Branching Characteristics and Wood Property Variation:
GF14 seedlot 1978 Genetic Gain Trial
NN530/2, Golden Downs

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EXECUTIVE SUMMARY

Detailed stem form, branching and wood property data were collected from eight GF14 trees in the 1978 genetic gain trial NN530/2, Golden Downs Forest, Nelson.

The primary purpose was to provide a dataset to be utilised in the development of an integrated tree growth, branching and wood formation model. The use of the data for this purpose has been previously described in SGMC Report No 132.

Three aspects of the data have been examined in this report:

- The number of branch clusters in an annual shoot
- The variation in wood properties with reference to the two thinnings
- Visual variation in wood properties as indicated by disc images

These analyses indicated that:

- There is real potential for using climatic data to estimate the number of branch clusters in an annual shoot.
- There was little response to the 1st thinning as the tree was actively growing at 1.4m at this time.
- There was more obvious response to the 2nd thinning, when the tree was older at 1.4m.
- The variation in wood properties at a particular point in the stem after a thinning will be influenced by the tree age at that point, at breast height.
- The type of wood formed after thinning can vary between trees and within a ring
- At this site, branching patterns appeared to have little or no influence on wood .properties at mid-internode. It is possible that more response would have been seen if the sampling position was immediately below the branch clusters.

There is the potential for the data to generate further hypotheses on tree development.

To be able to develop robust integrated tree growth, branching and wood formation models, the study needs to be repeated on a matrix of sites to cover the:

- Variation in environmental conditions (i.e. different growth modelling regions)
- Variation in silvicultural treatments
- Variation in genetic material

In particular, there is still a narrow window of opportunity to collect such data from the 1975 final crop stocking trials at Woodhill and Golden Downs where there are 7 different silvicultural treatments.

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INTRODUCTION

At the July 2004 Stand Growth Modelling Cooperative meeting, approval was given to carry out destructive sampling in the 1978 Genetic Gain Trial in Golden Downs (NN530/2) to provide data for the Internal Stem Modelling Theme.

The theme objective is:

> To develop and refine a tree-level model of internal wood properties with respect to stem shape, and crown architecture as well as site, stocking and planting stock.

Such a model should be able to predict the variation in wood properties in 3 dimensions (vertical, radial and circumferential). The output would be suitable as input for other models predicting timber performance (e.g. distortion).

The first study under this theme, a pilot study, was carried out in FR172/3, Kaingaroa. The data collected and initial analyses are discussed in SGMC Reports No. 126 and 127. The use of these data for developing an integrated stem growth, branching and wood property model is discussed in SGMC Report No. 131

This study in NN530/2, Golden Downs is the second study under the Internal Stem Modelling theme. Data were collected to address the following questions:

1. *How well can growth and wood properties be predicted from crown structure?* This is needed to develop integrated growth and quality models.
2. *How does branch diameter influence the variability of wood properties within an internode?* We have observed blocks of compression wood in an internode below branches.

The first topic is addressed in SGMC Report Nos 131 and 132.

This report provides a summary of the following:

- The number of branch clusters in an annual shoot
- The relationship between outerwood density samples and the SilviScan density data from the discs nearest breast height
- The trends in wood properties in the breast height discs
- A summary of the visual images of discs

DATA

The sample trees for this study were selected from plot 10/51 (see map in Appendix 1), as this was the closest plot to the road with a GF14 seedlot.

The sample trees were selected based on outerwood density cores, collected as part of the WQI benchmarking study (Figure 1), and a visual assessment of trees in August 2004.

The original intent had been to sample some straight and some bent trees, however the visual assessment in August 2004, revealed that the majority of the trees were leaning or had a slightly bent stem. Also the data (Figure 1) appear to seem to split into two distinct groups. For these reasons, it was decided to sample 4 pairs of trees:

- the two trees in each pair have a similar DBH,
- one tree has a low outerwood density and one tree has a higher outerwood density.

This sampling scheme (of having trees in pairs of similar size but different density) is aimed at understanding the relationship between crown structure and wood properties.

These pairs are listed in Table 1. There were only 2 trees common between this study and the WQI study because WQI is only sampling 3 trees from this plot. The third tree did not fit within the sampling scheme outlined above. The remaining trees being sampled by WQI are from the plot surround.

Figure 1. Relationship between breast height outerwood density and tree DBH.

