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A System to Generate *Pinus radiata* Starting Tree Lists in FFR Forecaster

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EXECUTIVE SUMMARY

FFR Forecaster requires a starting tree list consisting of tree heights and diameters to initiate a growth simulation. This list can be provided by the user, typically from an inventory measurement. Alternatively, it can be generated by Forecaster using a random sample of trees from a bivariate distribution of DBH and height. However, this requires the user to supply various distribution parameters (such as the variance and covariance between DBH and tree height). There is currently no guidance for users on appropriate values of these parameters when using Forecaster with a starting age.

The optimal way to start FFR Forecaster is to import a tree list collected from silvicultural quality control surveys or from early age inventory. When appropriate inventory data are unavailable, it is necessary to “generate” the tree list.

This project develops methods to obtain the parameters required by FFR Forecaster to generate a tree list suitable for starting growth runs, using data from permanent sample plots and pre-silviculture inventory plots. A series of simple models has been formulated and fitted to data that adjust starting values according to average tree size (DBH and Height). However, because of the limited data no adjustment for site or genotype was possible.

With this improvement to FFR Forecaster, users will be able to run the 300 Index growth model (and other individual tree models) in situations when starting tree lists are not available, e.g. “green-field” simulations. This ability will expand the site-options that forest owners and growers currently have to investigate for forest investment. ATLAS Technology is in the process of implementing these improvements, which will be available in Forecaster’s next release.

INTRODUCTION

Forecaster requires a starting tree list consisting of tree heights and diameters to initiate a growth run. This list can be provided by the user, typically from an early age inventory. Alternatively, this starting list can be generated by Forecaster using a random sample of trees from a bivariate distribution of DBH and height. To do this, DBH's are first generated from a reverse Weibull distribution. Heights of each tree are then generated from a normal distribution centred on the following generalised height x DBH function, where 'a' and 'b' are estimated parameters:

$$(\text{Height} - 1.4)^{-0.4} = a + b \times \text{DBH}^{-1}$$

Typically, random tree lists are generated for a stand age of 3 years. To characterise the random tree list, the user is required to specify five parameters, which are:

- For the diameter distribution,
    1. Quadratic Mean DBH (or equivalently basal area since stocking is known),
    2. Largest DBH, and
    3. Coefficient of variation (CV) of DBH.
- For the height distribution,
    4. Mean top height (MTH)
    5. CV of the height residuals (actual height minus predicted height) about the height x DBH curve.

Diameter distributions have been predicted by the 3-parameter Weibull distribution since the mid-1970s. One of the more widely used methods is Model 19 for the Central North Island [(1)] developed some 16 years ago and applicable from mid-rotation onwards. However, no function is currently available to generate a suitable diameter distribution with a starting stand age of approximately three years. Some previous work on the growth of very young trees has been carried out for use in VMAN [(2), (3)], but more data and analysis are required to refine an approach to generate a starting tree list for FFR Forecaster.

This report develops methods of obtaining the parameters required by Forecaster for generating a tree list suitable for starting growth runs, using data from permanent sample plots and pre-silviculture inventory plots.

METHODS

Data

The datasets of DBH and heights were obtained by screening the PSP System for suitable plots with measurements started at an early age (3-9 years), and continued through to near full rotation (~25 years). One hundred and thirty-five plots with 1621 measurements were available. Final age of measurement ranged from 15 to 33 years old. Data were checked for errors, and stand values of Site Index (SI) and 300 Index were estimated using the 300 Index Growth Model. These plots were used to test and develop models for estimating the quadratic mean DBH and MTH which are two of the parameters required by Forecaster.

Because of the small size of PSP plots, estimates of variance for DBH and height obtained from PSPs are likely to be narrower than those from stands. Therefore data from silvicultural assessments and inventory were used to develop functions for predicting the remaining three Forecaster parameters, namely; DBH and height CVs (coefficients of variation), and maximum DBH. Pre-pruning inventory data from 70 stands were provided by the industry. Nineteen stands were discarded due to incomplete plot measurement leaving 2533 trees for the analyses, with an average of 51 trees per stand. Stand age averaged 4.8 years and ranged from 3.5 to 6.5 years, while stocking averaged 1200 stems/ha and ranged from 480 to 2000 stems/ha, apart from one stand assessed at 4700 stems/ha. The stands were from several locations across the North Island including the East Coast, the Central North Island, and coastal sand sites. These inventory data were used to develop methods of estimating the maximum DBH, and the coefficients of variation for DBH and height, as required by Forecaster.

