FUTURE FORESTS RESEARCH

DIVERSIFIED SPECIES TECHNICAL NOTE

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Density and Stiffness of USA-grown Douglas-fir

Summary

FFR is interested in understanding the internal wood properties of Douglas-fir, and how they are distributed within the stem. The ultimate goal is to understand the value of the resource in New Zealand, particularly compared with second-growth trees in the USA.

This work provides information on the within-tree wood properties of USA-grown Douglas-fir. This information is only USA-based, but it will allow future comparisons once similar work is undertaken in New Zealand.

Through the Diversified Species Theme, we have been lucky enough to be working with Douglas-fir researchers from the Pacific Northwest on describing density and stiffness of USA-grown trees. Christine Todoroki has worked with researchers as part of a wider Agenda 2020 programme. This large programme is a joint effort of the USDA Forest Service Research & Development and the American Forest and Paper Association. Multiple research partners are involved.

Collaboration in this project will bring important global connections to the Diversified Species programme, through which we will gain understanding and leverage for our own research.

Christine has been given access to density and stiffness (acoustic stiffness) data on veneer sheets that had been peeled from coastal Pacific Northwest Douglas-fir trees. She has used this to construct three-dimensional maps of within-tree density and wood stiffness.

Both density and MOE increase from pith to bark. Trends for both density and stiffness in the vertical direction were highly significant in linear and nonlinear regression models. Predictive models were developed for the USA data, and are presented here.

These results show how Douglas-fir density and stiffness might be expected to behave within a stem in New Zealand. The models could be validated and/or adjusted for New Zealand conditions.

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Introduction

FFR is interested in understanding the internal wood properties of Douglas-fir, and how they are distributed within the stem. Trends in wood properties can be analysed in both a radial (pith-to-bark), or vertical direction. The ultimate goal is to understand the value of the resource in New Zealand, particularly compared with second-growth Douglas-fir in the USA.

This project involves collaboration with a large USA-based research programme known as Agenda 2020. International collaborations such as this not only allow us to leverage our own research spend, but will bring important global connections to the Diversified Species programme. These connections will also be vital to ensure our success in bidding for government funds for continuation of the Diversified Species Theme post 2013.

The research in this project is aimed at understanding how Douglas-fir density and stiffness behaves within a stem in the USA. Colour-coded profiles of the stem are presented to show trends of density and MOE from pith to bark and up the stem. Predictive models were

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developed for the USA data, and are also presented here.

The data and models produced could be validated and/or adjusted for New Zealand conditions with further research. The data produced are still relevant for resource comparisons between New Zealand and the USA.

Ultimately, this research will contribute to improving the Douglas-fir calculator and the 500-Index within Forecaster, particularly for the estimation of carbon.

Methods

All data collection was undertaken in the USA. Wood property data were obtained from veneer sheets, peeled from blocks cut from each of 21 trees (Figures 1, 2, 3). Different numbers of veneer sheets were obtained per tree depending on tree size. The trees, all acoustically tested for wood stiffness using a Fakopp TreeSonic™ time of flight device, grew on three sites and were 51, 36, or 45 years of age.
Each veneer sheet was weighed, measured, and non-destructively tested for strength and acoustic stiffness (e.g. Figures 4, 5). Veneer sheet density was estimated from sheet weight and dimensions, and the modulus of elasticity (MOE) was calculated using the relationship between density and velocity, derived from stress wave transit time.

Colour-coded density and MOE profiles were constructed for each tree by reassembling the sheets into radial and longitudinal components and by colouring each sheet according to its wood property value.

Models were developed using 20 of the 21 trees to predict density and stiffness distributions and verified on a single remaining tree.

Figure 1: One of the forest stands where trees were sampled for this study.

Figure 2 (left): Dennis Dykstra recording data on trees cut in the forest prior to peeling.

Figure 3: Peeling the veneer.

Figure 4: The Metriguard Veneer tester used to non-destructively test for strength

