Pilot Study for Internal Stem Modelling: Data Collection

J. C. Grace
C. Andersen
J. D. Hayes

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Executive Summary

A pilot data collection study was carried out in abandoned plots from Experiment FR172/3 in order to develop cost-effective data collection procedures for the internal stem modelling theme.

The data collected fell into several broad categories:

- Stem form
- Amount of foliage
- Crown structure
- Wood properties of stem and branches

The data collection strategy was essentially an extension to that currently used to collect crown data for TreeBLOSSIM development.

The following points were noted:

- PhotoMARVL images should be taken of all sample trees to provide quantitative information on stem form.
- It is not cost-effective to attempt to age branches using the botanical structure of the branch. Selecting branches based on position in the crown should be sufficient.
- Whole discs should be cut in order to see how the distribution of visual compression wood varies circumferentially.
- Images should be taken of all wood samples to provide a visual image for comparison with quantitative wood properties.
- Each sample tree should be given a simple unique number. Using a combination of plot and tree was harder to remember in the field than one number.
- As noted in other studies it is difficult to label damp/wet wood.

It is considered that this pilot study provided valuable knowledge for refining the proposed sampling strategy for rotation age trees. A summary and preliminary analysis of the data collected is provided in SGMC Report No. 127.

PILOT STUDY FOR INTERNAL STEM MODELLING:
DATA COLLECTION

J.C. Grace, C. Andersen, J.D. Hayes

Introduction

The objective of the Internal Stem Modelling theme within the Stand Growth Modelling Cooperative 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.

The objective of this pilot study was to design and test an appropriate data collection strategy to be used in the SGMC trials as they reached rotation age and/or time of felling.

It was agreed to use the non-established PSP plots in Experiment FR172/3 (*Appendix 1*), planted in 1992, for this pilot study. The reasons behind this decision were:

- Being close to Forest Research, we could stop and rethink strategy if things did not go according to plan.
- We avoided damage to plots due to be maintained to age 30 years.
- We reduced costs of the project by testing the strategy using young trees, because the trees were smaller and hence there were less measurements to collect.
- We gained an early indication in the variability of wood properties in some of the newer seedlots.

The pilot study attempted to address the following questions:

- How well can stem growth and wood properties be predicted from crown structure? This is needed to develop integrated growth and quality models. David Pont has developed a prototype model, utilising TreeBLOSSIM, that will predict ring width and density from crown structure, specifically foliage mass and distance to foliage. This prototype has been developed using data from one tree. The objective of this sub-project is to determine whether this model is more generally applicable.
- How does branch diameter and genotype influence the variability of wood properties within an internode? In a previous branch study, we observed blocks of compression wood in an internode below branches. This variability in wood properties will lead to distortion. We need to be able to model this variability.
- How does stem form and genotype influence wood properties? We have observed that different genotypes have different responses to stem lean in terms of the range of variation in wood properties. Again this variability will lead to distortion and will need to be modelled.
- Can variation in branch wood properties be used to predict variation in stem wood properties? Since branches form compression wood on their lower side, they exhibit a range in wood properties. If this range is closely related to the variation within an internode, and/or variation due to stem form, we may be able to develop a less destructive technique for measuring wood properties. This could be particularly useful for assessing breeding trials.

The data collection was split into several small sub-projects that addressed the above questions.

SGMC trials will reach rotation age (30 years) between 2005 and 2024, with the 1975 final crop stocking trials and the 1978 genetic gain trials being the first two trial series to reach rotation age. A proposed sampling strategy for these trial series, in terms of sites and treatments to be sampled, is outlined in SGMC Report No 123.

This current project aims to develop an appropriate data collection strategy for individual trees in rotation-age trials. The sampling strategy is unlikely to remain constant for all trials, as new techniques are continually being developed.

Field Trial Description

The series of SGMC trials, planted in 1992, were designed to:
- compare the performance of special-purpose seedlots of radiata pine,
- test their response to differing final crop stocking and thinning strategies,
- and to compare their performance across regions.