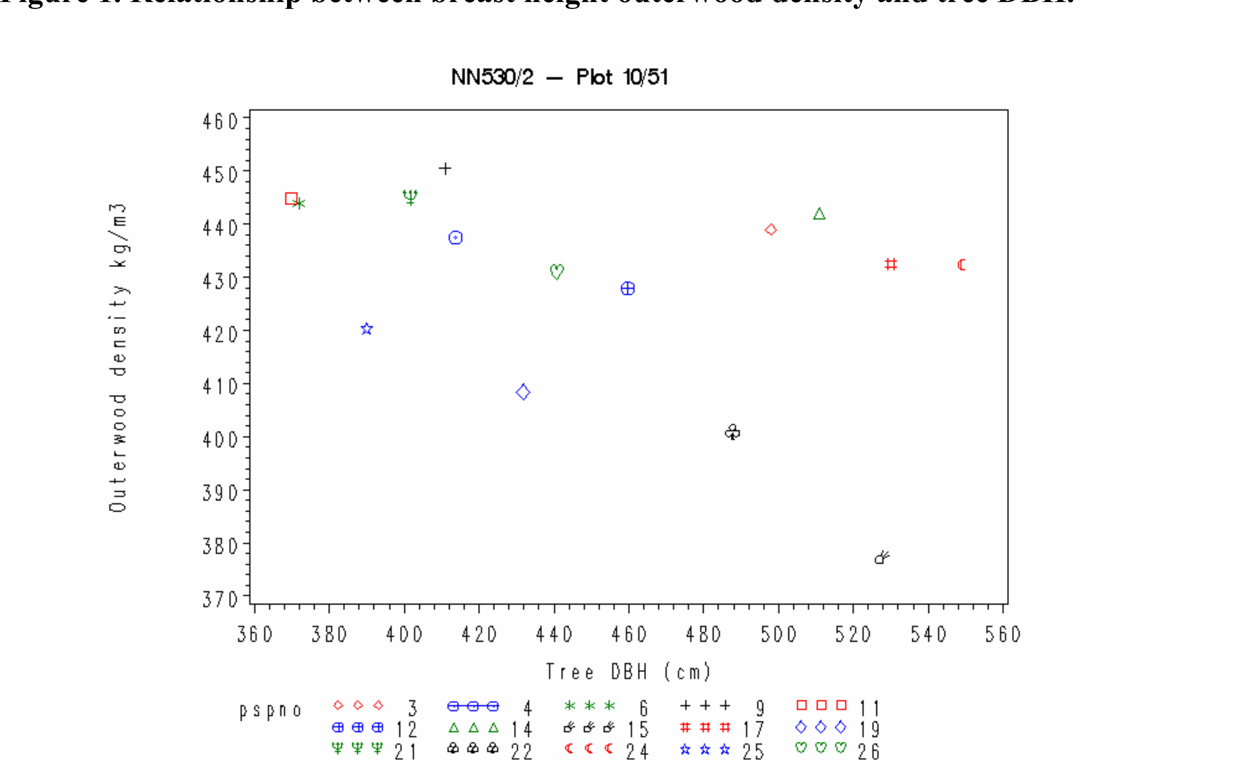


Table 1. Sample trees selected for felling

Tree	DBH (cm) August 2004	Density (kg/m^3)	Subjective field notes
Pair 1			
25*	40.0	420.5	Fine branching Leaning a bit uphill
9*	42.0	450.5	Bigger branches Reasonably straight
Pair 2			
19	44.5	408.5	Longer internodes Straight
26	44.5	431.0	Fine branches Crown suppressed on one side Butt sweep
Pair 3			
22	50.5	401	Big branches for size Lots of clusters Straight
3	51.0	439	Heavy crown Leaning uphill
Pair 4			
15	53.5	377.5	Some big branches Asymmetrical crown Straight/maybe leaning
24	55.5	432.5	Bigger branches Leaning uphill

Note: * Tree sampled for WQI benchmarking study.

Prior to felling (in November 2004) an image of each tree was taken using the PhotoMARVL system (Firth *et al.,* 2000). The orientation of the reference lines in the PhotoMARVL images and the reference lines on the felled stem are given in. All images of discs were taken with the reference line aligned to the top of the vertical line on the image board.

As part of the data collection, discs were cut at 7 positions (Table 3) within each tree, imaged and then up to 3 strips were cut from a disc for processing by SilviScan in Australia.

Table 2. Orientation of reference lines on sample trees in NN530/2

Tree	Bearing from approx. camera position to tree	Compass bearing of pink paint line in PhotoMARVL image	Compass bearing of reference line used	Colour of reference line	Blue 2nd line (left or right of reference line looking down)
3	119	297	297	pink/orange	Left
9	159	358	164	yellow	Left
15	195.5	359	359	pink/orange	Left
19	210	33	106	orange	Left
22	248	75	75	pink/orange	Left
24	268	90	90	pink/orange	Right
25	276	120	120	pink/orange	Right
26	281	120	222	orange	Right

Table 3. Disc positions with field disc number for samples saved for SilviScan.

Disc Position/Field Disc No.	Tree 3	Tree 9	Tree 15	Tree 19	Tree 22	Tree 24	Tree 25	Tree 26
Mid internode nearest 0.5 m	83		66		80			100
Mid internode nearest DBH	80		65	62	76	74		95
Mid way between DBH and crown base	76		57	57	66			87
Base crown	73	56	49	52	49	60	64	75
¾ way down crown	58		38	37	39	47	49	53
½ way down crown	40	31	27	28	26	35	37	43
¼ way down crown	22	17	15	17	14		22	24

Note: Discs were taken from mid internode below the above cluster numbers

BRANCHING CHARACTERISTICS

Number of branch clusters in an annual shoot

Branching data for GF14 seedlots are now available for two sites in Golden Downs (Table 4). The observed mean and maximum number of branch clusters in an annual shoot was slightly higher at NN530/2 compared to NN529/1. Both datasets were used in a study that investigated the possibility of predicting number of branch clusters from environmental variables in the Land Environments of New Zealand (SGMC Report No. 145). This study indicated that the site mean value for the number of branch clusters in an annual shoot was correlated ($p < 0.05$) with latitude and 5 of the 17 LENZ environmental variables, namely:

- Annual temperature (°C) – monthly mean daily temperature, averaged across all months (positive correlation).
- Winter minimum temperature (°C) – mean daily minimum temperature of the coldest month, usually July (positive correlation).
- Annual solar radiation ($MJ/m^2/day$) – monthly mean daily solar radiation, averaged across all months (positive correlation).
- Winter solar radiation ($MJ/m^2/day$) – mean daily solar radiation in June (positive correlation).
- Phosphorus – analysis of sub-soil concentration using half-molar sulphuric acid and a five-step scale (negative correlation).

Table 4. Lenz variables and branch clusters in annual shoots for two Golden Downs sites.

	NN529/1 – Site 12	NN530/2 – Site 15
Number of trees	3	8
Number of annual shoots	42	142
Mean number of clusters in an annual shoot	3.4	3.6
Minimum number of clusters in an annual shoot	1	1
Maximum number of clusters in an annual shoot	5	7
Lenz Environment	P5	E1
Lenz - Annual temperature (°C) – monthly mean daily temperature, averaged across all months.	9.2	9.3
Lenz - Winter minimum temperature (°C) – mean daily minimum temperature of the coldest month, usually July.	-1.2	-0.9
Lenz – Annual solar radiation ($MJ/m^2/day$) – monthly mean daily solar radiation, averaged across all months.	14.0	14.5
Lenz- Winter solar radiation ($MJ/m^2/day$) – mean daily solar radiation in June.	4.2	4.9
Lenz - Phosphorus – analysis of sub-soil concentration using half-molar sulphuric acid and a five-step scale.	2.4	2.7