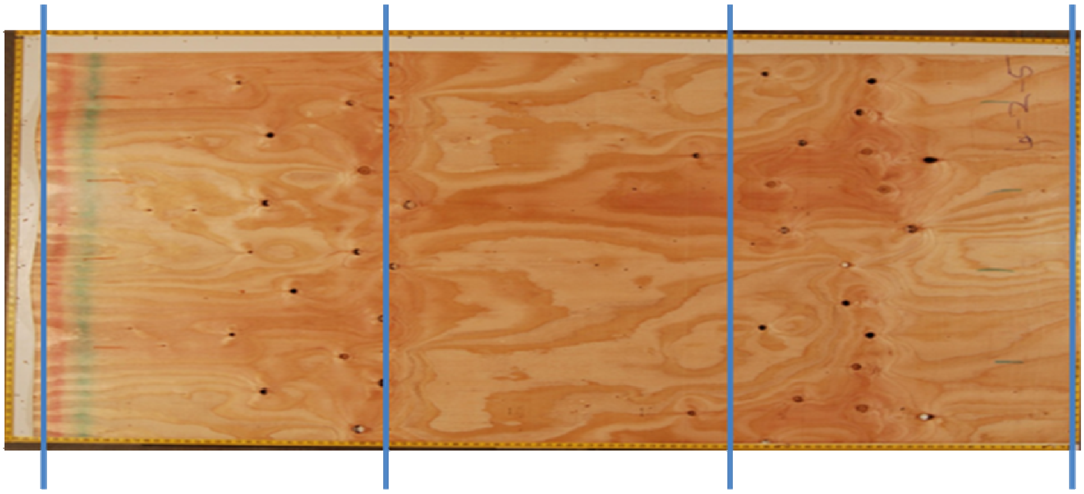

Figure 5: Veneer sheet showing approximate positions where stress-wave transit times were recorded.

Preliminary Results

The colour-coded profiles developed showed increasing density (Figure 6) and MOE (Figure 7) with increasing radial direction. Trends in the vertical direction were less obvious, yet were highly significant in linear and nonlinear regression models predicting the within-tree wood properties.

