# Crown and Wood Properties:
## WN377, Mohaka Forest

J.C. Grace

***Report No. 147*** ***September 2007***

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NOTE : Confidential to participants of the Stand Growth Modelling Cooperative.
: This is an unpublished report and must not be cited as a literature reference.

# EXECUTIVE SUMMARY

At the July 2006 Stand Growth Modelling Cooperative meeting, approval was given collect data from the 1978 Genetic Gain Trial at Mohaka (WN377) with the objectives:

- To collect data to improve the branching functions within TreeBLOSSIM.
- To collect wood samples for the determination of the within-stem variation in wood properties using SilviScan.
- To collect images of stem discs to extend our knowledge of within-stem variability of wood properties.

Six sample trees were selected to cover the range of DBH present in all GF14 plots within WN377. The position of each branch clusters and the number of stem growth rings below the cluster were recorded for all six sample trees in WN377 with the objective of examining how the number of branch clusters in an annual shoot varied with tree age and annual shoot length for another site within the Hawkes Bay growth modelling region. Images were taken of discs cut immediately below branch clusters to determine whether there were patterns of compression wood that might be associated with branch size. Also SilviScan data were obtained for three directions from selected mid-internode discs.

The number of branch clusters in an annual shoot was slightly higher at Mohaka compared to previously collected data from Esk. This may be due to the slightly higher site index at Mohaka.  An equation to predict the number of branch clusters in an annual shoot was developed using the same form of equation as included in TreeBLOSSIM. The shape of this function was similar to that developed using the Esk data, and provides confidence in the Esk function which was developed using a very small dataset.

The discs from which the SilviScan samples were taken were generally eccentric and/or contained compression wood, and in some instances there were a large within-ring variation in density.

The response of wood properties to silvicultural treatment could be examined using the SilviScan data from discs at breast height. There was little response to the first thinning carried out at a mean crop height at 6.2 m, but more response to the second thinning carried out at a mean crop height of 12 m. It is suggested that the trees were still actively growing at breast height at the time of the first thinning but that competition was affecting growth at breast height at the time of the second thinning.

These data will contribute to the datasets available for developing integrated tree, crown and wood property models. To be able to develop robust empirical models requires datasets that cover all likely combinations of site quality, silvicultural treatment and seedlots.

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## INTRODUCTION

Traditionally tree growth research has been carried out in isolation to tree wood property (quality) research. Consequently there is a lot of descriptive knowledge for radiata pine on both stem diameter and height growth patterns, and on the variation in wood properties with position in the stem. However the fundamental knowledge to develop integrated models, that predict wood formation and wood properties as a function of tree growth, is lacking.

The Internal Stem Modelling Theme within the Stand Growth Modelling Cooperative was initiated to fill this gap and had the objective:

> 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.

At the July 2006 Stand Growth Modelling Cooperative meeting, approval was given collect data from the 1978 Genetic Gain Trial at Mohaka (WN377) with the objectives:

- To collect data to improve the branching functions within TreeBLOSSIM.
- To collect wood samples for the determination of the within-stem variation in wood properties using SilviScan.
- To collect images of stem discs to extend our knowledge of within-stem variability of wood properties.

WN377 at Mohaka is one of six 1978 Genetic Gain Trials managed by the Stand Growth Modelling Cooperative. Six sample trees were selected (Table 1) to cover the range of DBH present in all GF14 plots within WN377. The logic behind this selection is discussed in Appendix 1. The field data were collected in February 2007.

**Table 1. Sample trees from WN377.**

| Tree Number assigned (Treeid) | Plot Number assigned (Plotid) | PSP Plot Number | PSP Tree Number |
|---|---|---|---|
| 1 | 4 | 4/51 | 25 |
| 2 | 10 | 10/21 | 2 |
| 3 | 4 | 4/51 | 7 |
| 4 | 8 | 8/31 | 24 |
| 5 | 8 | 8/31 | 4 |
| 6 | 12 | 12/11 | 18 |

This study complements a previous study the 1978 Genetic Gain Trial at Golden Downs (NN530/2), where, in December 2004, detailed crown and wood property data were collected concurrently for eight GF14 trees.

## PART 1. BRANCHING CHARACTERISTICS

### Number of Branch Clusters within an Annual Shoot

Background

One of the functions within TreeBLOSSIM predicts the number of branch clusters in an annual shoot. There is a separate function for each growth modelling region (Figure 1, or see SGMC Report No. 125 for further details) with the following form:

$$C_s = 1.0 + C_{\max}(\exp(-\exp(b - c \times L_{as})) \times (1 - \exp(-Age_{tree} \times d)) \qquad (1)$$

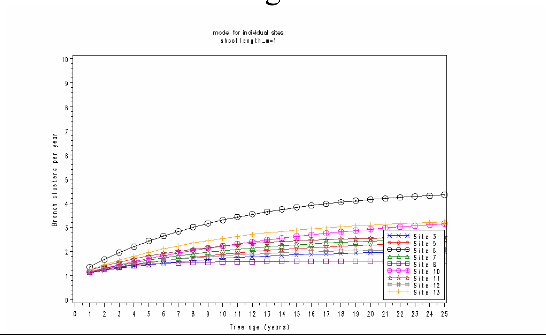
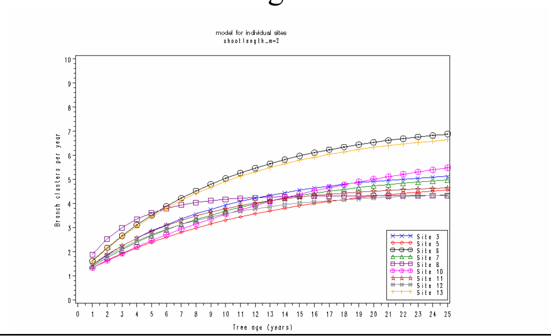
where:

$C_s$ is the number of branch clusters in the annual shoot
$C_{\max}$ is the maximum number of branch clusters in the annual shoot
$L_{as}$ is the length of the annual shoot
$Age_{tree}$ is the age of the tree in years
*b, c, d* are model parameters.

The equation was fitted to the observed data with $C_{\max}$ set at the observed maximum.

For a predicted shoot length of 1 m the shape of the function for Hawkes Bay (site 8) is comparable with other sites, however, the shape of the function is rather different for a predicted annual shoot length of 2 m. An important question is whether this shape is generally realistic or an artefact of the data used to derive the function. It was derived from data from 3 trees in Esk forest (see SGMC Report No. 87), but due to stem damage, the trees were only measured to the height of damage (between 20 m and 23.5 m).

**Figure 1. Predicted number of branch clusters in an annual shoot (from SGMC Report No. 125)**

| 1m annual shoot length | 2m annual shoot length |
|---|---|
|  |  |

Note: Esk is Site 8.

Methods

The position of each branch clusters and the number of stem growth rings below the cluster were recorded for all six sample trees in WN377 with the objective of examining how the number of branch clusters in an annual shoot varied with tree age and annual shoot length for another site within the Hawkes Bay growth modelling region.

Data Analysis

Data were available for 113 annual shoots (Figure 2). Incomplete annual shoots and annual shoots where a leader change was noted were excluded. While the two sites fall into the same level 2 Lenz environment, the site index is slightly higher at Mohaka. The mean number and maximum number of branch clusters in an annual shoot (Table 2) were both higher at Mohaka compared to Esk (4.1 versus 3.9 for mean number of clusters in an annual shoot and 8 versus 6 for the maximum number of clusters in an annual shoot).

To investigate whether branching patterns are different in the Hawkes Bay Region, compared to other regions, Equation 1 was fitted to the data from Mohaka (site 17), in the same manner as reported in SGMC Report 125. While the number of branch clusters in an annual shoot is higher than at Esk (site 8) due to the higher observed maximum, it is interesting to note that the fitted curve for Mohaka (site 17) tends to plateau earlier than other sites in a similar manner to curve for Esk (site 8). This suggests there may be regional differences in the branching patterns of radiata pine (Figure 3).

Alternative approaches to predicting the number of branch clusters in an annual shoot are discussed in SGMC Report No. 145.

