Using NIR to predict sawn timber quality in *E. nitens*

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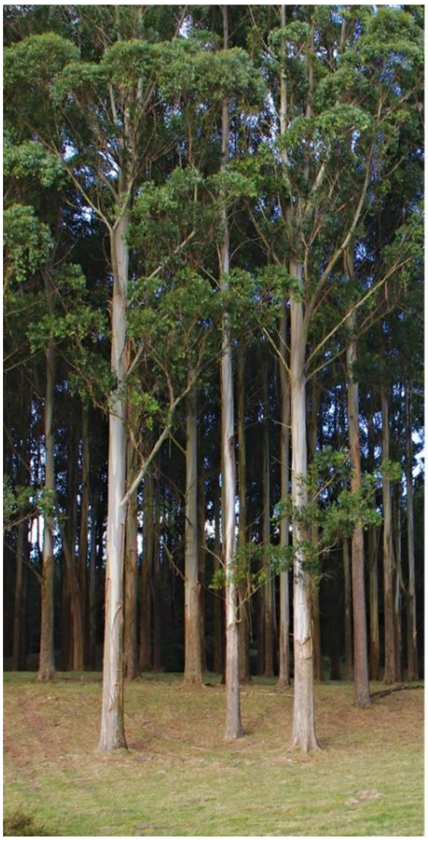

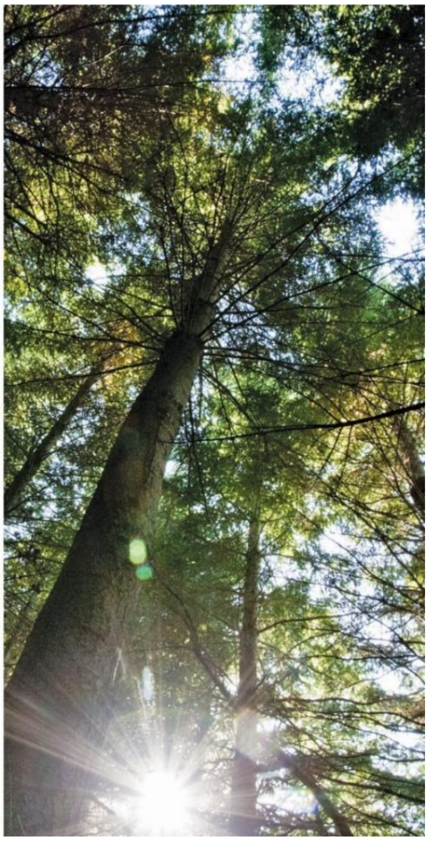

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EXECUTIVE SUMMARY

An existing NIR model, developed as a screening tool for tree breeding, has been assessed as a possible method for identifying *Eucalyptus nitens* trees that produce timber that is not susceptible to within-ring checking and collapse. Tangential shrinkage values were predicted for *E. nitens* discs cut from 28 trees, and these were compared to defect ratings given to the boards cut from each of these trees.

Tangential shrinkage values calculated for inner- and outerwood for each tree were used to predict the defect ratings of either kiln-dried or air-dried boards that had been cut from the same part of each tree. These predictions were very poor at predicting differences in defect ratings between trees, and tended to consistently predict very low defect ratings for air dried boards and very high defect ratings for kiln dried boards, even though both drying techniques showed a wide range of defect ratings between different boards and between trees. Because of these poor predictions it is not recommended that further work be done on predicting the behaviour of individual trees using this NIR model.

Despite not being able to predict defect ratings of individual trees, it was observed that the trees with the highest average tangential shrinkage also contained a high proportion of the trees with high levels of within-ring checking. This suggests that removing trees with high levels of tangential shrinkage from the breeding population could reduce the overall incidence of within-ring checking, without needing to predict the behaviour of individual trees.

