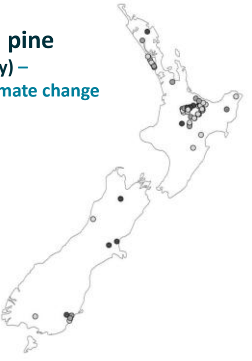




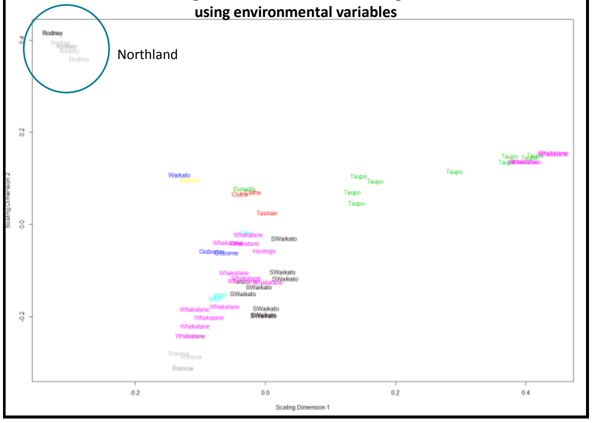
Genetic trials of Radiata pine

(Radiata Pine Breeding Company) –
resource to address G×E and climate change

- data on trials across NZ
- large concentration of trials in Kaingaroa Forest
- trial distribution and connectedness an issue



Random Forests clustering and Multidimensional Scaling of New Zealand districts using environmental variables



Determining drivers of GxE

Kruskal-Wallis significance test using trial clusters of (Cullis and Jefferson2012) as class variables

Potential evapo-transpiration	Soil temp.	Mean temp.	Min temp.
0.04*	0.011**	0.023**	0.011**

- **Multiple regressions -** genetic vs. environmental distance matrices
- **Random Forest clustering and regressions** on distance matrices
- **Bi-plots and GIS mapping** for visualisation

Climate Change will affect genotype performance

Multiple Regression Tree for 32 genotypes in NZ based on average temperature (TAVG)

- Temperature is expected to increase over next rotation

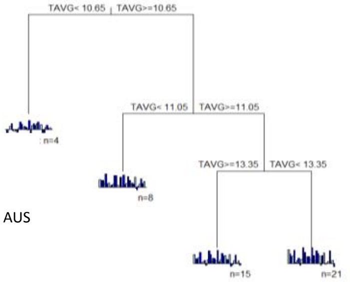
  0.4 to 1.3°C in NZ

  0.6 to 1.2°C in AUS

- Rainfall will also change

  -2.8 to +5.0 % in NZ

  winter and spring drying in SE AUS



Summary

- Significant G×E was found for growth in Australia and New Zealand
- Large-scale drivers of G×E are mainly climatic, but regional-scale drivers can be also soils, terrain and geology
- Current deployment zones are not optimal and will be re-defined based on G×E patterns
- Climate change will influence site clustering and rankings of genotypes in different deployment zones

Project team:
Washington Gapare, Harry Wu, Tom Jovanovic (CSIRO, AUS)
Paul Jefferson, John Butcher (RPBC, NZ)
Greg Dutkowski, Peter Buxton , Tony McRae (STBA, PPG, AUS)
Alvin Yanchuk, Heidi Dungey, Andy Dunningham, Marie Heaphy (SCION, NZ)
Don Aurik (Timberlands Pacific, AUS)

Thank you

Milos Ivkovich
t +61 2 2646 4847
e Milosh.Ivkovich@csiro.au
w www.csiro.au

PLANT INDUSTRY/FOREST GENETICS
www.csiro.au