**Figure 2. Number of branch clusters in an annual shoot**

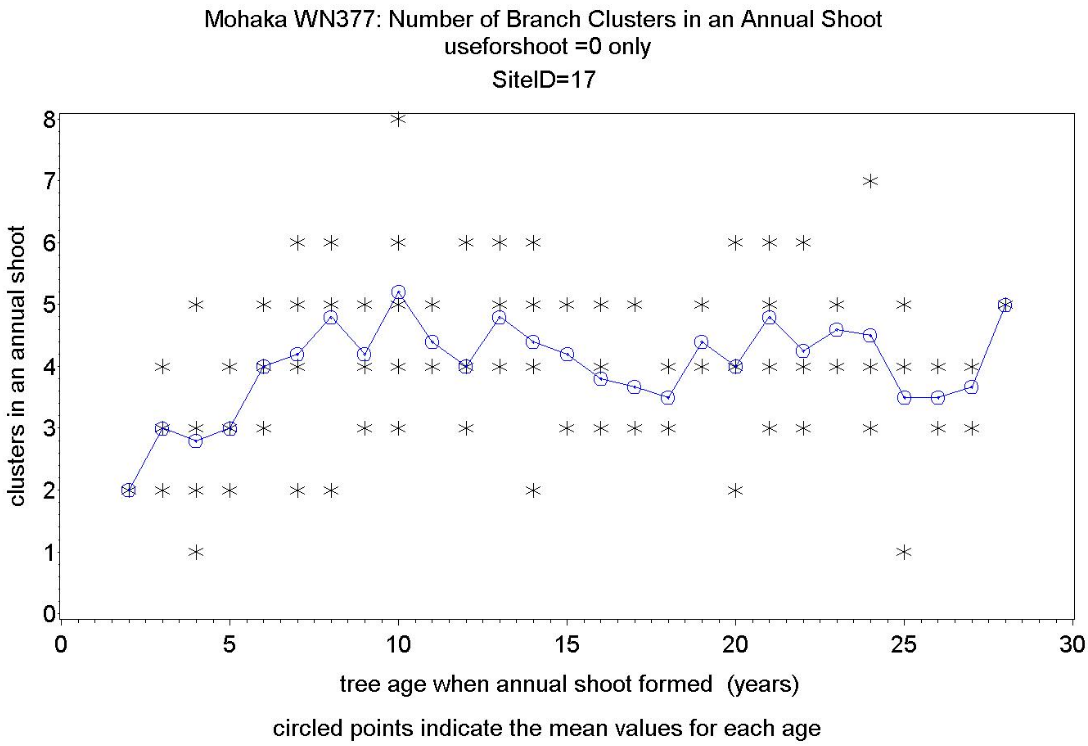
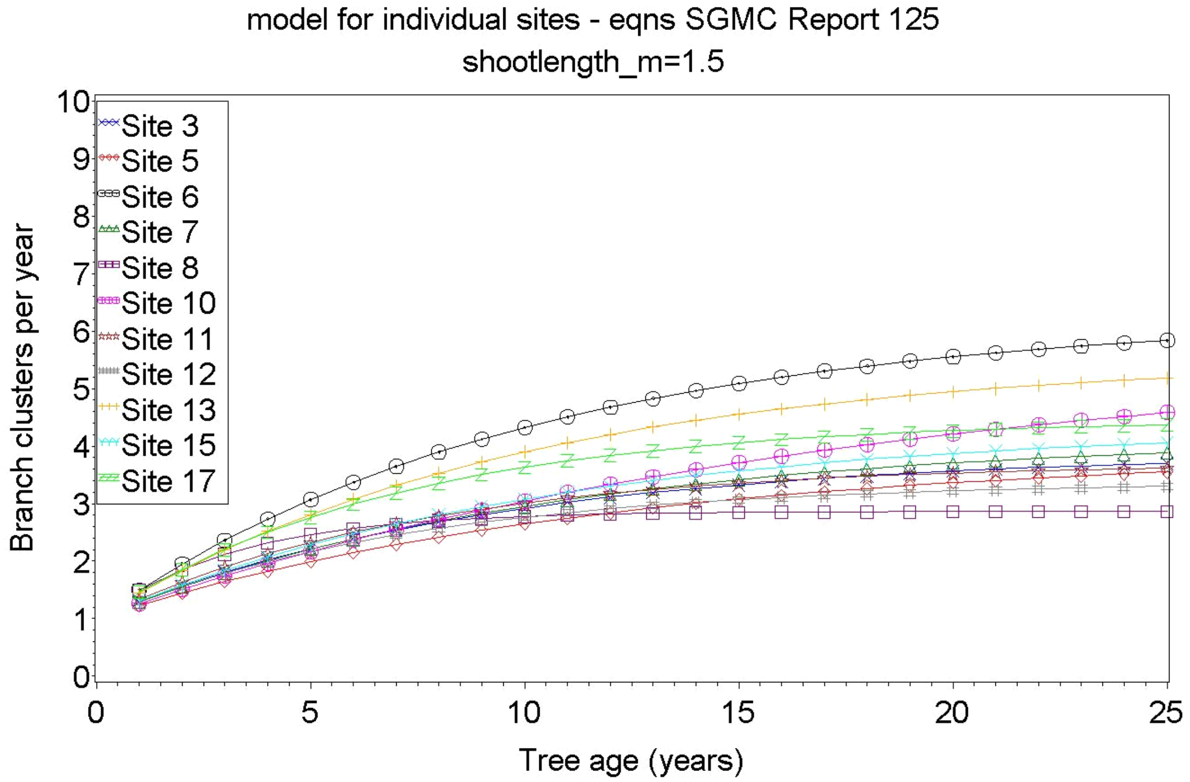


**Table 2. Branch clusters in an annual shoot – Hawkes Bay**

| | Mohaka WN377 | Esk WN235/0 31/0 |
|---|---|---|
| Lenz Environment | D3 | D3 |
| Lenz – mean annual temperature (°C) | 12.8 | 12.8 |
| Site Index | 36.5 | 31.8 |
| Number of trees | 6 | 3 |
| Number of complete annual shoots | 113 | 21 |
| Mean number of clusters in an annual shoot | 4.1 | 3.9 |
| Minimum number of clusters in an annual shoot | 1 | 1 |
| Maximum number of clusters in an annual shoot | 8 | 6 |
| Mean + 2*standard deviation | 6.6 | 6.9 |

**Figure 3. Predicted the number of branch clusters in an annual shoot for different sites using Equation 1.**




Note: Site 8 is Esk, Site 17 is Mohaka

## Long Internodes

Background

Long internodes seedlots may be used to provide clearwood for the forest industry. This analysis attempts to identify whether long internodes observed occur as part of the regular branching pattern, or whether they result from the stem being damaged and a branch taking over as the leader.

Data Analysis

Branching characteristics recorded for the six sample trees from WN 377 varied (Table 3).

**Table 3. Branching data collected for sample trees in Mohaka, WN377.**

| Tree | Cluster position recorded | Branch diameters recorded for clusters | Stem visually examined, and possible leader changed noted |
|---|---|---|---|
| 1 | ✓ | ✓ | ✓ |
| 2 | ✓ | | ✓ |
| 3 | ✓ | ✓ | ✓ |
| 4 | ✓ | ✓ | ✓ |
| 5 | ✓ | | |
| 6 | ✓ | ✓ | ✓ |

The length of each internode was calculated. The data set contained 610 internodes (Figure 4). For each tree over 50% of the internodes were less than or equal to 30 cm. There were 38 internodes over 60 cm, of which 9 longer than 90 cm. The distribution of internode lengths with respect to tree age when the internode was formed (Figure 5) indicates that the longer internodes tended to be formed between 4 and 6 years.

Three of the internodes over 90 cm were in Tree 5 (no notes on stem features were recorded for this tree). Comments on the other 6 internodes over 90 cm are listed in Table 4. Four of these internodes were above the pruned zone and are considered to be related to visible stem damage. From examining the disc images taken below these clusters, the other two internodes (in the pruned zone) show signs related to leader changes – eccentric growth and compression wood.

The fact that these long internodes are formed as a consequence of stem damage may have important consequences for the wood property distributions within these internodes and this requires further investigation.

Additional leader changes were noted in the data set. These are listed in Table 5. The observed lengths of internodes above these leader changes were quite variable, with some being less than 30 cm and some being over 60 cm.

A possible hypothesis for long internodes in the vicinity of stem damage is as follows:

*When the stem loses its leader, Branches it the uppermost cluster remaining compete to become the new leader. This leads to steeply angled branches, and one (or more) takes over as the new leader. As part of SGMC studies we have not measured the position of clusters along branches attached to the main stem, but we have observed some long internodes on such branches. It is possible that this is a reason for long internodes in the vicinity of leader damage. In addition, compression wood is formed as the branch straightens to become the new leader, so such long internodes may contain compression wood.*

It is suggested that an experiment be designed to monitor tree response to leader changes, and determine how/where long internodes and compression wood are formed.