INTRODUCTION

A major barrier to the use of *E. nitens* for sawn timber production is the high levels of degrade (within-ring checking and cell collapse) that occur in many *E. nitens* trees when the wood is dried. Despite these high levels of degrade, timber from some trees appears to be very resistant to degrade, and give good quality timber, even after kiln drying (Sargent, et al., 2017). If these degrade-resistant trees could be identified via a screening tool, it would be possible to divert a small proportion of high-quality logs away from chip production and into sawn timber. Work at Scion to date to identify degrade-resistant trees using shrinkage in cores, and Resi™ data have been unsuccessful (Sargent & Gaunt, 2018; Sargent, et al., 2017).

Near infrared spectroscopy (NIR) is commonly used as a non-destructive method to relate the chemistry of a material to another property of interest. NIR data gathered by the Scion DiscBot has previously been used to create a model which predicts a range of wood properties in *E. nitens* discs. This model has been developed for use as a screening tool in tree breeding, where the aim is to identify poorly performing trees, or families and remove them from the breeding population. Details of this model are covered in a separate report (Stovold, et al., 2022).

One of the properties predicted by this model is the tangential shrinkage of wood blocks cut from either the inner or outer part of a disc. The predominant forms of drying degrade in *E. nitens* are cell collapse, and within-ring checking, both of which are caused by excessive shrinkage in the tangential direction. Therefore, we would expect to see a relationship between levels of tangential shrinkage in blocks, and levels of defects in timber sawn from the same trees. While it was not the original intention of this model to predict sawn timber quality, there was an opportunity to test the model's ability to predict sawn timber quality for relatively little effort.

Previous *E. nitens* sawing studies at Scion have generated a lot of data on defects in timber sawn from a range of trees. Discs cut from many of these trees had been retained. In this study, the discs have been scanned in the Scion DiscBot and the existing NIR model was used to predict levels of tangential shrinkage in each tree. These predictions can then be compared to the sawn timber quality from each tree.

METHODS

Development of the NIR model is described in more detail in (Stovold, et al., 2022). Briefly:

- Discs plus two sets of shrinkage blocks (inner/outer wood) were cut from 752 trees.
- 800 half discs were scanned in the Scion DiscBot to obtain hyperspectral NIR images.
- Shrinkage (tangential, radial, longitudinal) was measured in each shrinkage block, both following initial drying, and following steam reconditioning.
- The NIR data was partitioned into inner and outerwood at the hyperspectral pixel level for each disc, then for of these two regions, the spectra were averaged over the region to give a single spectrum each for the inner and outer wood region of each disc.
- A model was created to predict the inner and outerwood tangential shrinkage from the equivalent average NIR spectra from each tree.

A range of other properties were assessed and included in the model (e.g. density, cellulose content) but these were not of interest in this study. Tangential shrinkage following drying and reconditioning ('tangential shrinkage') is the primary property of interest in this study, because it has a direct relationship with within ring checking and collapse.

Two models were created to relate the NIR spectra to each of the measured properties for either inner or outer wood (here the boundary between inner and outer wood was defined as 70% of the attained disc radius).

Two previous sawing studies on *E. nitens* have been conducted at Scion in recent years (Sargent & Gaunt, 2018; Sargent, et al., 2017). Discs and increment cores from the trees used in these studies were retained for use in future projects. The discs were cut at two heights (breast height, and 3m up the tree, which corresponded to the bottom of the saw log, which was located from 3 to 6m up the tree). Discs from 28 trees were available for this study and were scanned in the Scion DiscBot to give NIR spectra of the disc surfaces. For each disc, predictions of tangential shrinkage were made for both the inner and outer wood. Previous attempts to use NIR data gathered from cores had not given good model predictions (M. Riddell, pers. comm.), due to a combination of oxidation products on the core surface (from the wood reacting with the steel corer) and differences in surface preparation between discs. Given that the model calibration and testing was performed using spectra from discs with sawn surfaces; using spectra from cores (with sliced surfaces) as new data to make predictions from the model would introduce additional variables and would be less likely to give accurate predictions. In future studies it should be possible to overcome these issues through appropriate preparation of the cores, but because this study was using existing cores, that was not possible here. For this reason, although it was originally intended to include cores in this analysis, it was decided not to include them.