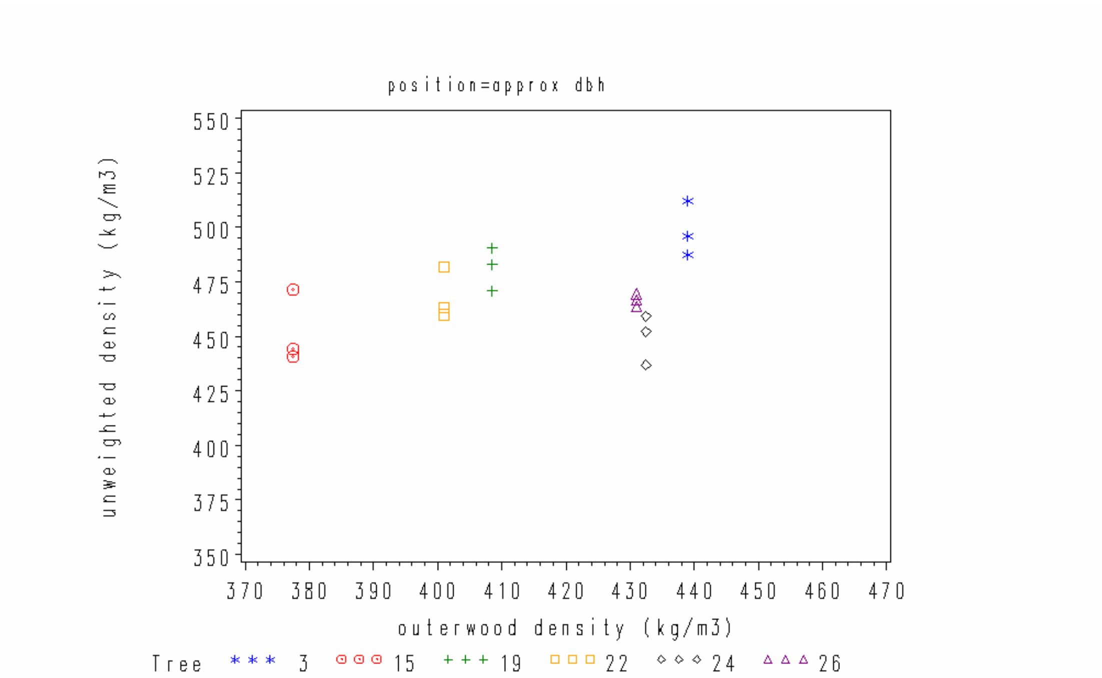
WOOD PROPERTIES

Relationship between strip average density and outerwood density

The sample trees were selected in pairs based on breast height stem diameter (DBH) and outerwood density. Trees 19, 22, and 15 had lower outerwood density compared to their pair (trees 26, 3 and 24 respectively). The relationship between unweighted strip average density and outerwood density for the SilviScan data closest to breast height was examined (Figure 2). Two points can be noted:

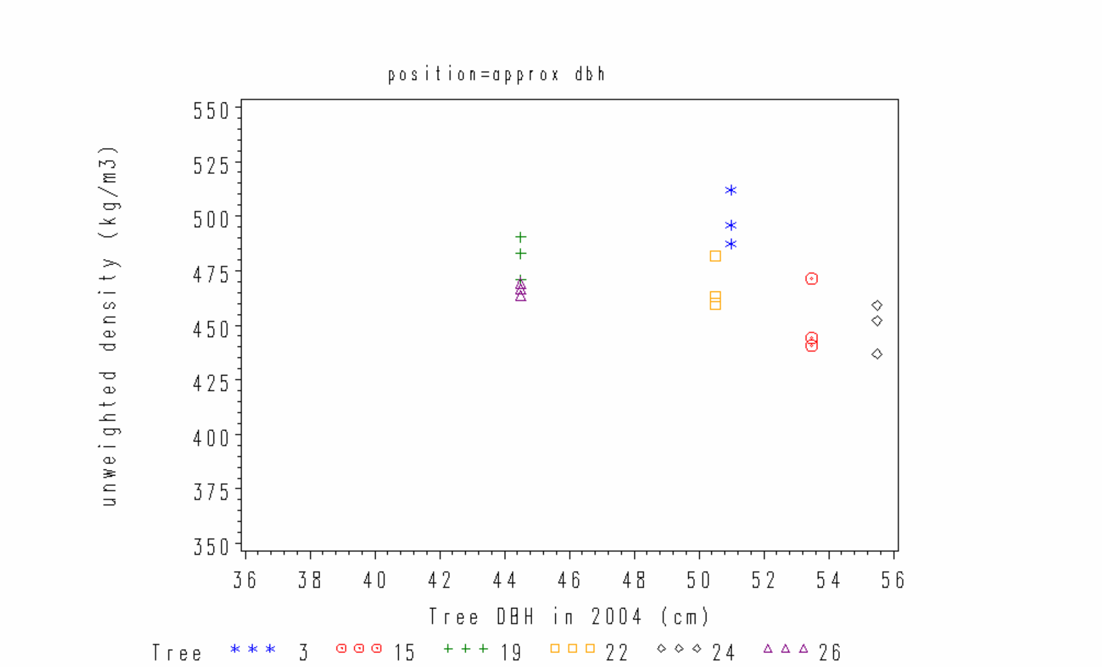
- It would be feasible to derive a regression equation to predict between unweighted strip average density and outerwood density for trees 3, 15, 19 and 22.
- The unweighted strip average density for trees 24 and 26 was lower compared to their outerwood densities.
- The unweighted density is similar for pair 4 (trees 15 and 24).
- The unweighted density was lower for tree 26 compared to its pair, tree 19.

Figure 2. Relationship between unweighted strip average density and outerwood density for samples from approximately breast height.



The strip unweighted average density tended to decrease with increasing tree DBH (Figure 3). Tree 3 stood out as having a higher density for its DBH - tree 3 was noted as having a heavy crown.

Figure 3. Relationship between strip unweighted density from SilviScan and tree DBH.



Wood property data for discs closest to breast height

The SilviScan data from the breast height discs have been examined in detail (Tree3;
Figure 4, Tree 15; Figure 5, Tree 19; Figure 6, Tree 22; Figure 7, Tree 24; Figure 8, Tree 26; Figure 9)

Each figure contains 5 images/graphs laid out as follows:

Image of disc	
Variation in ring width versus tree age when the ring was formed for the 3 strips	Maximum ring average density for the 3 strips (maximum), minimum ring average density for the 3 strips (minimum), and difference between maximum and minimum as measured by SilviScan versus tree age when the ring was formed
Maximum ring average microfibril angle for the three strips (maximum), minimum ring average microfibril angle for the 3 strips (minimum) and difference between maximum and minimum (difference) as measured by SilviScan versus tree age when the ring was formed	Maximum ring average MOE for the three strips (maximum), minimum ring average MOE for the 3 strips (minimum) and difference between maximum and minimum (difference) as estimated by SilviScan versus tree age when the ring was formed

Each graph contains two vertical lines. These lines correspond to the two times of thinning (from an initial stocking of 1111 stems/ha to a nominal stocking of 600 stems/ha, and then to a nominal stocking of 300 stems/ha).

Also the actual data points were joined so that the trends through time are clearer.

The following points may be noted from examining these figures:

- All 6 breast height discs are eccentric to some extent.
- The within-ring variation in density (difference on graphs) was similar for all trees.
- The within-ring variation in microfibril angle, and MOE (difference on graphs) was much larger for trees 3 and 19 compared with the other trees. Visually these two discs had more compression wood.
- Apart from tree 22, there was a decrease in ring width following the first thinning.
- There was no obvious change in the trend of wood properties as a result of this thinning
- There was generally a slight increase in ring width at the time of the second thinning
- There was a slight increase in microfibril angle at the time of the second thinning
- There was little change in density as a result of the second thinning
- There was a slight decrease in MOE after the second thinning

Figure 4. Breast height disc, ring width and wood properties from SilviScan for tree 3.