**Figure 4. Distribution of internode lengths within sample trees at Mohaka, WN377.**

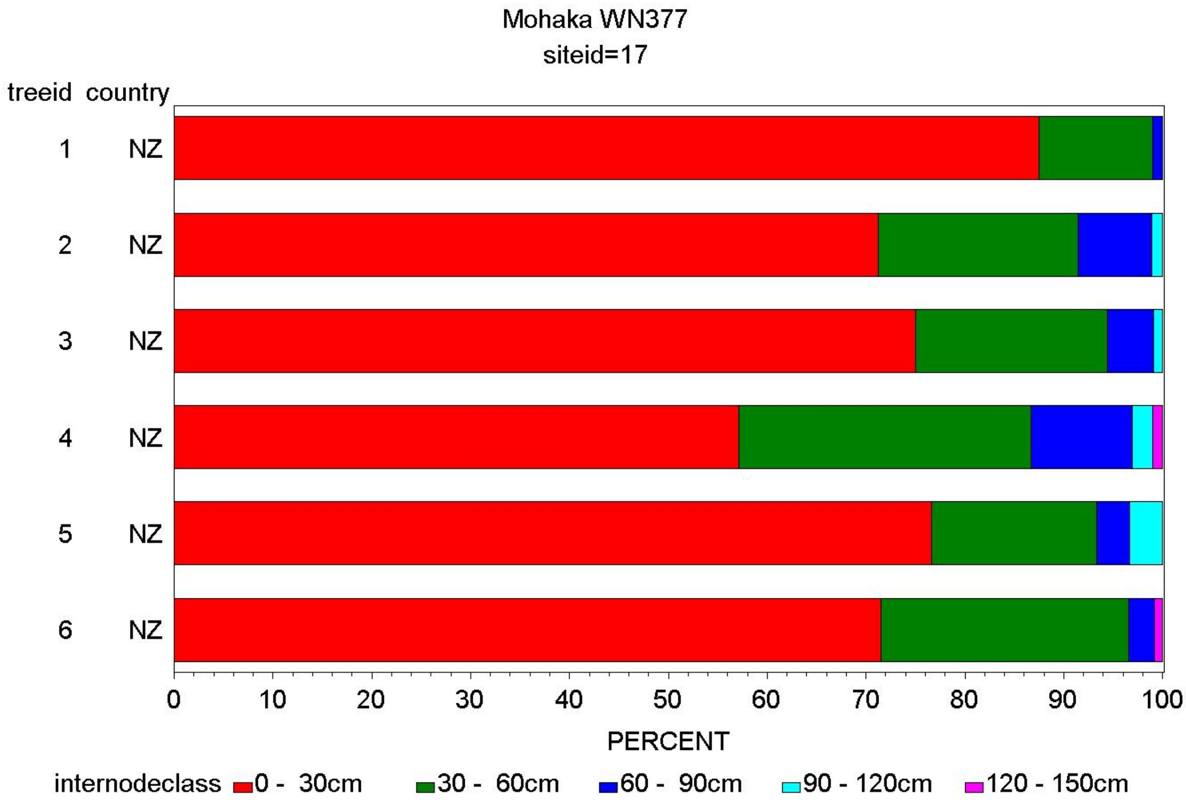


**Figure 5. Distribution of internode lengths with respect to tree age when the internode elongated.**

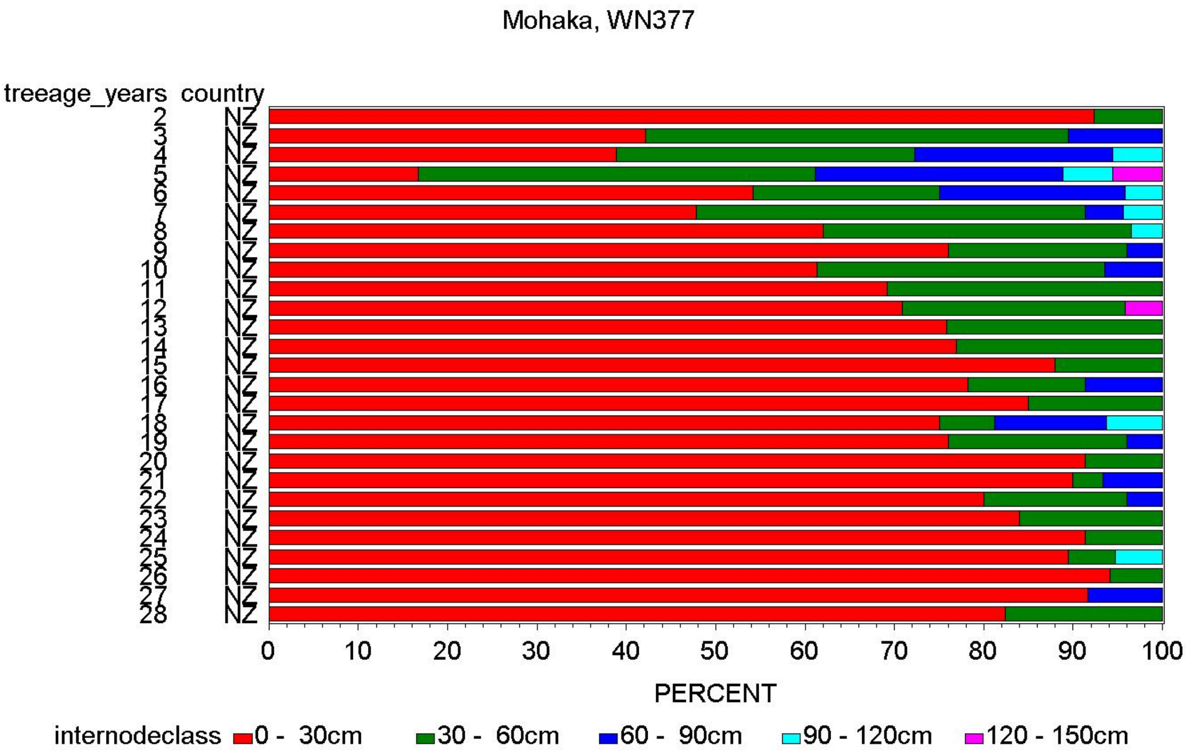



**Table 4. Comments on internodes longer than 90 cm**

| Tree | Clusterid | Length of internode below cluster | Comments on any leader changes noted in vicinity |
|---|---|---|---|
| 2 | 32 | 100 | Leader change noted at cluster 33, i.e. long internode immediately above damage (No disc images for this tree) |
| 3 | 97 | 105 | In pruned section – No obvious compression wood in disc, but eccentric growth |
| 4 | 84 | 98 | Steep branches noted in cluster 85 (a sign of damage). Disc image shows eccentric growth and some signs of compression wood. |
| 4 | 63 | 137 | Leader change occurred, probably in cluster 65. Disc image shows eccentric growth and some signs of compression wood |
| 4 | 15 | 105 | Leader change noted in cluster 16<br>Disc small, difficult to say whether there was any compression wood |
| 6 | 107 | 130 | In pruned section – stem disc contains a patch of compression wood as if tree had to correct for stem lean |

**Table 5. Comments internode length in vicinity of other leader changes**

| Tree | Clusterid | Comment | Internode |
|---|---|---|---|
| 1 | 6 | Leader change in cluster | Internode below cluster 4 was 29 cm |
| 1 | 19 | Leader change in cluster | Internode below cluster 17 was 25 cm |
| 1 | 36 | Leader change in cluster | Internode below cluster 35 was 11 cm |
| 2 | 2 | Multiple leaders from this cluster | Internode below cluster 1 was 66 cm |
| 2 | 22/23 | Possible leader change | Internode below cluster 21 was 83 cm |
| 3 | 47 | Steep branches in cluster | Internode below cluster 45 was 84 cm, and internode below cluster43 was 61 cm |
| 6 | 9 | Multiple leaders from this cluster | Internode in cluster 8 was 49 cm |
| 6 | 52 | Leader change around this cluster | Internode was 50 cm below cluster 51 and 57 cm below cluster 49 (no cluster 50) |

## PART 2. WOOD PROPERTY DATA FROM SILVISCAN

### Methods

Sample discs, five centimetres wide, with the top surface at mid- internode, were cut from the following 6 positions from trees 1, 3, 4 and 6:

- One quarter way down live crown (below both 1st quarter sample branches)
- Half way down live crown (below both 2nd quarter sample branch samples)
- Three quarters way down live crown (below both 3rd quarter sample branch samples)
- Base of live crown
- Halfway between DBH and base of live crown
- DBH (approx. 1.4 m)

Three strips were cut from each disc for analysis of density and microfibril angle using SilviScan. These data were then used to provide an estimate of modulus of elasticity. The first two strips were at 180° to each other with one passing through any obvious compression wood. The third strip was at 90° to the other two strips. This sampling strategy was comparable to that in NN530/2.

The number of the nearest branch cluster above each of these discs is shown in Table 6.