Sawn timber quality had been previously assessed using a 4 point defect rating scale for the severity of drying defects (0 = no visible defects, 3 = severe defects). Collapse and within-ring checking were each assessed separately. Ratings were available for 189 boards cut from the trees that were measured in this study, and they were all included in the analysis. The boards were also classified as ‘air dried’ or ‘kiln dried’, because previous work found that kiln drying significantly increases levels of degrade. Levels of checking and collapse in each board were analysed separately. For each tree the boundary between inner and outerwood was calculated as 70% of the radius of the disc cut at 3m. Each board was classified as being cut from inner- or outerwood according to the distance from the pith of the mid point of the board. Each board was assigned an average predicted shrinkage value based on the appropriate inner or outerwood predicted shrinkage for the tree it was cut from.

Multinomial logistic regression was used to create a linear model relating the individual board defect ratings to the tangential shrinkage values, taking into account whether the boards were from the inner or outer part of the tree, and whether they had been kiln dried or air dried. Separate models were created for checking and for collapse. The strength of these models was tested by creating a ‘confusion matrix’ where the condition of each board is predicted using the model, and this is compared to the actual board condition. From this the proportion of boards that have been correctly classified can be calculated. This process was repeated using a linear model that did not include the tangential shrinkage data (i.e. predicting the board condition solely from drying method and position in board) and the proportion of boards correctly classified by this model was calculated. This gives an indication of the increase in prediction accuracy that is contributed by the tangential shrinkage prediction data.

RESULTS

Tangential shrinkage predictions

For each tree, four tangential shrinkage values were predicted (inner and outer wood of both breast height and log height discs). On average predicted tangential shrinkage was higher in breast height discs, and higher in outer wood, but there was a lot of scatter in the results, and these differences were not statistically significant across all the trees. The predicted shrinkage values for each tree (arranged from lowest to highest average shrinkage) are shown in the box and whisker plot in Figure 1. Because the differences between the shrinkage values predicted at different heights, and between inner and outerwood, no attempt has been made to distinguish values from different log heights and positions in the figure. Overlaid on Figure 1 are the average defect ratings (within ring checking and collapse) for the air-dried boards cut from each tree. These defect ratings don't show a strong trend with increasing tangential shrinkage, but among the trees with the highest predicted tangential shrinkage are some of the trees with the highest ratings for internal checking. Conversely, trees with the lowest predicted shrinkage have very low levels of internal checking (average board defect ratings of zero). This confirms the value of this NIR model as a tool to remove some of the worst performing trees from a breeding population, without necessarily needing to accurately predict the behaviour of each individual tree. Levels of collapse do not show any obvious trend with increasing tangential shrinkage, indeed the two trees with the highest average collapse rating have the lowest average predicted tangential shrinkage.