Large plot trials were established to test seedlots of the highly multinodal, long internode, high wood density and low wood density breeds on contrasting sites. A GF14 seedlot was also planted as a control. The trials were planted with 3 initial stockings: 250 sph, 500 sph and 1000 sph; but with a consolidation of treatments to provide better on-site replication it was decided to abandon plots planted at 250 stems/ha.

Plots A1 – E5 at the Kaingaroa site of this trial series (FR172/3) (*Appendix 1*), planted at 250sph and left unthinned, were chosen for this study:
- because it would not affect the integrity of the trial,
- because of the close location to Forest Research and easy access (little understory).

Sample Tree Selection.

Visual form and foliage assessments were carried out for all trees in Plots A1 – E5 as follows:

- **Stem Straightness** with a ranking of 1 – 9, where 9 is straight (using GTI Scoring system).
- **Stem Malformation** with a ranking of 1 – 9 where 9 is no forks or malformation (using GTI scoring system).
- **Foliage** with a ranking of 1 – 3 where 1 is little needle drop and 3 is for heavy needle drop.

Twelve trees were selected for the study (Table 1):

- 7 trees were chosen that had straight stems, no malformation and little foliage loss.
- 5 trees were chosen that had lean/sweep with no malformation and little foliage loss.

Table 1. Sample trees selected for study

Plot/ Tree No.	Seedlot	DBH(mm)	Straightness Score	Malformation Score	Foliage Score
A24	Highly multinodal(GF27)	385	9	9	1
A16	Highly multinodal(GF27)	388	9	9	1
C9	High wood density(GF18)	349	9	9	1
D13	Low wood density(GF28)	316	9	9	1
D11	Low wood density(GF28)	388	9	9	1
E16	Gwavas seed orchard(GF14)	318	9	9	1
E17	Gwavas seed orchard(GF14)	352	9	9	1
A5	Highly multinodal(GF27)	381	4	9	1
B24	Long internode(GF13-LI25)	354	4	9	1
C11	High wood density(GF18)	352	4	9	1
D9	Low wood density(GF28)	326	4(leaning)	9	1
E22	Gwavas seed orchard(GF14)	318	3	9	1

Data collection in the field.

The data collection procedures used in the field were an expansion of the data collection procedures used for the development of TreeBLOSSIM. The data collected from the straight and the bent trees varied slightly due to the questions being addressed.

1. Field data – Straight Trees

The primary objectives of collecting data in the straight trees were:

- To collect wood property data from specific locations within the stem, which together with crown structure data could be used to test the extension to TreeBLOSSIM developed by D. Pont
- To determine how wood properties varied within an internode of a straight tree. Using straight trees minimised the possibility of any compression wood present being due to stem form.

Step 1: PhotoMARVL

PhotoMARVL images were not taken of the straight trees because we did not want to remove any branches prior to selecting branches for foliage measurements. In retrospect this was a mistake because the straight trees did contain compression wood, and we cannot go back to an image to determine whether these trees were really straight.

In future: PhotoMARVL images should be taken of all trees that are being sampled to determine the influence of tree growth on wood properties.

Step 2: Foliage Measurements

An estimate of the amount and location of foliage in the tree crown was needed to be able to test the extension to TreeBLOSSIM that predicts ring width and wood density (Pont, 2003).

Undamaged branches were selected for “foliage” measurements. The aim was to select a large diameter and a small diameter branch from branches formed in alternate years. We aimed to sample 2 × 10-year-old, 2 × 8-year-old, 2 × 6-year-old, 2 × 4-year-old and 2 × 2-year-old branches per tree.

To be able to select these branches, we first needed to age the tree stem. This was time-consuming.

In future: The crown should be divided into sections, and sample branches selected from each section.

The sample branches were removed leaving a branch stub just large enough for the branch to be planed open and branch development measured. The sample branch and the branch stub were then labelled with the same sample number.

The centre-of-gravity of the branch with all foliage present was found and the distance from stem to centre-of-gravity measured. The weight of the whole branch was recorded.

All foliage was then stripped off and the new centre of gravity found. The distance from stem to the new centre-of-gravity was measured and the weight of the defoliated branch recorded (*Appendix 3, Figure 1*).

<u>Step 3: Measuring Cluster positions – all trees</u>

The rest of the branches were then trimmed and the distance to each cluster measured as per a normal branch study.