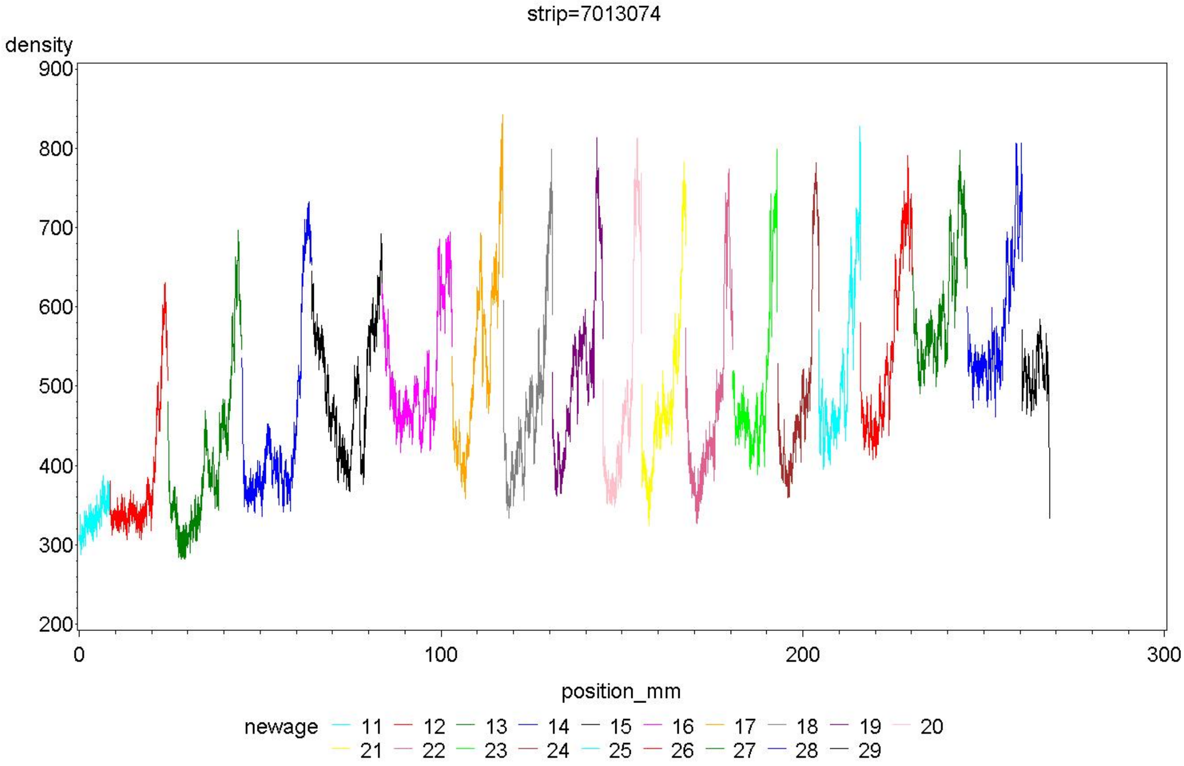
**Table 6. Number of branch cluster above each of the discs saved for SilviScan analysis.**

| Disc Position / Cluster No. | Tree 1 | Tree 3 | Tree 4 | Tree 6 |
|---|---|---|---|---|
| Mid internode nearest DBH | 100 | 103 | 96 | 112 |
| Mid way between DBH and crown base | 76 | 83 | 81 | 95 |
| Base crown | 52 | 65 | 65 | 78 |
| ¾ way down crown | 34 | 45 | 53 | 57 |
| ½ way down crown | 25 | 30 | 38 | 39 |
| ¼ way down crown | 13 | 17 | 22 | 18 |

### Results

SilviScan provides values of density at 0.025 mm resolution, and values of microfibril angle and modulus of elasticity at 5 mm resolution along a sample (see Figure 6 for an example of density data). The position of ring boundaries were linked to these data and ring average values of density, microfibril angle and modulus of elasticity were calculated. These data may be examined in a variety of ways.

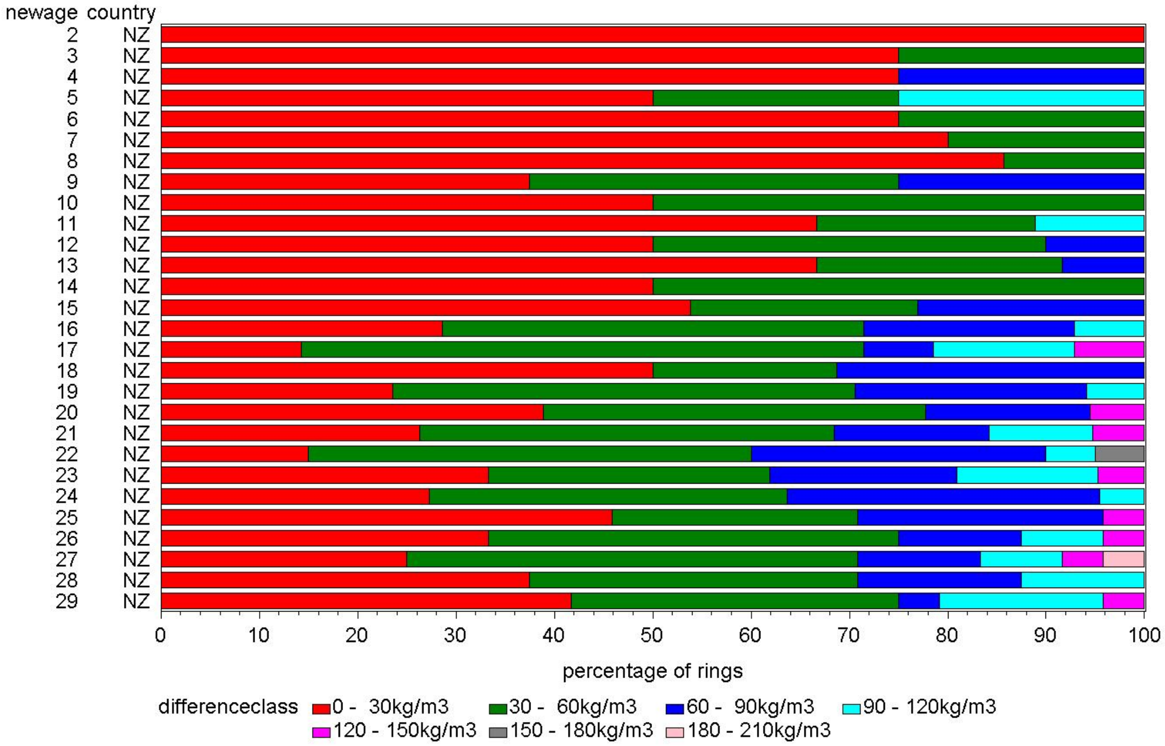
**Figure 6. Example of SilviScan density measurements.**




Note: Density is in kg/ $m^3$. Newage is the tree age when the ring was formed in years.

For each growth ring within each disc, the range in density between the different samples was calculated and grouped into classes. The within-ring variation in density tended to increase with increasing tree age (Figure 7).

**Figure 7. Within ring variation in density with respect to the tree age in years when the ring was formed (newage).**




The within-ring variation in density varied between rings within a disc from a given tree (Figure 8). Most of the discs were eccentric and/ or showed signs of compression wood. There were only 2 discs where the "differenceclass" was always 0-30 kg/$m^3$. These were discs from near the top of the tree. There were two rings where the variation in density was over 150kg/$m^3$. These were:

- Tree 1, disc 34 (see Figure 9): This was obviously an eccentric disc, and was situated just above the leader change that occurred in cluster 36 (see above). The most likely cause of the compression wood formation is to correct the angle of a branch as it became the new leader.
- Tree 6, disc 78 (see Figure 9): This was another eccentric disc. No signs of stem damage were noted in this vicinity.

Disc 65, from tree 4 (see Figure 9) was another disc where the density was quite variable. This disc was in the vicinity of some stem damage with obvious patches of compression wood.

Disc 18 from tree 6 (see Figure 9) appeared reasonably uniform in colour, yet the density was variable.

Consequently it is not a good idea to reduce the number of strips sampled from a disc based on the uniformity of the disc colour.