Analysis

The 300 Index growth model has been extensively used to predict the growth of individual trees within a stand. Because the model can project backwards in time as well as forwards, it is possible to use it to predict the quadratic mean DBH and MTH at an early age. These are two of the parameters required by FFR Forecaster. A procedure to perform this operation will be available in the next version release of Forecaster. This method was tested by using it to predict quadratic mean DBH and MTH at the earliest measurement age in each PSP using their 300 Index and Site Index (SI). These predictions were compared with the measured quadratic mean DBH and MTH to test the robustness of the procedure. When there is no access to the 300 Index growth model, as an alternative approach regression models were developed from the PSP data to predict MTH from Site Index and age, and to predict quadratic mean DBH from MTH.

From the pre-silviculture inventory data, CVs for DBH, and the residual of MTH centred around the height x DBH function were estimated for each stand. The maximum DBH was estimated for each stand by fitting the 3-parameter Weibull distribution using the SAS (Version 9.2) UNIVARIATE procedure. This estimates the threshold parameter (in this case the maximum DBH parameter) using a maximum likelihood procedure. Regression models were then fitted for predicting CVs and maximum DBH from quadratic mean DBH and MTH.

RESULTS

Using 300 Index growth model, SI and 300 Index of each stand were calculated from later measurements, and then used to predict MTH and quadratic mean DBH at the first PSP measurement age. The actual PSP measurements and predicted values are shown in Figures 1 and 2. These show that the 300 Index growth model predictions for MTH and Quadratic Mean DBH were reasonably accurate. MTH was slightly over-predicted for younger trees, but the prediction for quadratic mean DBH showed very little bias. Overall, the results show that 300 Index growth model will predict early MTH and DBH with sufficient accuracy for a specified SI and 300 Index.

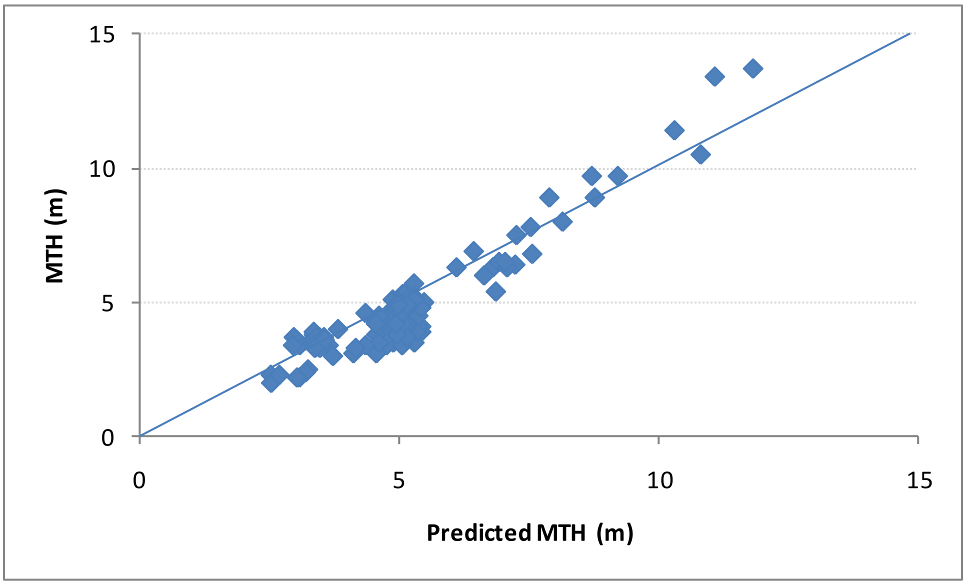

Figure 1. Actual MTH at first measurement against Predicted with 1:1 correspondence line.