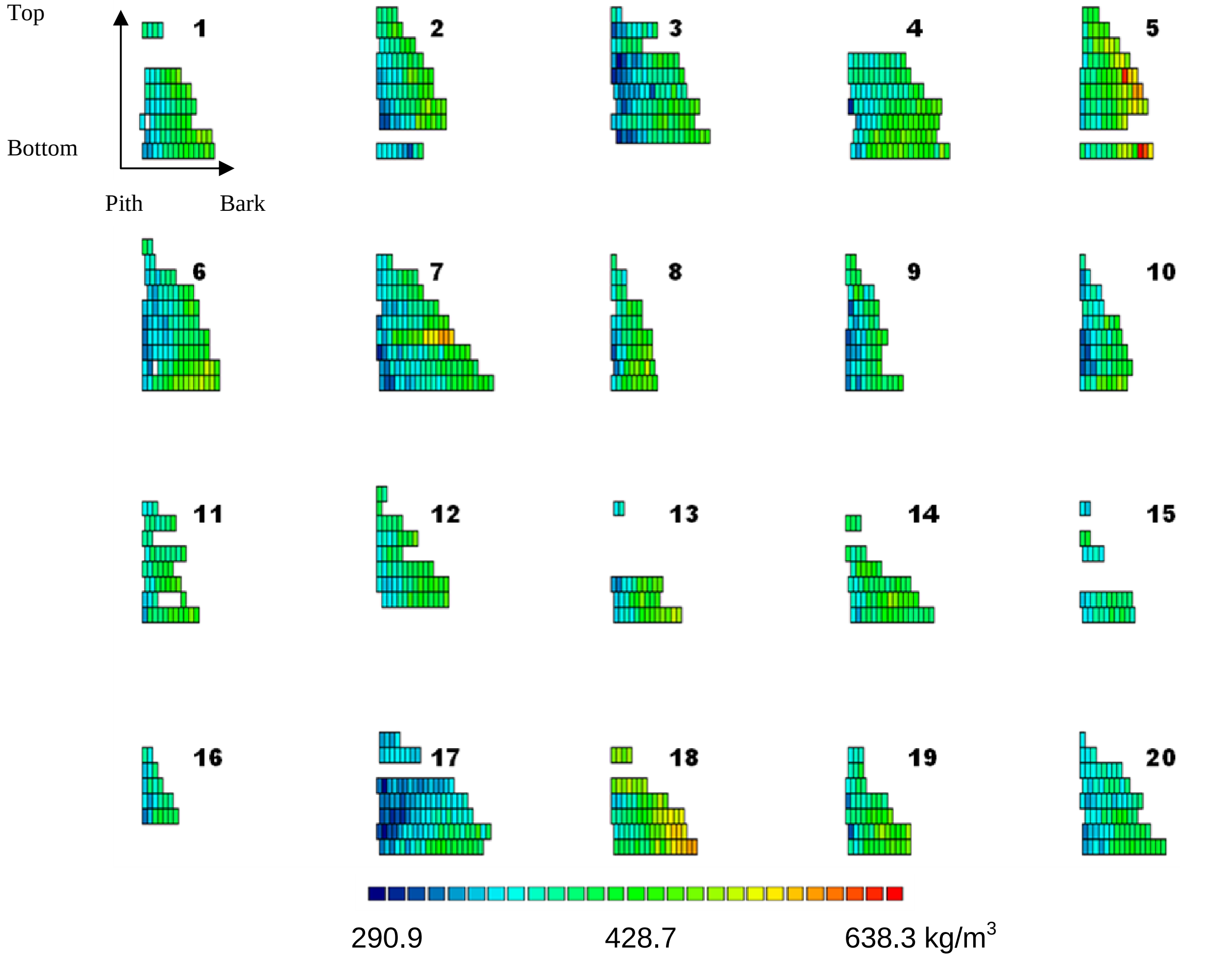

Figure 6: Within-tree distributions of density distributions for trees 1 to 20. Density in the 20-tree sample averaged (429 kg/m^3, s.d. 53 kg/m^{30}). Each colour change represented about 5% of the specified wood property range. Each veneer sheet was denoted by a coloured rectangle.

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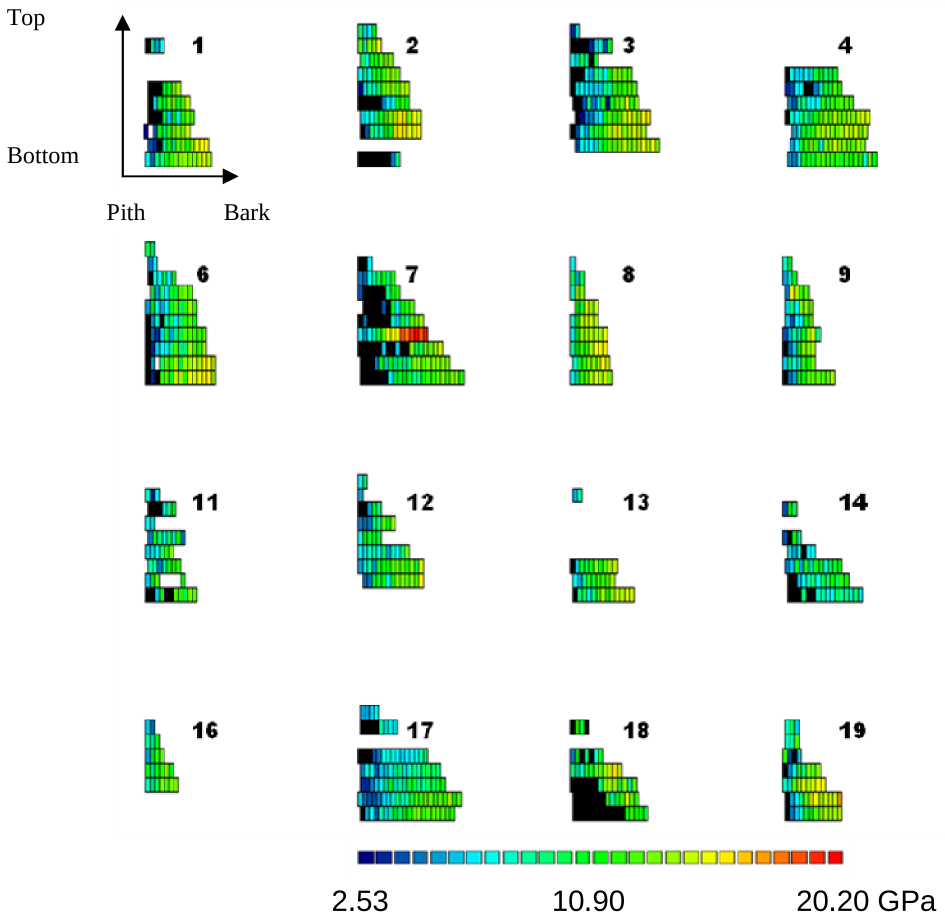

Figure 7: Within-tree distribution of stiffness for all 20 trees. Stiffness, estimated from stress wave transit times on veneer sheets, averaged from 10.89 giga Pascals (GPa; s.d. 3 GPa). Each colour represented about 5% of the specified wood property range. Each veneer sheet was denoted by a coloured rectangle. Where MOE data were absent, sheets were coloured black.

The best models for predicting density and MOE (Models 1 and 2 respectively) had correlation coefficients between measured and predicted values of 0.8. Thirty-one models were tested for density and 23 for MOE. The parameters tested in model development were radial veneer index (the sheet count from the core), tree diameter at breast height, acoustic tree velocity, vertical veneer index (related to the portion of stem peeled), tree height, taper, radius from the pith, and height from the base of the tree.

The density models included interactions between independent variables (tree height (H), breast-height diameter (D), taper (T), and radial (r) and vertical distances (h)) and tree acoustic velocity (V). When validated by visual inspection of colour-coded wood density and MOE profiles within individual trees, reasonable correspondence was obtained between measured and predicted values.