**Figure 8. Within ring variation in density with respect to disc within tree.**

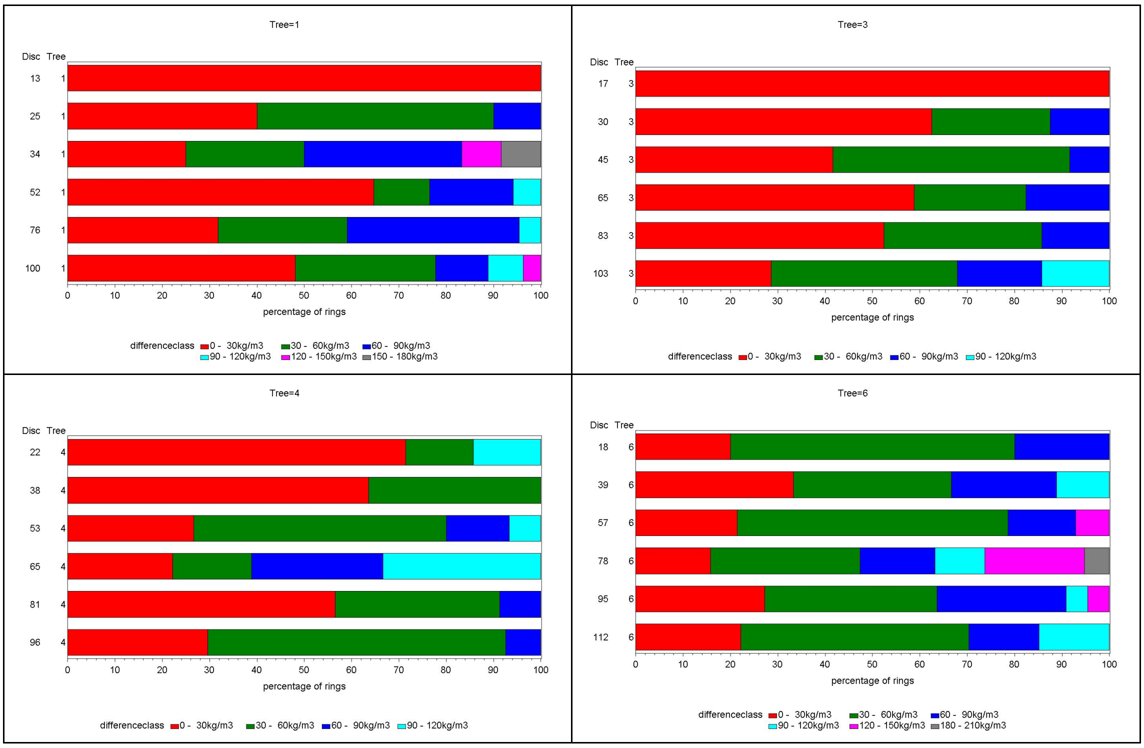
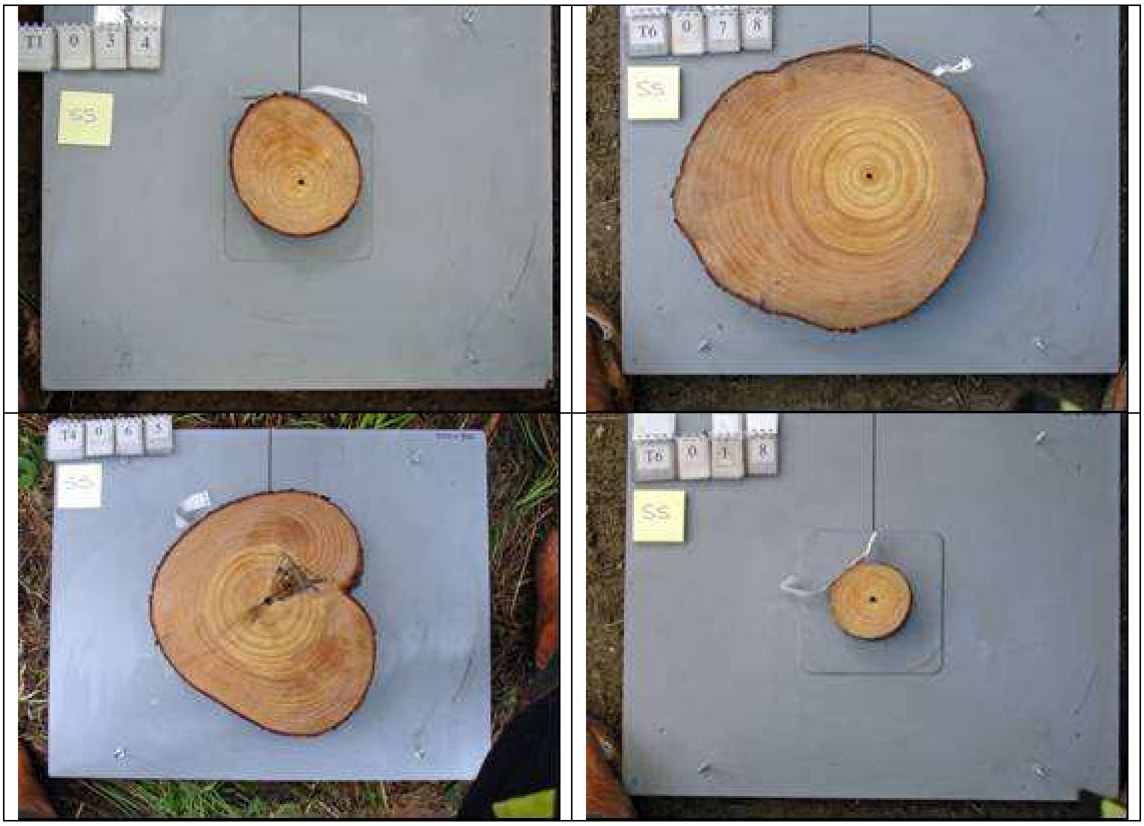



**Figure 9. Images of discs with high variation in density within a growth ring.**



All discs, apart from the breast height discs were too high in the trees to be able to examine whether there where any changes in ring width and wood properties as a result of the two thinnings. The SilviScan data from the breast height discs were therefore examined in more detail (Figure 10, 11, 12 and 13). Each figure contains 6 images/graphs laid out as follows:

| | |
|---|---|
| Image of disc | Image of strips sent to SilviScan |
| 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.

All four discs show similar patterns. In particular a response to the second thinning is visible. This is most obvious for ring width, with a large growth ring at age 10 years. There was also a noticeable increase in microfibril angle in this growth ring. Changes in density and modulus of elasticity were slight. The following points may be noted from examining these figures:

- At the time of the first thinning, the ring widths were large indicating the trees were growing quite rapidly at this point, and there is only a slight change in ring width after the thinning. Any change in wood properties at this height is minor compared to the overall pith to bark trend.
- The ring width dropped between the first and second thinning, and there was a noticeable response in ring width after the second thinning.
- There was a noticeable increase in microfibril angle after the second thinning.
- There was little change in density after the second thinning.
- Modulus of elasticity (which is estimated from density and microfibril angle) decreases slightly after the second thinning.
- The maximum microfibril angle increased slightly at age 19 for tree1, noticeably for tree 3 at age 18, and noticeably at age 20 for tree 4. The following events were recorded in the PSP system - some wind damage in 1995, snow damage July 1996 and wind damage 1997, resulting in observable stem defects. These results suggest that wind/ snow damage may influence the development of microfibril angle.
- There was little change in density as a consequence of these events.

For three of the four trees, the disc mid-way between DBH and crown height was formed just prior to the second thinning. The SilviScan data from these discs showed no obvious changes in wood properties as a result of the second thinning, presumably because the trees were actively growing at this point.

