Section 3: NZDFI Site-Species Matching Research Plan

Background

The NZDFI aims to establish an industry based on drought-tolerant eucalypts that produce naturally ground-durable timber in New Zealand's dry environments (Millen 2009). Eucalypt trials have been planted since 2003 throughout Marlborough, the Hawkes Bay, and Canterbury on sites with annual rainfall ranging from <700 mm to >1400 mm. To date 525 permanent sample plots (PSPs) at 27 sites have been established. In this instance a PSP includes blocks within breeding trials. These PSPs form the backbone of site-species matching research by allowing for repeated measurements of growth for eleven durable eucalyptus species (Table 1).

Table 1 – A description of the NZDFI's permanent sample plots.

Species	# of Permanent Sample Plots
E.bosistoana	84
E.globoidea	74
E.quadrangulata	59
E.tricarpa	52
E.argophloia	30
E.cladocalyx	52
E.camaldulensis	46
E.macrorhyncha	48
E.longifolia	37
E.eugenioides	28
E.notabilis	15
Total	**525**

Unlike radiata pine which is not as limited by site conditions in NZ, durable eucalypts are believed to be relatively sensitive to surrounding environmental conditions. So, to deploy these eucalyptus species effectively, it is important to understand how their growth and survival are affected by a wide range of site conditions, including climatic, edaphic, and topographic factors. Site-species matching of eucalypts has previously been undertaken in South Africa (Schönau and Fitzpatrick 1981,Schönau and Gardner 1991,Herbert 2000,Swain, et al. 2003) and Australia (Dunn, et al. 1994,Jovanovic, et al. 2000), resulting significant increases in plantation productivity.

Aims of the Research Programme

The site-species matching research aims to ensure that growers effectively match durable eucalypt species and genotypes to dryland sites. Site-species matching should not simply maximise growth or other desirable traits (e.g. heartwood formation), but must also include the risk of damage or loss due to frost, snowfall, pests and diseases, and fire (Caulfleld, et al. 1992). Achieving this overarching objective requires:

1. A comprehensive site characterisation for all permanent plots. This includes a description of climatic, edaphic, and topographic factors at each plot.
2. Multiple measurements, spanning years, of DBH, height and tree form for all trees at all PSPs.
3. Measuring heartwood volume for a large subsample of trees at all PSPs regularly if possible over the rotation length to understand environmental and age related influences on heartwood formation.
4. Developing species-specific taper and volume equations for all NZDFI durable eucalypts including representations of heartwood.
5. Using site characterisation data, PSP measurement data, and taper/volume equations to develop site-, species-, and genotype-specific models of eucalypt survival and growth.
6. Use the model developed in (5) to provide an on line decision support system for growers to match dryland sites with the optimal eucalypt species/genotype.
7. Monitor pest loading at all PSPs to understand environmental influences on pest loading.

These steps will contribute to effectively matching NZDFI durable eucalypts to the full variety of environmental conditions within NZ drylands. The resulting growth and yield models will allow growers to successfully match species and genotypes to the right sites and, to estimate volumes of wood and heartwood that are likely to be produced on these sites, while considering any potential interactions between pest loads and sites.

Environmental influences and data availability

Characterising a site's topography, edaphic features, and climate is necessary if we wish to understand environmental conditions that affect eucalypt growth at each of the NZDFI trials. Unlike radiata pine, which is reputed to thrive on a wide range of sites, successfully growing durable eucalypts on NZ drylands requires a more detailed understanding of site-specific environmental conditions. These data are necessary explanatory variables in growth and yield models; in other words, environmental conditions can help to explain measured differences in eucalypt growth and survival. Understanding influences of environmental conditions on eucalypt growth underpins the aim of matching species or genotypes to sites. Coarse-scale descriptions of environmental conditions at all PSPs are possible using the nationally available environmental data described below.

Soil data availability

Soil descriptions will be developed from three different sources: estimated data from nationwide Fundamental Soil Layers (FSL); estimated data from S-map; and measured data from site-specific ground-based measurements.

FSL data map 16 soil properties at a coarse 1:50,000 scale can be obtained from a raster with a spatial resolution of 25 m (Tobler 1988) and a minimum mapping unit (MMU) of 0.0625 hectares, which means that any site with an area less than the MMU will have no variation in soil attributes. This is highly unlikely in reality, but is an artefact of the coarse scale of the FSL. Partly because of this, the quality of the soil attribute data in the FSL has been questioned (Pearse, et al. 2015). For this reason, the FSL is progressively being replaced by S-map, which is purported to provide more reliable soil descriptions, however, current coverage is very limited outside of historically productive agricultural areas. Unfortunately, very few of the NZDFI's PSPs have current S-map coverage.