Density = r*h+(D+H)*T+(r2+H)*V [Model 1]
MOE = r+r2+h+D+H+T+V [Model 2]

There was also a strong linear relationship between mean tree density and mean density of the two lowermost bolts within the tree (r = 0.9). A similar relationship was found between mean tree MOE and that of the two lowermost bolts (r = 0.8).

Validation of the model (Figure 8) was undertaken with four trees, three used in model development (Tree 5, 8, and 17), and one independent (Tree 21). The validation trees spanned the diameter range, and each was grown under a different silvicultural treatment. Predicted density and MOE profiles were reasonably close to the measured profiles for those trees used in model development, but the colours indicate that MOE was over-estimated in the independent validation tree.

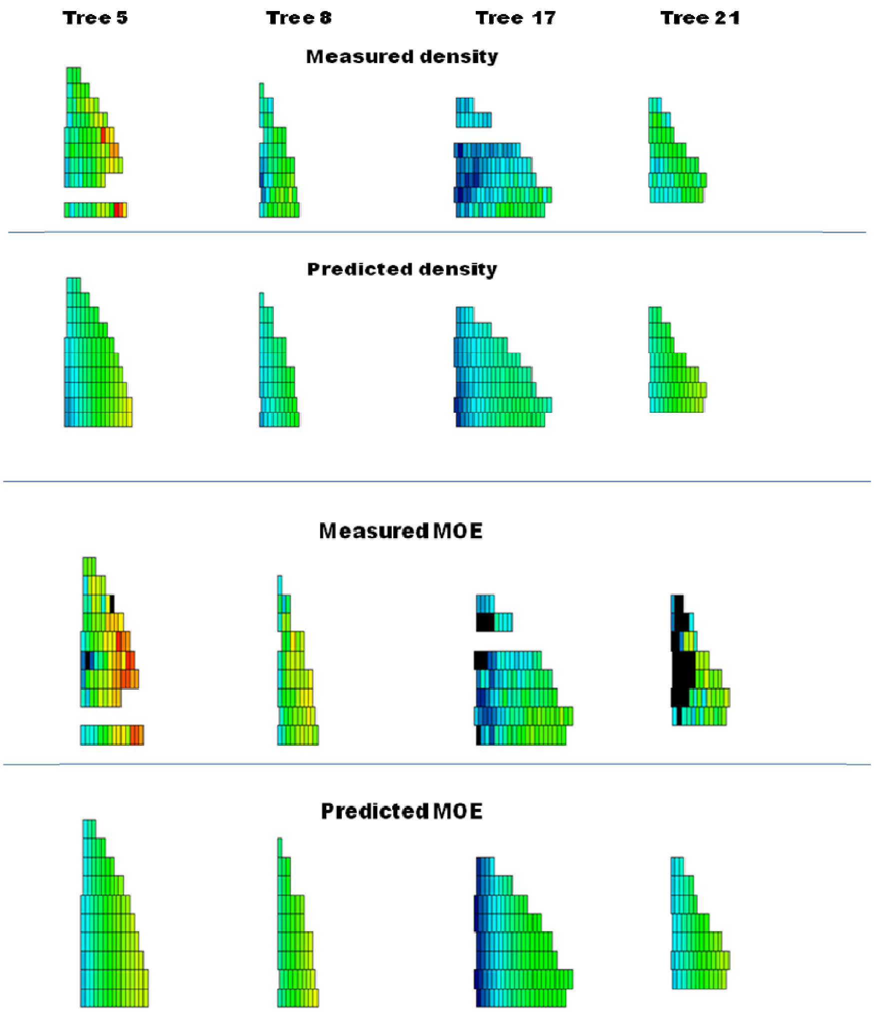

Figure 8: Validation of density and MOE profiles of four Douglas-fir trees; three of which were used in model development and one independent (Tree 21).

In the research presented here, the focus has been on within-tree wood properties. Differences due to site and silviculture will be the focus of future work. Future work could be replicated in New Zealand to facilitate a comparison of the USA and New Zealand Douglas-fir resources.

Conclusion

The colour-coded profiles developed showed increasing density and MOE with increasing radial direction. Models have been developed that predict within-tree distributions of density and MOE for USA-grown Douglas-fir. Future work should include validation of these models for New Zealand-grown Douglas-fir.

This work should be very useful to compare and improve the current density-distribution model for New Zealand-grown Douglas-fir. Currently, the density model for Douglas-fir within the Douglas-fir calculator could be improved. Further improvement of this model will facilitate improved carbon estimates from the 500-Index for ETS reporting. Further work is needed to 1) quantify the possible improvement, and 2) ensure an improved density distribution model is developed for FFR.

Ultimately, this will contribute to improving the Douglas-fir calculator and the 500-Index within Forecaster, particularly for the estimation of carbon.