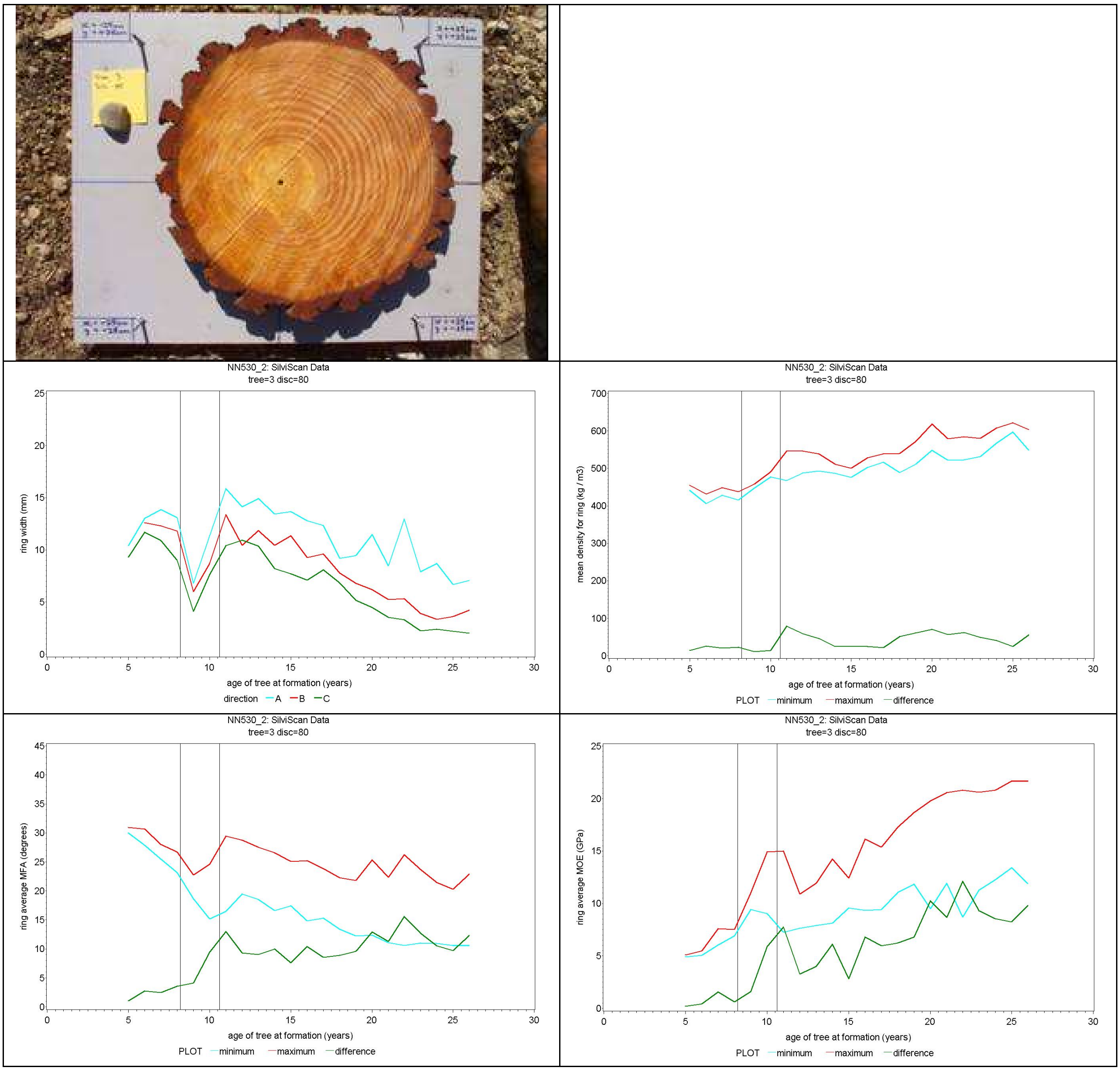


Figure 5. Breast height disc, ring width and wood properties from SilviScan for tree 15.

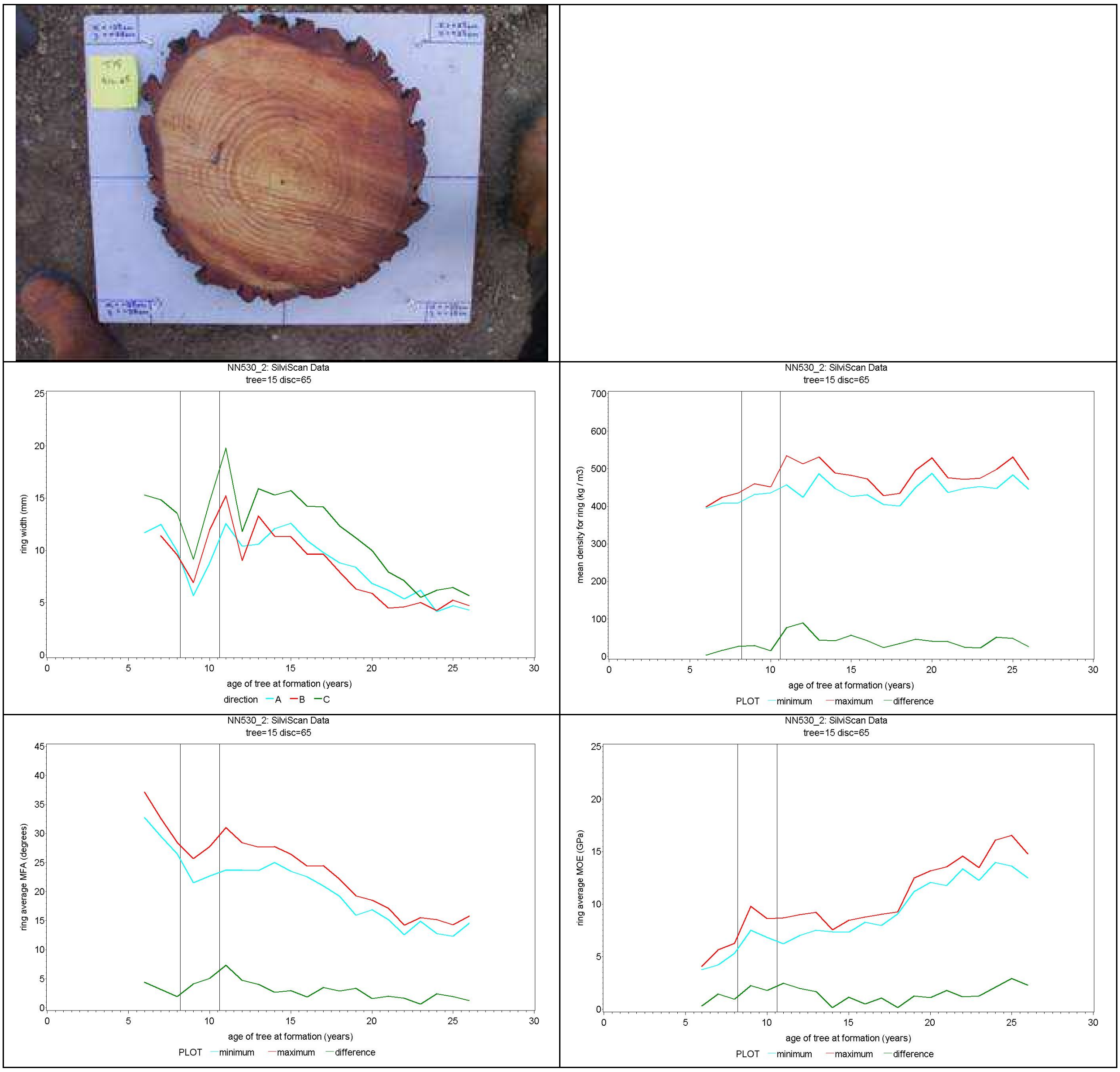


Figure 6. Breast height disc, ring width and wood properties from SilviScan for tree 19.