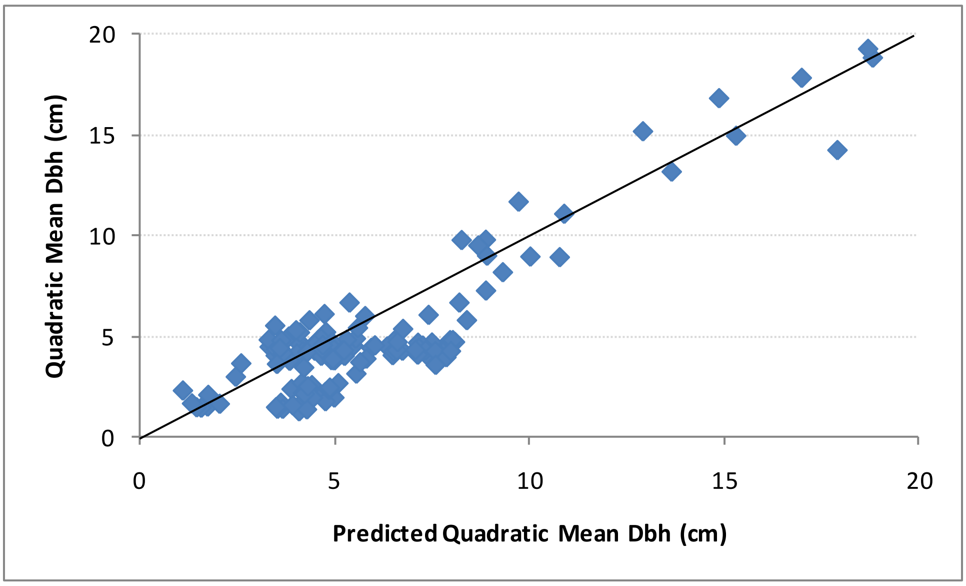

Figure 2. Actual Quadratic Mean DBH at first measurement against Predicted with 1:1 correspondence line.

When there is no access to the 300 Index growth model, the following alternative regression models can be used to predict MTH directly from SI and age (years), and quadratic mean DBH from MTH:

$$\text{MTH} = -3.68 + 1.35 \times \text{Age (yrs)} + 0.095 \times \text{SI} \qquad (R^2=0.884)$$

$$\text{Quadratic Mean DBH} = 1.767 \times \text{MTH} - 2.24 \qquad (R^2=0.881)$$

Figures 3 and 4 show measured values against predicted MTH and Quadratic Mean DBH using these models.

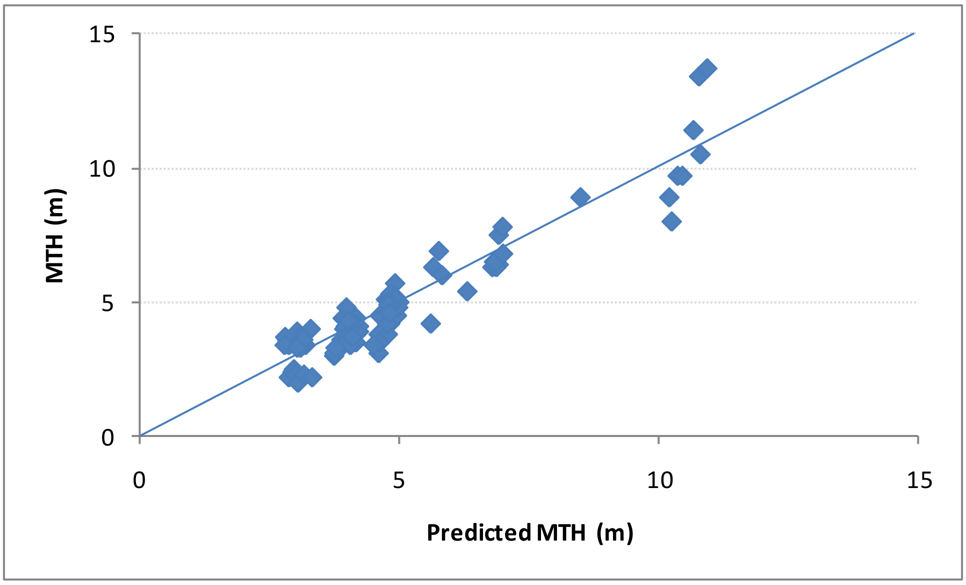

Figure 3. Actual MTH at first measurement against Predicted using the alternative method.