Where possible, soil attributes will be measured directly. This will include soil depth and texture. Apart from these basic attributes, other soil attributes will be extracted from S-map where data are available. If soil data is not available from either of these sources, then data will be extracted from the FSL.

Climate data availability

Climate data are similarly limiting. The best climate data available nationally is NIWA's Virtual Climate Station Network (VCSN), which has a temporal resolution of 1 day, but a spatial resolution of only 5 km, and a minimum mapping unit of 2,500 hectares. The VCSN provides acceptable local estimates of absolute global solar radiation and adjusted mean daily maximum and minimum temperatures, but poorer local estimates of rainfall and relative humidity (Mason, et al. 2017). Consequently climate data will be obtained from nine climate stations established at individual NZDFI trials. As funding permits, all NZDFI trials with PSPs will be equipped with a climate station. These climate stations measure air temperature, wind speed, wind direction, precipitation, relative humidity and radiation. Where climate stations have not currently been established, VCSN estimates will be used to describe climatic conditions.

Topographic data availability

Nationally available topographic data is limited to the 1:50,000 contours (NZTopo50 series) and the 25 m resolution digital elevation model (DEM) derived by Landcare Research, or the peer-reviewed 15 m resolution digital elevation model (Columbus, et al. 2011). Even the 15 m resolution DEM results in a minimum mapping unit of 0.0225 hectares, which assumes no changes in topography within areas less than the MMU. Instead of relying on national scale topographic data, this research will use fine- or very-fine scale DEMs. Very fine-scale (< 3 m) digital elevation models can be produced from LiDAR data (Watt, et al. 2013); though areas of NZ with LiDAR data availability are limited to a handful of NZDFI trials. Where LiDAR data do not exist, fine-scale DEMs have been produced using a mapping grade Global Navigation Satellite System (GNSS) receiver taking waypoints at each trial on a 3 – 5 m grid. Waypoints were then interpolated into a 5 m resolution DEM.

Other topographic surfaces can be estimated from the fine- and very-fine resolution DEMs. Surfaces describing slope, aspect, and topographic exposure can be derived from the DEMs and subsequently used as explanatory factors in growth and yield modelling.

Micro-site variation

In addition to the macro-scale characterisation of climatic, edaphic, and topographic attributes described in the previous section, the research will also characterise within site differences in environmental attributes, called micro-scale or micro-site variation. Due to the intensity of measurement required, this will only be undertaken for a subset of the NZDFI trials. This within-site variation in environmental conditions will help to explain within-site differences in eucalypt growth.

As described in the previous section, high resolution, micro-scale DEMs have being developed for all NZDFI trials containing PSPs in order to account for small changes in topography within growing sites. Moreover, changes in soil characteristics are being measured across topographic gradients within four NZDFI sites. For example, the soil moisture holding capacity is being measured at the top of a slope, mid-slope and on the toe of the slope for all aspects present in these four sites and temperature is monitored on a variety of aspects. Finally, micro-site climatic data are being collected by climate stations installed at a small subset of NZDFI trials, in many cases half-hourly to better capture variances in the air temperature and soil water across these trial sites. Furthermore, soil pits have been dug on a range of microsites at these experiments so that within site variation in soil depth, texture, structure and chemistry can be characterised.

Growth and yield modelling research

Traditionally, forest modelling has relied on large, comprehensive datasets, like those that exist for radiata pine in NZ. Though the NZDFI would like to strategically deploy new PSPs in under-represented regions of NZ, the current number of PSPs (Table 1) limits the potential for traditional forest modelling. Instead, this research will employ hybrid physiological and mensuration modelling (Mason, et al. 2011), which combines knowledge of plant physiology with site-specific descriptions of environmental conditions, and productivity data from permanent sample plots to produce flexible, accurate models of eucalypt growth and survival. These growth and yield models will assess, at a monthly level, the limitations of sunlight use by plants imposed by seasonal soil water deficits, by sub- or supra-optimal temperatures for photosynthesis, by high vapour pressure deficits (VPDs), and by nutrient deficiencies in soils.