**Figure 10. Breast height disc, SilviScan samples and measured properties for tree 1.**

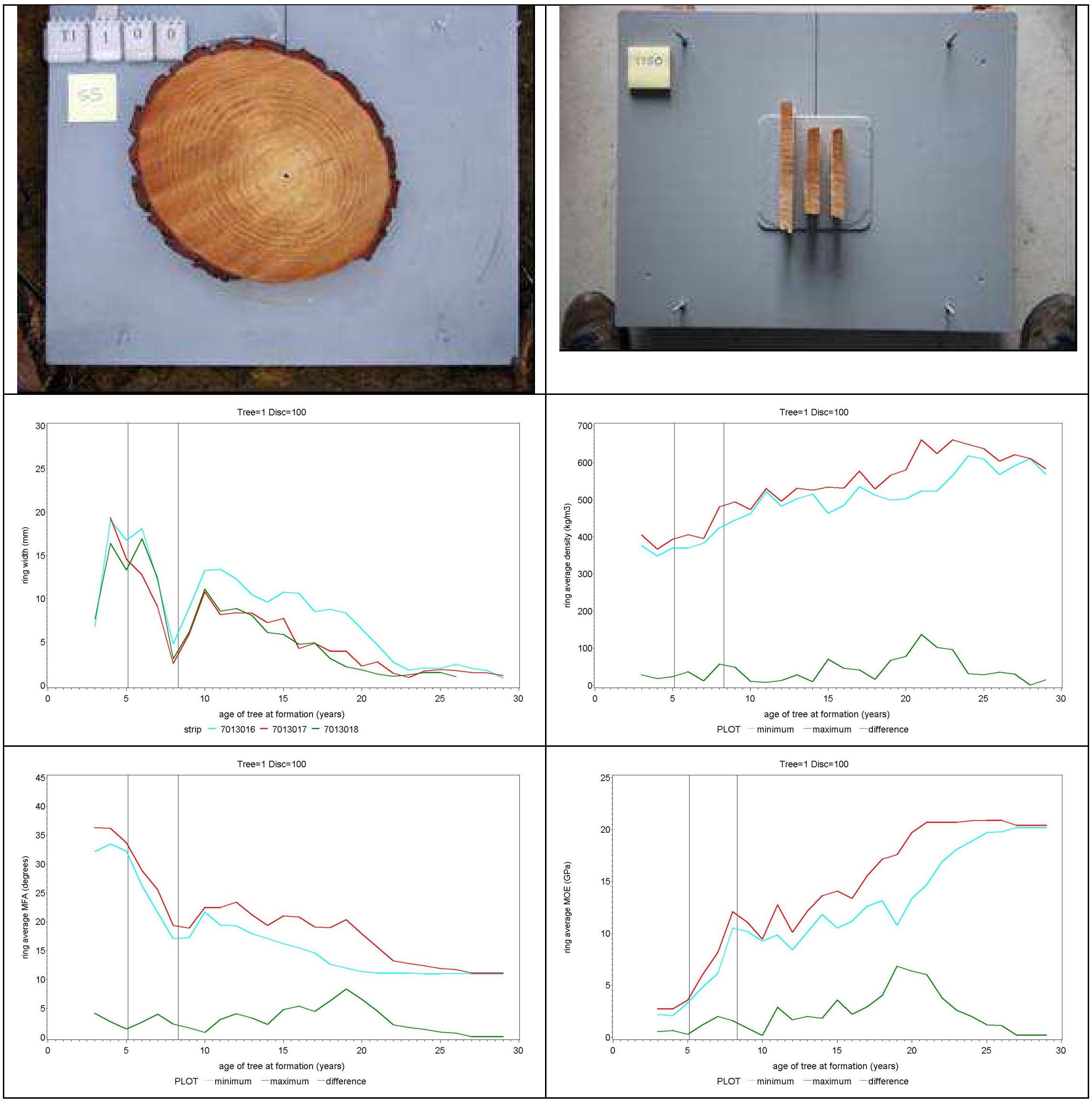


**Figure 11. Breast height disc, SilviScan samples and measured properties for tree 3.**

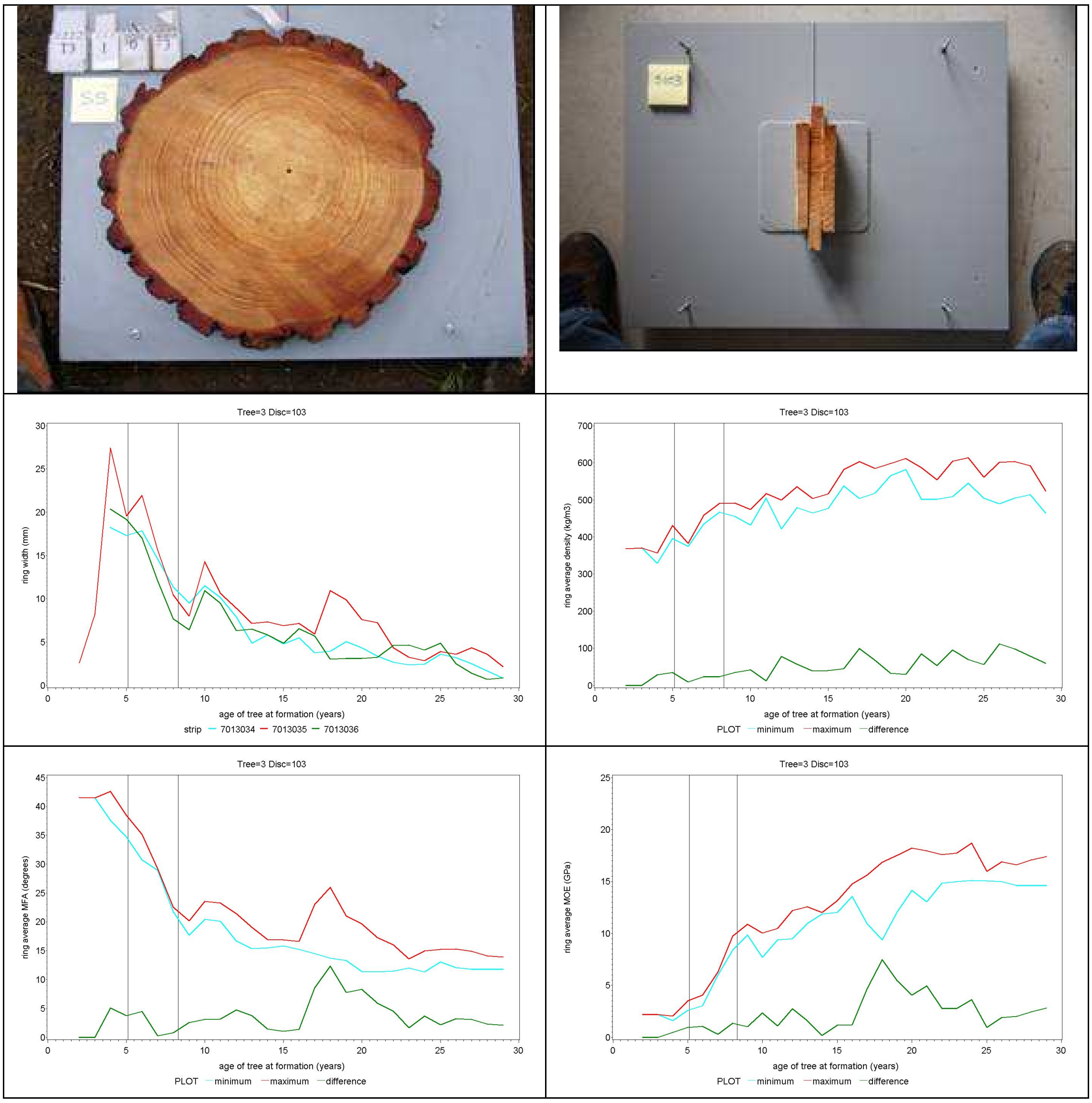


**Figure 12 Breast height disc, SilviScan samples and measured properties for tree 4.**

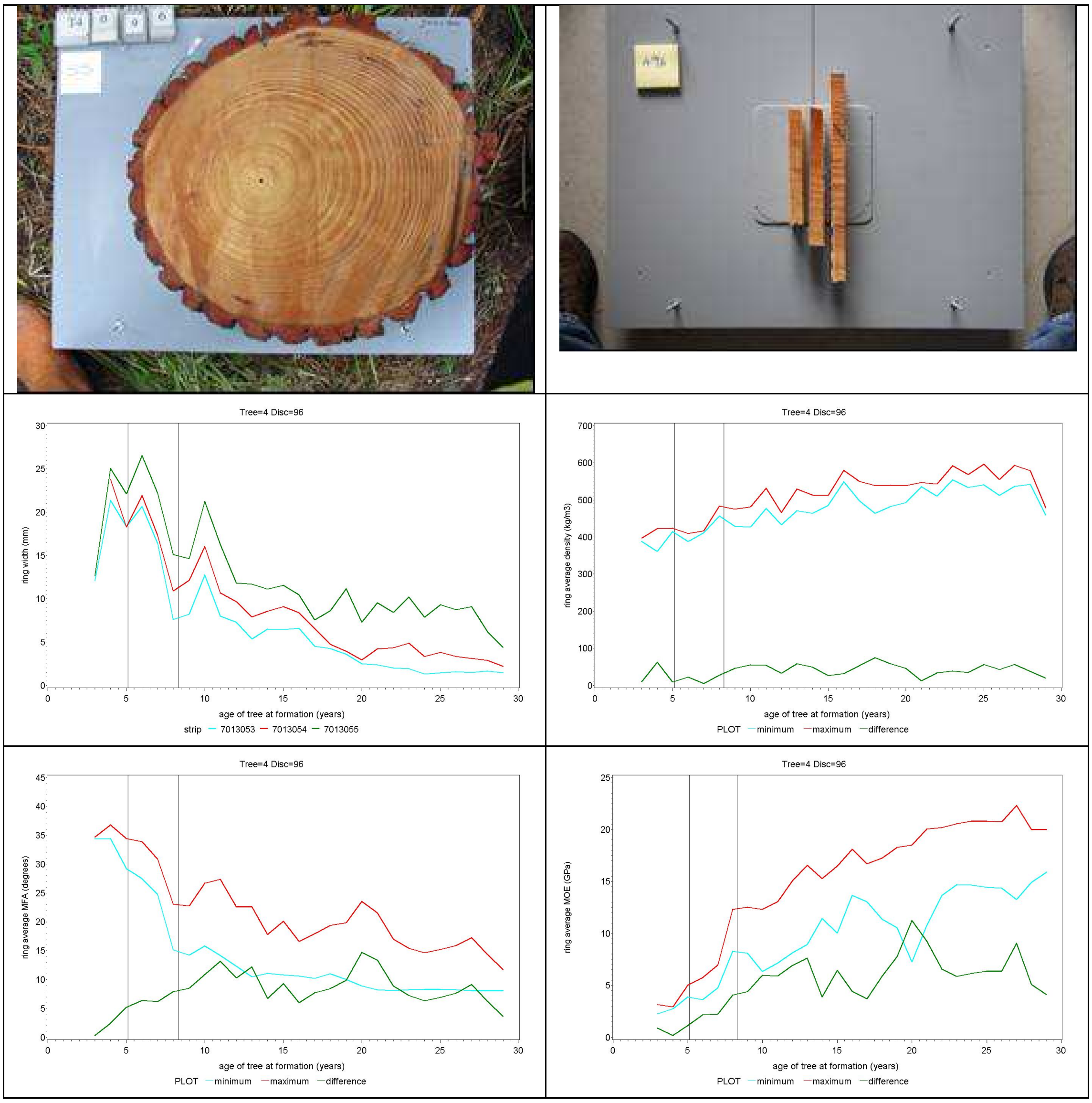
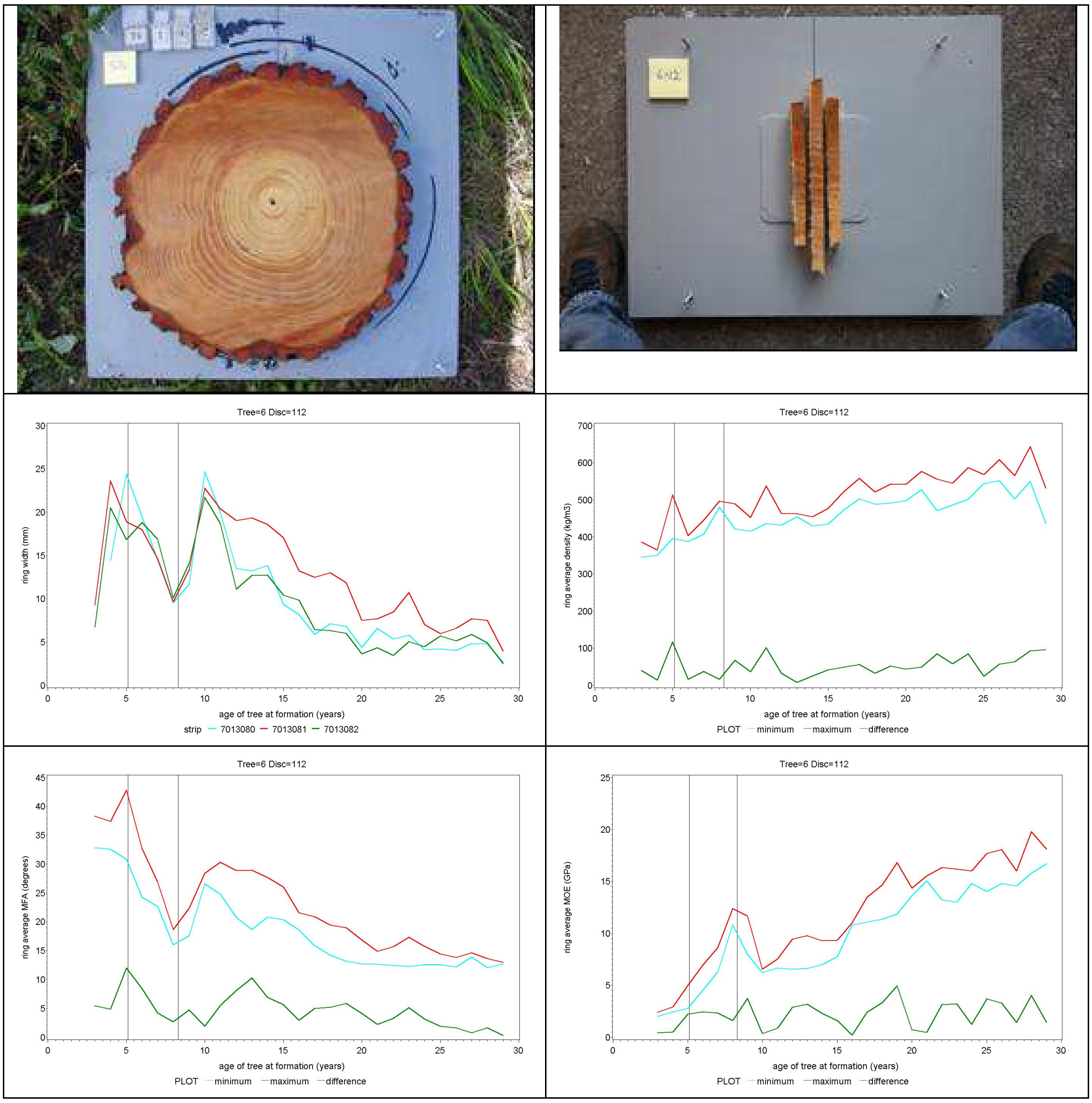