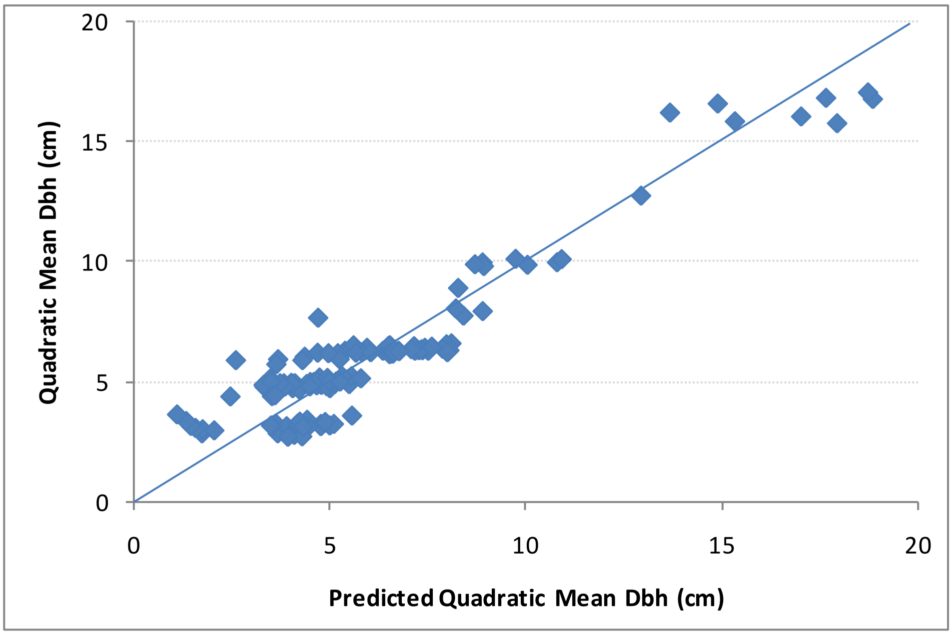

Figure 4. Actual Quadratic Mean DBH at first measurement against Predicted using the alternative method.

Figures 5-7 show the CVs and Maximum DBH for the inventory data plotted against quadratic mean DBH and MTH. The following regression model was obtained for predicting Maximum DBH from Quadratic mean DBH (see Figure 5):

Maximum DBH=3.578 + 1.067 Quadratic Mean DBH $(R^2=0.815)$

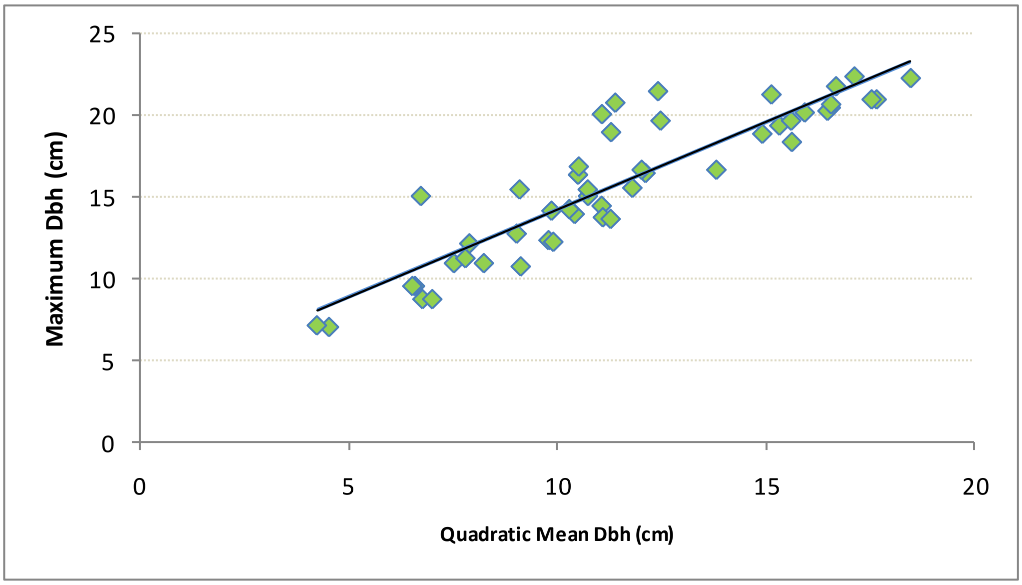

Figure 5. Relationship between Maximum DBH and Quadratic Mean DBH. The line shows the fitted regression function.

The following regression model was fitted for predicting DBH CV from Quadratic mean DBH (see Figure 6):