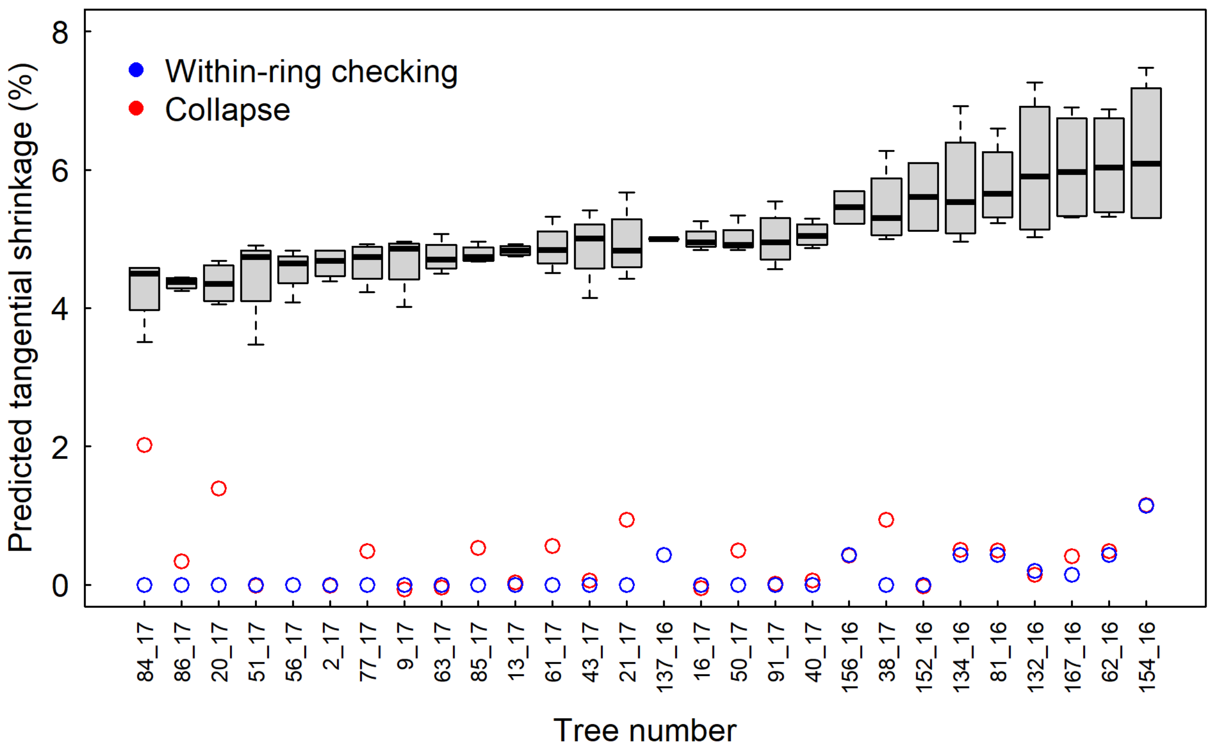

Figure 1: Predicted shrinkage values for each tree, ordered from lowest to highest average shrinkage (four predicted values for each tree). Average air-dried board ratings for within-ring checking and collapse are also shown for each tree (n = 4 for "_17" trees and n = 2 for "_16" trees).

Predicting board quality

Predicting levels of collapse in individual boards from the tangential shrinkage data gave the correct defect rating for 56% of boards. Predicting levels of collapse without taking into account the tangential shrinkage data gave the correct board rating 54% of the time – suggesting that the tangential shrinkage data is not providing much additional information to help distinguish between trees.

Tangential shrinkage also was found not to be a good predictor of levels of within-ring checks. The correct board rating was predicted 77% of the time, but this percentage was the same whether the tangential shrinkage values were taken into account in the model or not, suggesting that tangential shrinkage is not providing any additional useful information to distinguish between defect-prone and defect-resistant trees.

From the predictions of levels of checking and collapse in individual boards, the average defect rating (both actual, and predicted) of the boards cut from each tree can be calculated. The predicted average rating of each tree is plotted against the actual average rating in Figure 2. This figure shows ratings for both within-ring checking and collapse, for both air dried and kiln dried boards. Overall, the predicted ratings are consistently low for the air-dried boards, even when the actual average ratings were as high as 2 (indicating severe levels of checking or collapse). The predicted ratings were consistently high for the kiln dried boards, with the majority having an average rating of 2, even though the actual average ratings varied from 0 to 2.5, with a large number of trees having an average check rating of 0 (i.e. no defects) for the kiln dried boards.