**Figure 13. Breast height disc, SilviScan samples and measured properties for tree 6.**



## PART 3. INFLUENCE OF BRANCHING ON WITHIN STEM VARIABILITY IN WOOD PROPERTIES

### Background

Compression wood is known to be formed in trees to correct for stem lean. Previous studies had raised the possibility that some of the compression wood in trees might be related to the position and size of branches. One objective of the data collection was to better understand the influence of branches on the within stem variability in wood properties.

### Methods

A 5 cm disc was cut immediately below each branch cluster and imaged. Each image was visually scored, by 3 people, for the presence of patches of compression wood around the stem, which might be related to branching pattern, rather than correction for stem lean. The scoring system was:

- 0 – no obvious compression wood related to branching
- 1 – possible compression wood related to branching
- 2 – obvious compression wood related to branching

The individual scores were then summarised as shown in Table 7.

### Results

Only 25 of the 396 discs showed obvious signs of compression wood that were considered to be related to branching i.e. a score of 2 (Table 7).

**Table 7. Disc scoring system for visual compression wood related to branching**

| Individual Scores | Overall Score | Number of Discs |
|---|---|---|
| 0, 0, 0 | 0 | 165 |
| 0, 0, 1 | 0 | 116 |
| 0, 1, 1 | 1 | 43 |
| 1, 1, 1 | 1 | 24 |
| 1, 1, 2 | 1 | 23 |
| 1, 2, 2 | 2 | 18 |
| 2, 2, 2 | 2 | 7 |

Examples of discs with a score of 2 are shown in Figure 14. Interestingly most of the pattern is in inner rings, at the time when the branches would have been growing most rapidly.

There were 20 additional discs (not included in Table 7), where one person’s score was 2 and another person’s score was 0. Most of these were discs containing compression wood, however the origin of the compression wood was debateable.

**Figure 14. Images of discs with an overall visual compression wood score of 2**


As the diameter of the largest branch in a cluster increased, then there was more likely to be patches of visible compression wood in the disc immediately below the cluster (Figure 15). The discs with a compression wood score of 1 or 2 tended to occur more frequently between ages 10 and 14 years (Figure 16). This is just after the second thinning, suggesting that spacing may also be implicated.

**Figure 15. Bar chart showing the relationship between the diameter of the largest branch in a cluster and the compression wood score for the disc cut immediately below the cluster.**

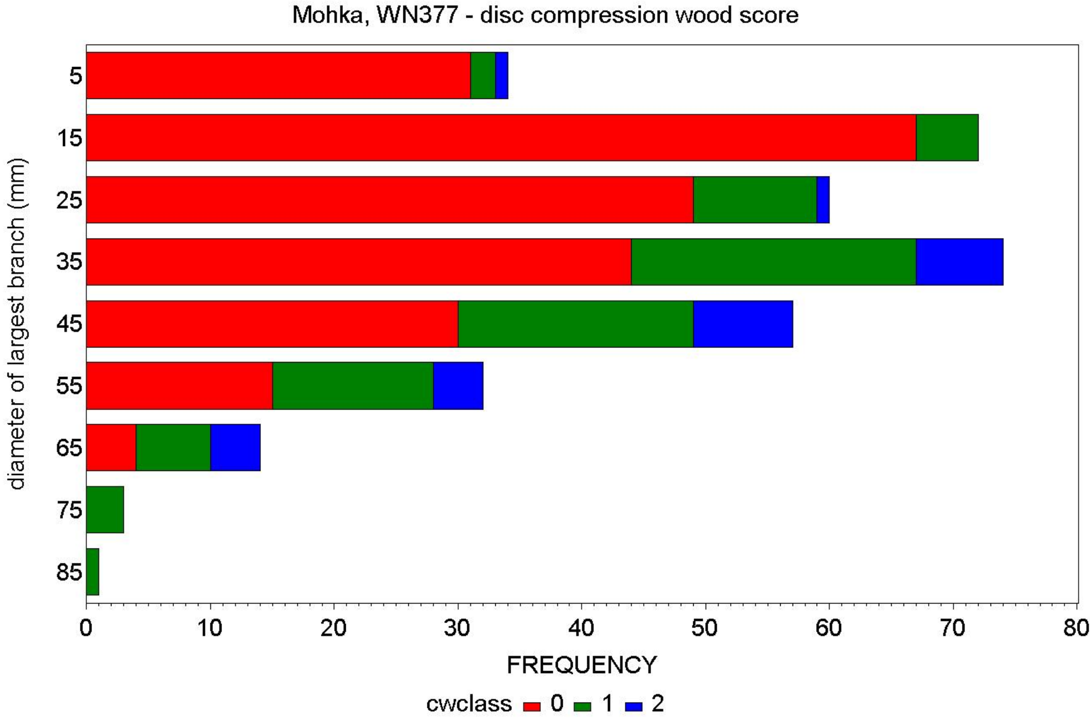
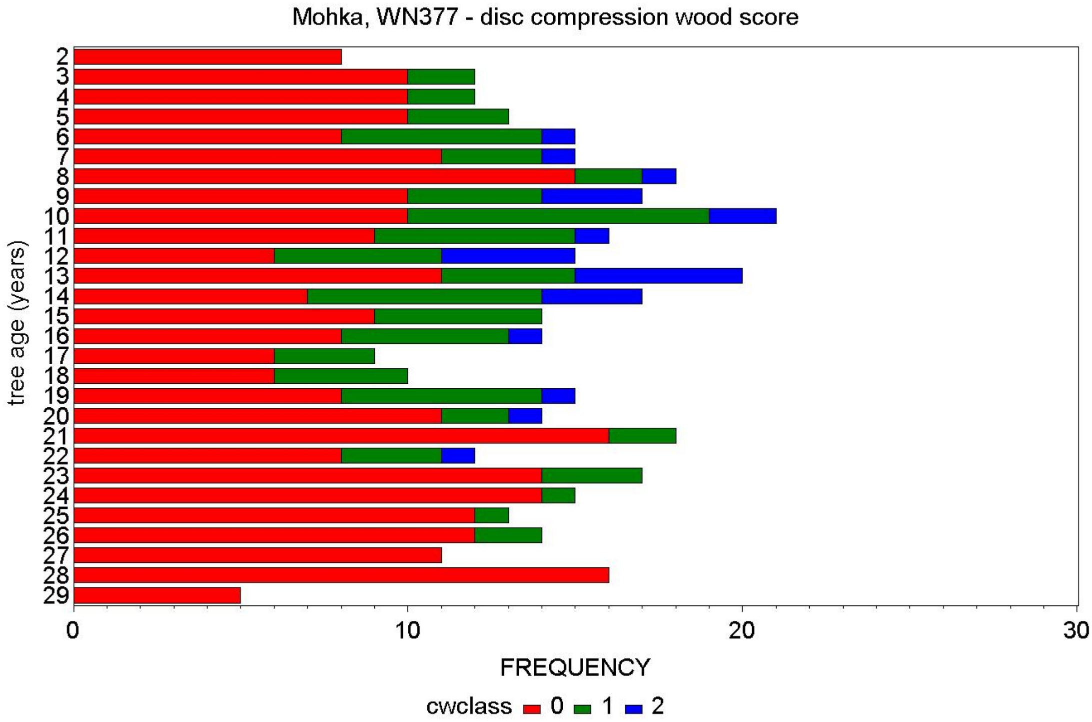