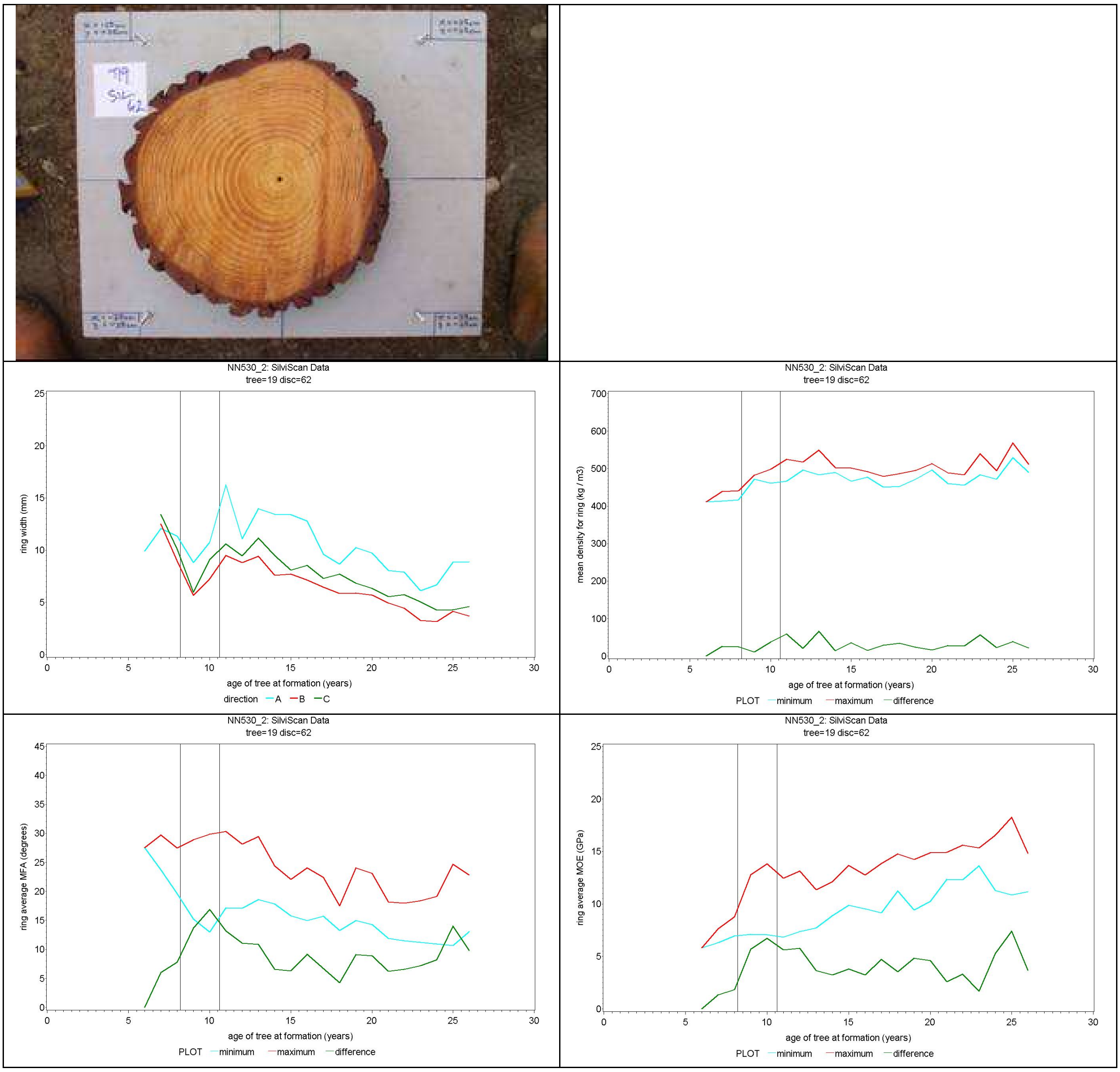


Figure 7. Breast height disc, ring width and wood properties from SilviScan for tree 22.