In this research plan, we are developing juvenile growth and yield models for up to eleven durable eucalyptus species. This research is based on measuring permanent sample plots at NZDFI trials throughout NZ (Table 1) and correlating measured tree growth with site-specific environmental conditions (climatic, edaphic, topographic) present at the PSPs. Though taper and volume equations for *E. globoidea* have been developed by Scion (Gordon, et al. 1999), we will develop these equations for other durable eucalypts in order to estimate volumes of trees, using stem diameter and height measurements (Demaerschalk 1972) as soon a older trees are available for sampling. Where feasible we shall represent different breeds in these models.

Matching species to sites

Past efforts to optimise site-species matching have been hampered by poor data availability and, where data are available, coarse data resolution (both spatially and temporally coarse). This research differs from previous efforts by establishing robust relationships between measured growth of eucalypts at PSPs throughout Marlborough, Canterbury, and Hawkes Bay and the environmental conditions present at these sites; and in some cases, the environmental variation that exists within these sites.

Growth and yield models that are developed as part of this research will be used for site-species matching. Growers will have the opportunity to identify their prospective growing sites within an internet-based decision support system with a Google Maps plug-in. Once a grower identifies their growing site on Google Maps, the DSS will model the environmental conditions present at the site and subsequently rank durable eucalypts with respect to their suitability to the nominated site and grower objectives.

References

1. Millen, P. 2009 NZ dryland forests initiative: a market focused durable eucalypt R&D project. In *Revisiting eucalypts.* L.A. Apiolaza, S.V.S. Chauhan and J.C.F. Walker (eds.), Wood Technology Research Centre, University of Canterbury, Christchurch, N.Z., pp. 57-74.

2. Schönau, A.P.G. and Fitzpatrick, R.W. 1981 A Tentative Evaluation of Soil Types for Commercial Afforestation in the Transvaal and Natal. *South African Forestry Journal*, **116** (1), 28-39.
3. Schönau, A. and Gardner, R. Eucalypts for colder areas in southern Africa, pp. 2-6.
4. Herbert, M. 2000 Site requirements and species matching: Eucalypts and Wattles. *South African Forestry Handbook. South African Institute of Forestry, Pretoria, South Africa*, 85-94.
5. Swain, T., Gardner, R., Wei, R. and Xu, D. Use of site–species matching and genetic gain to maximise yield–a South African example. World Scientific, p. 167.
6. Dunn, G.M., Taylor, D.W., Nester, M.R. and Beetson, T.B. 1994 Performance of twelve selected Australian tree species on a saline site in southeast Queensland. *Forest Ecology and Management*, **70** (1), 255-264.
7. Jovanovic, T., Arnold, R. and Booth, T. 2000 Determining the climatic suitability of Eucalyptus dunnii for plantations in Australia, China and Central and South America. *New Forests*, **19** (3), 215-226.
8. Caulfleld, J., Schönau, A. and Donald, D. 1992 Incorporating Risk into Eucalyptus Species—Site Selection Decisions. *South African Forestry Journal*, **160** (1), 25-31.
9. Tobler, W. 1988 *Resolution, resampling, and all that*. Taylor and Francis: London.
10. Pearse, G., Moltchanova, E. and Bloomberg, M. 2015 Assessment of the accuracy of profile available water and potential rooting depth estimates held within New Zealand's fundamental soil layers geo-database. *Soil Research*, **53** (7), 737-744.
11. Mason, E.G., Salekin, S. and Morgenroth, J. 2017 Comparison between meteorological data from the New Zealand Institute of Water and Atmospheric Research (NIWA) and data from independent meteorological stations. *New Zealand Journal of Forestry Science*, **47** (7).
12. Columbus, J., Sirguey, P. and Tenzer, R. 2011 A free fully assessed 15 metre digital elevation model for New Zealand. *Survey Quarterly*, **300** (66), 16.
13. Watt, M.S., Adams, T., Watt, P. and Marshall, H. 2013 Influence of stand and site conditions on the quality of digital elevation models underlying New Zealand forests. *New Zealand Journal of Forestry Science*, **43** (1), 1-9.
14. Mason, E.G., Methol, R. and Cochrane, H. 2011 Hybrid mensurational and physiological modelling of growth and yield of Pinus radiata D. Don. using potentially useable radiation sums. *Forestry*, **84** (2), 99-108.
15. Gordon, A.D., Lundgren, C. and Hay, E. 1999 Composite taper equations to predict over- and under-bark diameter and volume of Eucalyptus pilularis, E. globoidea, and E. muelleriana in New Zealand. *New Zealand Journal of Forestry Science*, **29** (2), 311-317.
16. Demaerschalk, J.P. 1972 Converting volume equations to compatible taper equations. *Forest Science*, **18** (3), 241-245.