**Figure 16. Bar chart showing the relationship between tree age when the cluster was formed and the compression wood score for the disc cut immediately below the cluster.**



## DISCUSSION

Six GF14 trees were felled in February 2007 from the 1978 Genetic Gain trial, WN377 at Mohaka. Detailed data were collected on stem branching patterns for these trees. Images were obtained of the standing stem, the felled stem, and individual discs to provide a visual record of the sample trees. In addition selected wood samples were analysed using SilviScan. Specific aspects of the data have been analysed in this study. The dataset will contribute to the development of integrated tree, crown and wood property models.

### Number of branch clusters in an annual shoot

Currently TreeBLOSSIM contains an equation that predicts the number of branch clusters in an annual shoot from annual shoot length and tree age when the annual shoot was formed. A separate function was developed for each dataset collected. As the number of datasets available increases, it becomes feasible to investigate whether the variation between datasets may be attributable to site, silvicultural or seedlot variables. Such an analysis is discussed in SGMC Report No. 145.

In this study, Equation 1 (used to predict the number of branch clusters within an annual shoot within TreeBLOSSIM) was fitted to the data from Mohaka and compared with equations included in TreeBLOSSIM. The shape of the predicted curve for Mohaka was similar to that for Esk (Figure 3), and hence provides confidence in the previously derived function using data from Esk.

The Esk function was included in TreeBLOSSIM v3 which was used to compare TreeBLOSSIM predictions with TreeD from several Hawkes Bay forests (SGMC Report No. 134). This function provided good predictions of the number of branch clusters for PSPs with a medium site index, but was poor at predicting the number of branch clusters for Mohaka sites with high to very high site indices. A possible future study would be to repeat the analyses using the Mohaka function derived in this report.

### Long Internodes

Occurrences of both long internodes and stem damage within the Mohaka dataset were examined. Some of the longest internodes were in the vicinity of stem damage. Equally there were no really long internodes in the vicinity of some instances of stem damage.

It is considered that some of the long internodes observed may have been from as part of a branch that has since corrected its position to become the stem leader. It would be interesting to carry out an experiment to confirm this hypothesis.

### Wood property data

SilviScan data were obtained for three directions from selected discs to examine the variability in wood properties within a ring. Most of the discs sampled were eccentric in shape and / or contained compression wood. As a consequence there was often large within-ring variation in density (Figure 8).

The breast-height discs were examined in more detail to determine the response of different wood properties to the two scheduled thinnings. There was little response in wood properties to the first thinning, but a more obvious response to the second thinning. The first thinning was carried out at a mean crop height of approximately 6.2 m. The ring-widths at 1.3 m indicate that the stem was still actively growing, and this is a possible explanation for the lack of response. The second thinning was carried out at a mean crop height of 12m. By this time the ring-widths at 1.3 m were smaller suggesting that competition was affecting the growth of the trees. There was a more obvious response to the second thinning. There was an increase in ring width and microfibril angle after the second thinning.

**Disc Images**

Previous studies has raised the possibility that there may be patches of compression wood immediately below branch clusters that could be attributed to branching rather than stem form, but no study had examined the pattern throughout a tree.

For 4 of the 6 sample trees, images were taken of discs cut immediately below each branch cluster. These discs were visually scored for occurrence of patches of compression wood around the disc. 281 discs showed no signs, 90 discs showed possible signs, while 25 discs showed obvious patches of compression wood. The discs with obvious patches of compression wood tended to occur below clusters with large branches (Figure 15) and around the time of thinning (Figure 16).

It is suggested that these patterns may be related to the movement of the tree, and it is suggested that a similar study be carried out to determine whether there is any variation with windiness of sites / tree spacing/ timing of thinning treatments.

**Modelling**

These data were collected for the purpose of developing integrated tree, crown and wood property models. It is easy to collect data for developing stem growth models as few measurements are required on an individual tree. Far more measurements per tree are required to develop models of crown architecture and within stem distributions of wood properties. To be able to develop robust empirical models requires datasets that cover all likely combinations of site quality, silvicultural treatment and seedlots. Each new dataset collected provides further insights into tree development that can be utilised in model development.

## Appendix 1. Methodology behind selection of potential sample trees

There are six GF14 plots within WN377, which are varying distance from the access track. One plot was used for a SGMC PhotoMARVL study, and later most trees felled for a WQI study. Some of these plots received damage during winter 2006. Characteristics of the six plots are:

- 2/61 – greatest distance from track
- 4/51 – mid-distance from track
- 6/41 – near track, this plot was used for SGMC PhotoMARVL study, and then trees felled for WQI study
- 8/31 – near track
- 10/21 – mid distance from track
- 12/11 – near track but separate from rest of trial

One possibility was to select sample trees that had been imaged as part of an SGMC PhotoMARVL study, but this was not feasible, see below.

> Five trees were imaged in spring 2002 from plot 6/41. The trees selected were those closest to 10, 30, 50, 70 and 90 percentile of diameter distribution. They were tree-key 18, 19, 11, 20 and 8. None of these trees remain after the WQI study.

For PhotoMARVL study, plots were selected on basis of:

- minimal mortality
- stocking remained close to prescribed treatment
- stocking similar between 3 selected plots

For GF14 seedlot in WN377, the 1st choice was 6/41, with 2nd choice being 8/31. Plot 12/11 would have been the 3rd choice.

Eight trees were sampled from one plot in the Golden Downs replicate of this trial in December 2004. The trees were selected in pairs of similar DBH and varying outerwood density. The outerwood density data were available from another study. The range of DBH was 40 – 55 cm.

As one of the major objectives of this study is to collect data to improve the branching functions within TreeBLOSSIM for the Hawkes Bay region, the sample trees selected should be selected to avoid any stem damage that might have altered branching patterns.

The second consideration was whether to choose trees in pairs of similar DBH. It was considered whether 3 such pairs of trees could be selected using plots 8/31 and 12/11 (the two plots closest to the track). This was feasible – but to avoid trees where descriptive codes related to stem damage had been assigned, all pairs were above the average DBH of 56 cm (Table 8).

It was then considered whether a more representative sample of DBH could be obtained by considering all GF14 trees within the experiment. This was feasible – but there was little choice for the smaller trees (Table 9). This was the sampling strategy chosen for this study.

**Table 8. Sample trees selected based on similar DBH**

| DBH class | Plot 8/31 | Plot 12/11 |
|---|---|---|
| Approx. 60 cm | Tree 19 (DBH: 60.6 cm) | Tree 21 (DBH: 60.5 cm) |
| Approx. 65 cm | Tree 4 (DBH: 65.3 cm) | Tree 16 (DBH: 64.5 cm) |
| Approx. 70 cm | Tree 8 (DBH: 72.6 cm) | Tree 18 (DBH: 71.3 cm) |

**Table 9. Sample trees selected based on a range of DBH**

| | 1st choice | | | 2nd choice | | |
|---|---|---|---|---|---|---|
| DBH class | Plot | Tree | DBH (cm) | Plot | Tree | DBH (cm) |
| Approx. 40 cm | 4/51 | 25 | 40.4 | | | |
| Approx. 45 cm | 10/21 | 2 | 47.2 | | | |
| Approx. 50 cm | 4/51 | 7 | 51.6 | | | |
| Approx. 60 cm | 8/31 | 24 | 58.2 | | | |
| Approx. 65 cm | 8/31 | 4 | 65.3 | 8/31 | 9 | 65.8 |
| Approx. 70 cm | 12/11 | 18 | 71.3 | 10/21 | 15 | 71.4 |