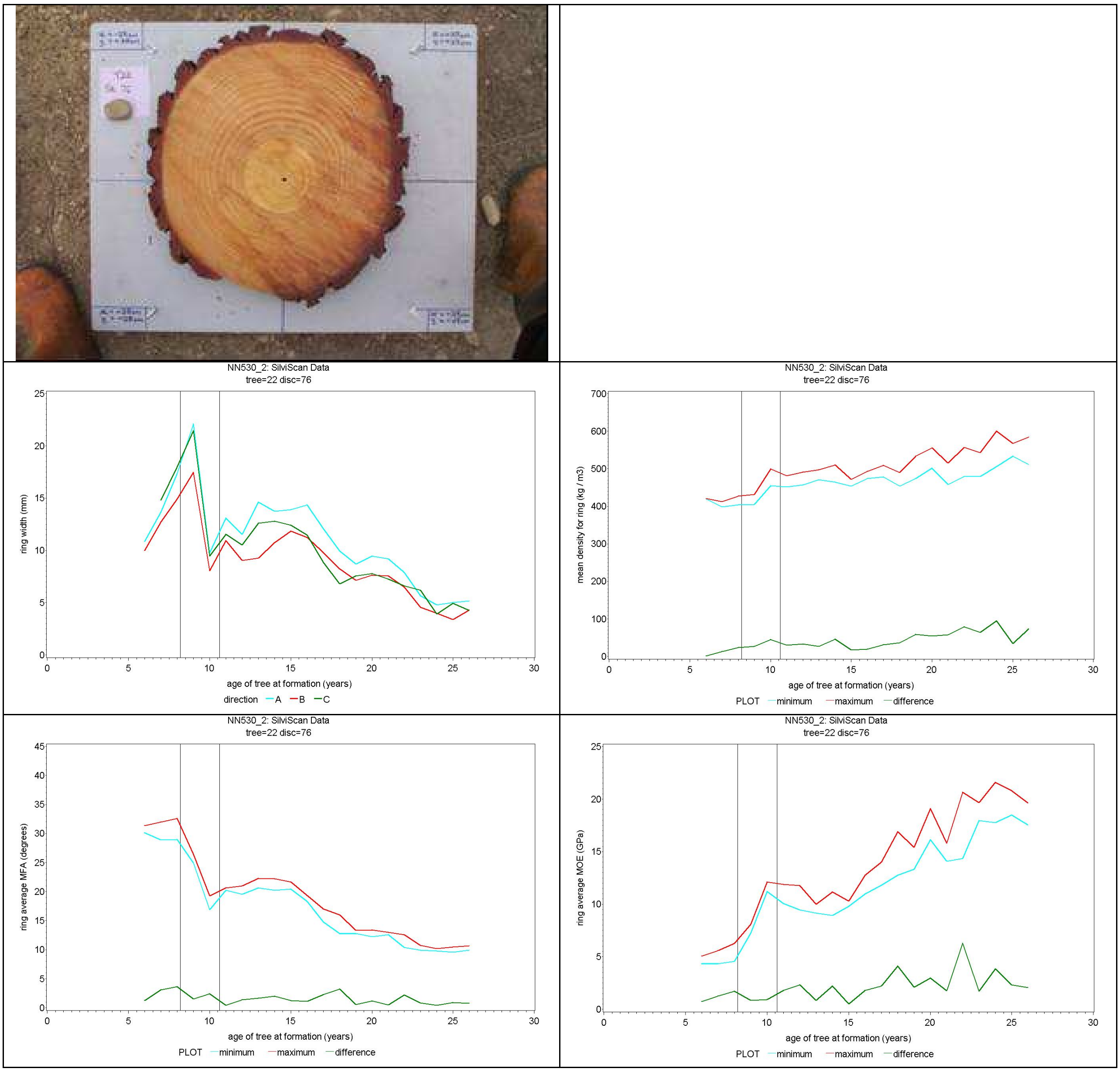


Figure 8. Breast height disc, ring width and wood properties from SilviScan for tree 24.

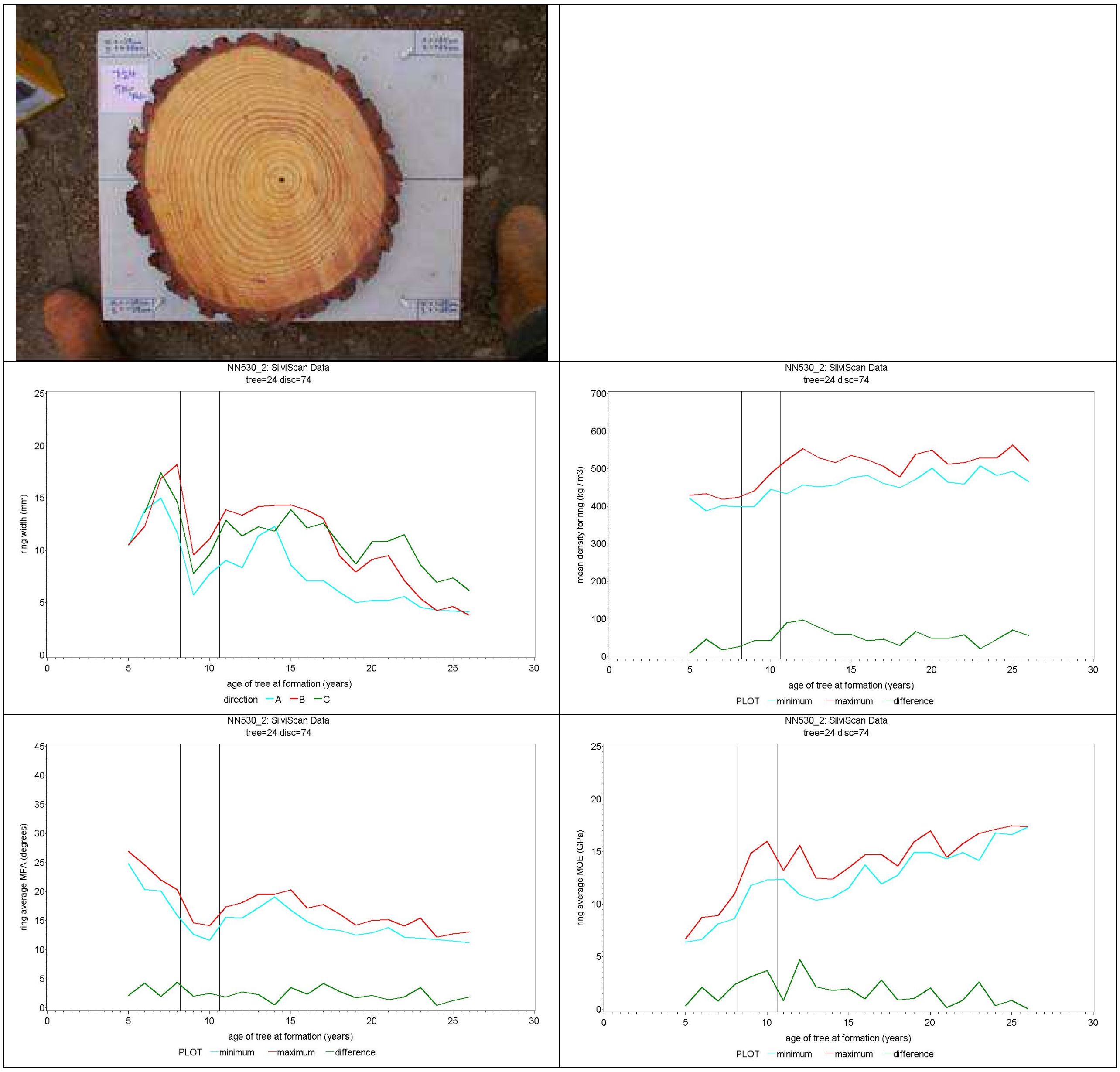
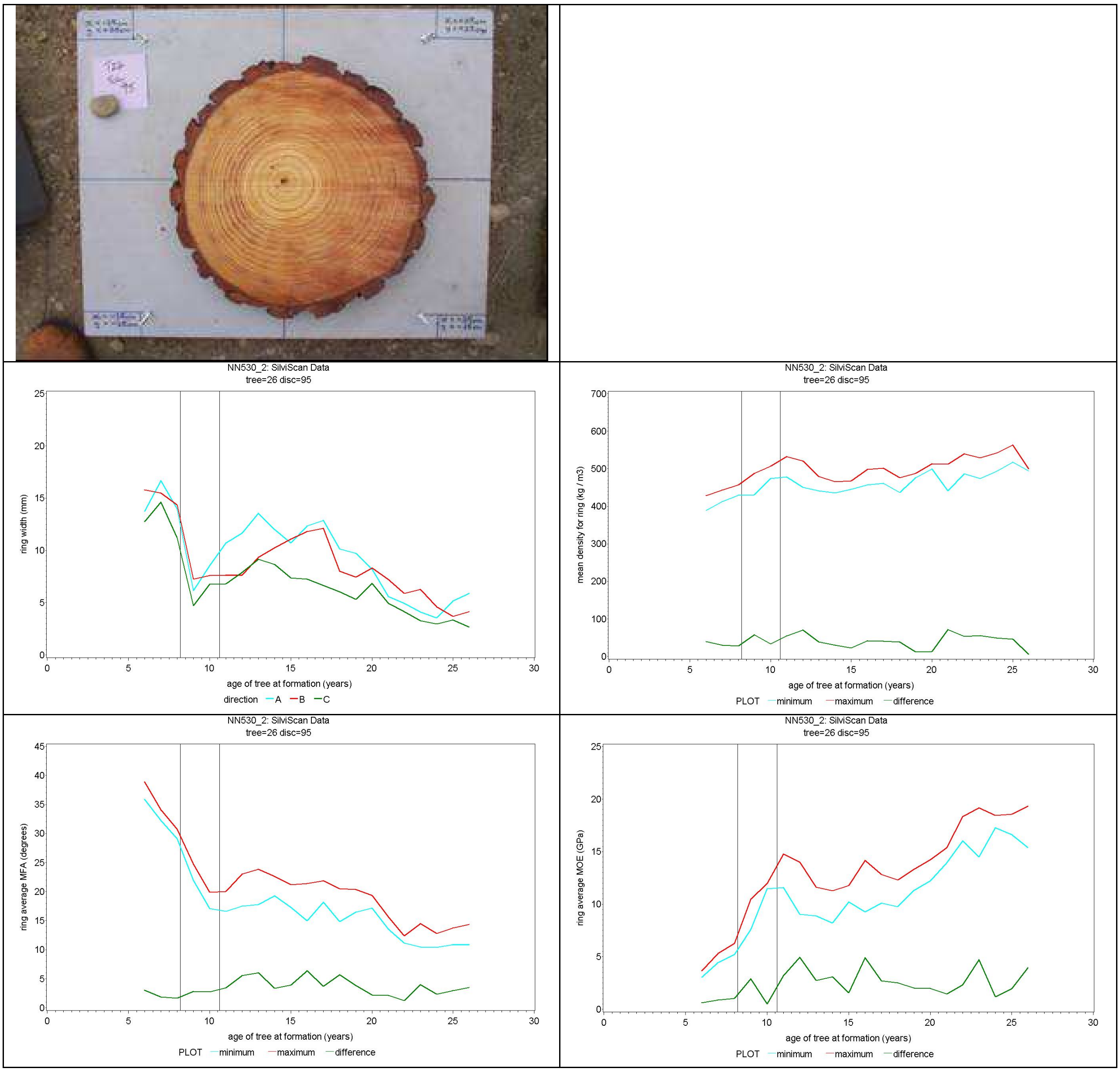