CV DBH=0.724 x Exp $^{(-0.0582 \text{ x Quadratic Mean DBH})}$ $(R^2=0.407)$

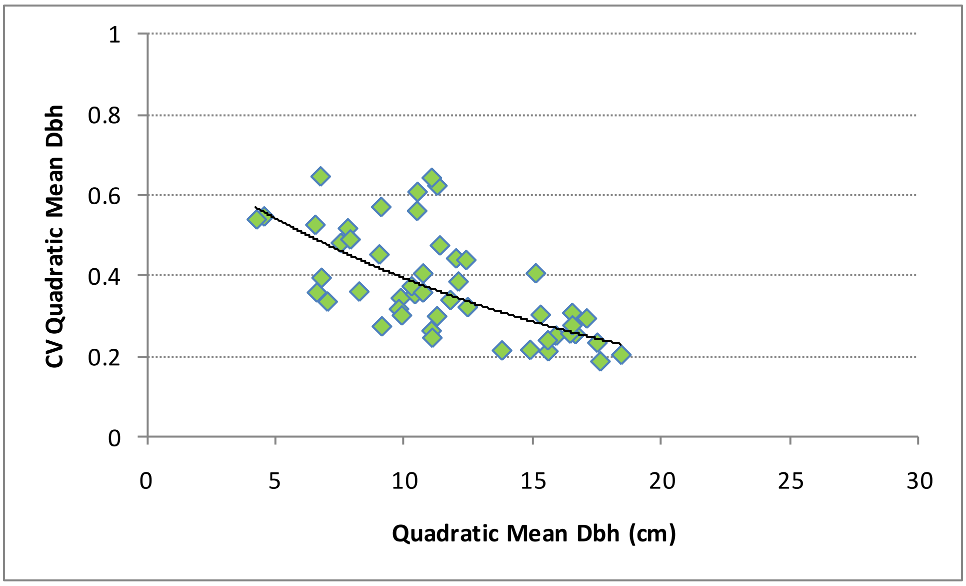

Figure 6. Relationship between Coefficient of Variation of DBH and Quadratic Mean DBH. The line shows the fitted regression function.

The CV of residual height hardly varies with tree size (Figure 7) and could be estimated as a constant. However, for completeness, the following regression model for predicting residual height CV from MTH was derived:

$$\text{CV Residual Height} = 0.183 - 0.003 \times \text{MTH} \qquad (R^2 = 0.012)$$

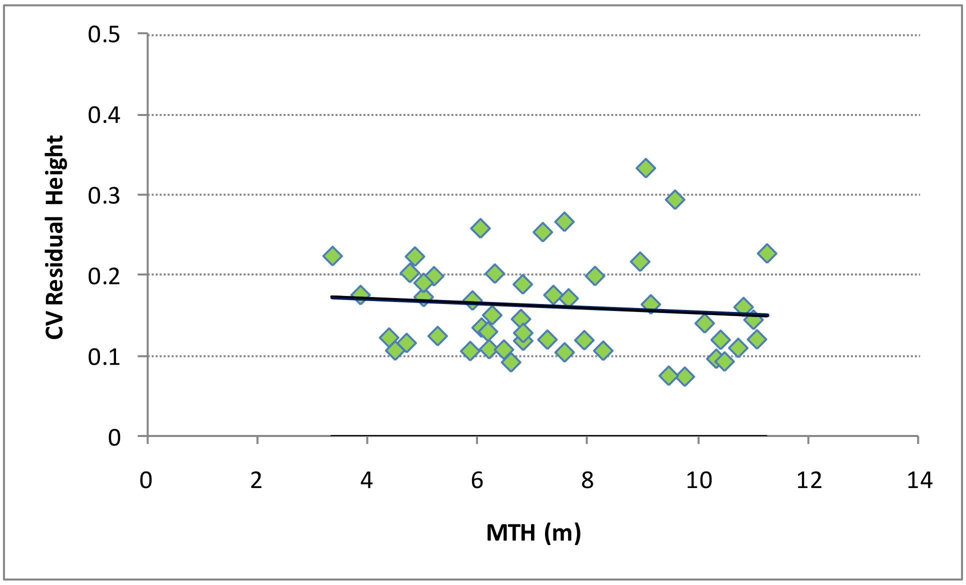

Figure 7. Relationship between Coefficient of Variation of Residual Height and MTH. The line shows the fitted regression function

CONCLUSION

- Methods of estimating the five parameters required by Forecaster for generating starting tree lists for radiata pine were developed for trees aged three years.

- Analysis of PSP data indicates that the 300 Index Growth Model can be used to predict two of these parameters, namely, MTH and Quadratic Mean DBH, from user-specified 300 Index and SI, and is the preferred method for generating tree lists in FFR Forecaster. However, alternative regression models to predict Quadratic Mean DBH and MTH directly from SI and age were also developed for use in the event that there is no access to the 300 Index growth model. The flow chart in the Appendix shows the associated pathways to generate starting tree lists in FFR Forecaster.

- Regression models using Quadratic Mean DBH and MTH as independent variables were developed from pre-silviculture inventory data to predict the other three parameters, namely CVs for DBH and height, and maximum DBH. To increase the robustness of the predictions, we need to refine these models further using additional pre-silviculture inventory data.

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APPENDICES

APPENDIX 1 – Flow Chart