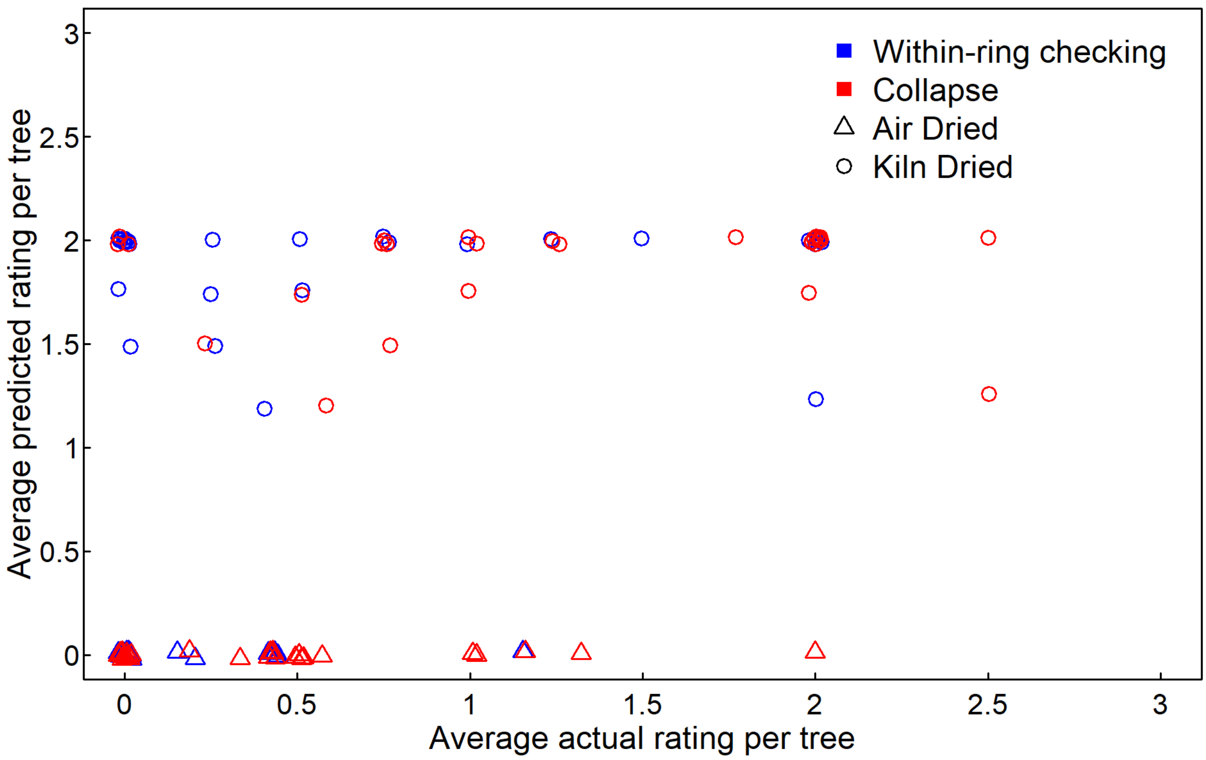

Figure 2: Average predicted board rating for each tree as a function of the actual average rating of the tree. Ratings for within-ring checking and collapse are shown in blue and red respectively. Circles indicate ratings for kiln dried boards and triangles indicate ratings for air dried boards.

CONCLUSION

Overall, levels of tangential shrinkage predicted by the NIR model were a poor predictor of the level of defects seen in individual dried boards, or of whether an individual tree is defect-prone or defect-resistant. While it does not appear to be possible to identify the particular trees that are likely to have high levels of checking, there is still some correlation between tangential shrinkage and within-ring checking. If the trees with predicted high levels of tangential shrinkage were excluded from a breeding population, this would likely also remove a large proportion of the trees with high levels of within-ring checking. No relationship between levels of collapse and tangential shrinkage were seen.

Due to the poor predictions of individual tree performance, it is not recommended that further work be done using this NIR model as a method for predicting the sawn timber properties of individual trees. The use of this model for its original intended purpose, as a screening tool for tree breeding, has the potential to remove a high proportion of internal check-prone trees from the breeding population, by excluding the trees with the highest predicted tangential shrinkage.

Further work could be done to develop a new NIR model that was better suited to identifying defects in individual boards. For example, because within ring checking and collapse tend to be concentrated in particular growth rings, and absent in others, predicting maximum levels of shrinkage in a disc may be more informative than average levels of shrinkage.

ACKNOWLEDGEMENTS

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The NIR model was based on the work of many Scion staff including John Lee, Mark Riddell, Jaroslav Klápště.
The *E. nitens* discs used in this study were prepared and scanned in the DiscBot by John Lee. NIR data analysis was carried out by Mark Riddell.

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