Figure 9. Breast height disc, ring width and wood properties from SilviScan for tree 26.



Within ring variation in density after thinning

When stands are thinned, there is the opportunity for more individual tree movement (flexure). Tree flexure influences the characteristics of the wood cells laid down (see SGMC Report No. 114 for further details).

The density profile for the SilviScan strips from the discs closest to breast height were visually examined to determine whether the type of wood laid down varied after the second thinning. This can be seen by examining the within ring profile of density for the ring laid down at "newage=11" (see Figures 10 and 11)..

Two possible scenarios that could occur are:

- The ring width is increased but the wood cells formed are more like compression wood, due to increased stem flexure. This is likely to result in an increase in ring average density (see Figure 10 for an example).

- The ring width is increased, more early wood is formed but the early wood density cells remains similar. This is likely to result in a reduced ring average density (see Figure 11 for an example).

Figure 10. SilviScan density profile for a strip where the cell density has increased after thinning (compare profile for newage= 11, with earlier ages).

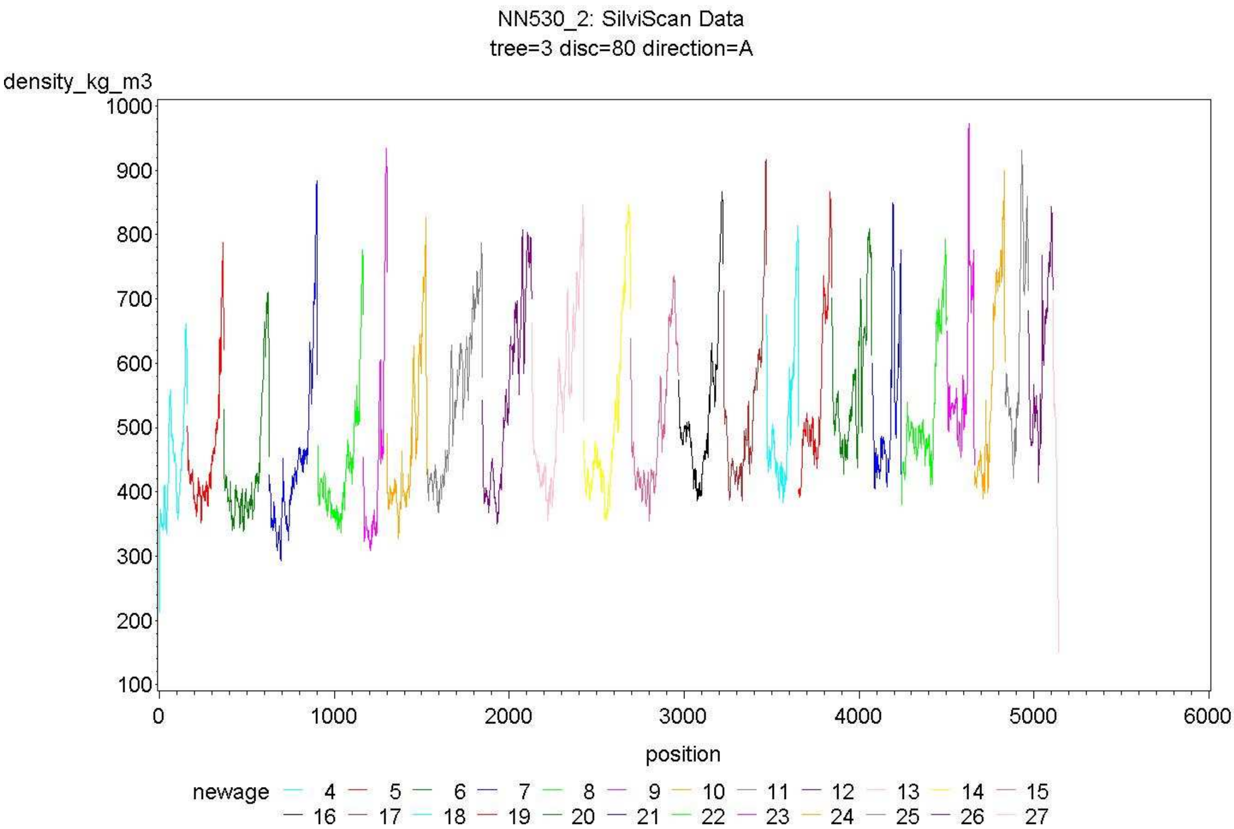
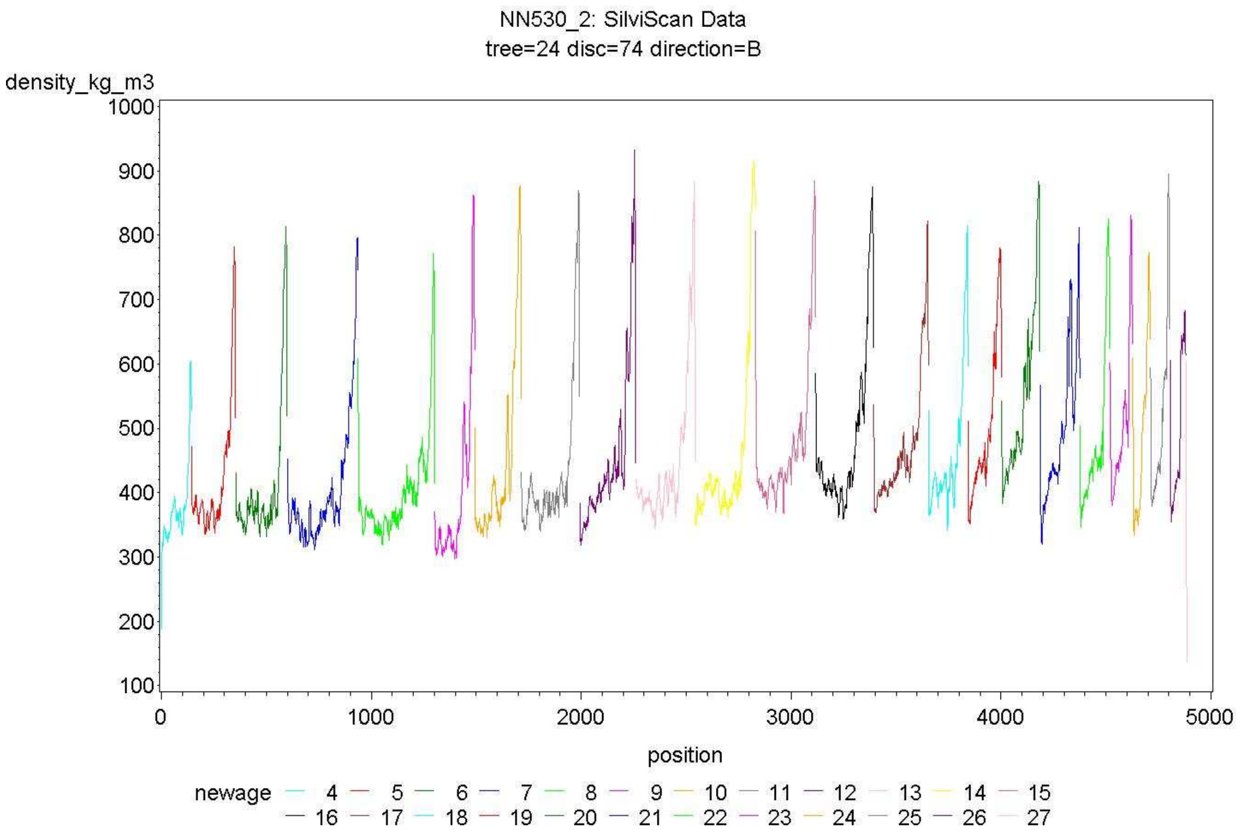


Figure 11. SilviScan density profile for a strip where the cell density remains similar after thinning (compare profile for newage= 11, with earlier ages).



DISC IMAGES

Images were taken of selected discs to gain an understanding of compression wood was distributed throughout a tree and in particular, whether branches had an influence on compression wood distribution. Discs, 5 cm thick, with their top at mid-internode, were cut from the internodes closest to 2.5 m, 4.5 m, 6.5 m … to top of tree.

There were 110 disc images that were examined visually for signs of compression wood in a block (assumed to be associated with correction for stem lean) and for blocks of compression wood around the disc (assumed to be associated with branching pattern).

There were only two discs where it was considered there were blocks of compression wood around the stem (Figure 12). The compression wood was far less obvious than in FR172/3. Plausible reasons for this result are that:

- The stocking is higher (approx. 300 sph) compared to FR172/3 (approx. 100 sph) resulting in a smaller branch diameters and less stem movement.
- The disc images were taken at mid-internode, and there is less compression wood here compared to immediately below the cluster.

This study should be repeated in a trial with a range of different thinning intensities, and disc images taken immediately below each branch cluster, so that the pattern of variation within a tree is captured.

Figure 12. Images of discs where there was considered to be blocks of compression wood around the stem.

There were many disc images with compression wood that was considered to be associated with stem form. This was particularly so for trees 3, 9 and 25. Both trees 3 and 25 were noted as leaning uphill (see Table 1).

DISCUSSION

The primary objective of this study was to obtain a dataset to be used in the development of an intergrated stem growth, branch and wood property model (see SGMC Report No. 132).

For the 8 sample trees the following data were collected:

- stem shape using PhotoMARVL
- the amount of foliage on selected sample branches
- the position of branch clusters and branch diameters
- disc images showing the location of compression wood
- quantitative wood properties using SilviScan.

In this study, the sample trees were selected on the basis of both tree DBH and outerwood density cores. For this detailed study, where the objective was to begin to understand within tree patterns of wood properties, there were no added advantages to selection based on outerwood density. There was variability in the relationship between strip average unweighted density and outerwood density (Figure 2), and in the relationship between strip average unweighted density and tree DBH (Figure 3).

The branching data is available for use in future revisions of TreeBLOSSIM. The data on the number of branch clusters in an annual shoot were compared with previously collected data from another experiment in Golden Downs (NN529/1), a site with slightly cooler climate. There were slightly more branch clusters in an annual shoot in NN530/2 compared to NN529/1. This was consistent with results from a larger study examining the relationship between number of branch clusters in an annual shoot and environmental variables (SGMC Report No. 145).

From the SilviScan data, it appeared that the first thinning had little impact on wood properties as the stem was actively growing, but that the second thinning had a larger impact on ring width, and microfibril angle, with increases in both variables after the thinning. The variation in wood properties at a particular point in the stem after a thinning will be influenced by the tree age at that point.

Examining the individual density profiles indicated that the type of wood cells laid down after thinning varied between strips, and this could lead to an increase or decrease in ring average density.

Images of discs from mid-internode indicated that there was little compression wood that could be associated with branching, rather than stem form. Possible reasons for this results are the higher final crop stocking compared to FR172/3 where there was noticeable compression wood.

This study should be repeated in the 1975 final crop stocking trials to determine whether the observed trends in wood properties vary with the severity of thinning treatment.

ACKNOWLEDGMENTS

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Thanks to Ensis staff who helped with the data collection: Carolyn Andersen, Rod Brownlie, Jeremy Cox, Geoff Downes, Dave Henley, Trevor Jones, and Pat Hodgkiss.

APPENDIX 1. Layout of NN530/2