<u>Step 4: Selecting samples to be measured for wood properties – straight trees</u>

Samples to be saved for wood property measurements were marked.

The aim was to cut discs from growth units formed two years apart, and formed in the same year as the sample branches. The position for these discs was based on ageing of the stem using morphological features and having an internode of sufficient length and quality to extract the wood samples. Discs, approx. 30 mm in length were cut towards the base of the lowest aged 10, 8, 6, 4, and 2-year-old internodes.

The discs were then bought back to Forest Research the same evening as they were cut and stored in a cool store until ready for cutting into samples. This was generally less than one week.

The usual procedure is to store wood samples in plastic bags to prevent drying out but we had insufficient bags for this purpose. Consequently, when the samples were cut back at Forest Research, those discs not in bags had started to dry out (approx. 5-10 mm at the base).

Samples to be saved for within-internode wood property measurements were marked.

We selected an internode near the base of the tree that satisfied the following criteria:
the internode was reasonable length and the cluster above contained large branches. One branch was selected as a ‘sample’ branch and marked by two yellow paint lines. A new reference line, running the length of the internode, was drawn under this branch (*Appendix 3, Figure 2*).

A 30 mm section was removed from the branch, cut adjacent to the stem, and at right angles to the branch direction. This was bought back to Forest Research. The aim was to also bring the whole internode back to Forest Research, but this was not feasible (too heavy) so we cut and bought back a wedge from the internode.

In retrospect this was not the best approach – we lost the ability to observe how visual compression wood distribution varied throughout a disc.

In future: it will be better to cut a number of whole discs from within an internode.

The wedges and branch discs were then bought back to Forest Research the same evening as they were cut and stored in a cool store until ready for cutting into samples. This was generally less than one week.

Step 5 – Traditional branch study

The azimuth angle of all branches and stem cones were recorded. The diameter, adjacent to the stem, was measured for all branches.

The foliage branches were removed from the stem, planed open and measured for branch growth.

2. Field Data – Bent Trees

Step 1: PhotoMARVL

The five 'bent' trees were PhotoMARVL'd on the 18th March 2003. The films were developed and 10"x8" enlargement prints were produced.

Step 2: Foliage measurements

No foliage data were collected for the bent trees. The current extension to TreeBLOSSIM is for straight trees. It was decided to wait until the extension had been tested for straight trees before collecting foliage data for bent trees.

Step 3: Measuring Cluster positions – all trees

After felling, the branches were trimmed and the distance to each cluster measured as per a normal branch study.

Step 4: Selecting samples to be measured for wood properties – bent trees

The initial plan was to cut one disc at the base of each "swept" tree to determine whether SilviScan data could be related to longitudinal shrinkage. The direction of lean was marked far enough up the tree to cut the required disc. For some of the trees this was determined after the tree had been felled by examination of the stump. These discs were cut the same day as the tree was felled and bought back to Forest Research that evening and stored in a cool store until ready for cutting into samples. This was between one week and two weeks. The usual procedure is to store wood samples in plastic bags to prevent drying out. Discs from two trees were stored in bags. For the other three trees, top and bottom surfaces were covered with plastic.

When in the field, it seemed sensible to collect some more wood samples from these trees.
A reference line was extended all the way for Trees A5 and C11. For these two trees, two extra discs were marked at approximately 6 m and 12 m.

Step 5 – Traditional branch study

The azimuth angle of all branches and stem cones were recorded. The diameter, adjacent to the stem, was measured for all branches.

Data collection in laboratory

1. Laboratory data - Cutting wood samples to be measured

Stem discs from straight trees

Before cutting any disc:
- all discs were examined for signs of compression wood. The direction of the most severe compression wood (if any) on the lowest disc was chosen as the A-direction.
- the angle of this direction with respect to the "north line" was measured.

Note: all straight trees showed signs of compression wood (darker coloration in rings) in the lowest discs. This was more obvious in the outer, rather than the inner rings. The smaller discs higher in the trees showed less obvious signs of compression wood. Perhaps this is due to the weight of the tree.

For the lowest disc in a straight tree:
- 4 strips, at right angles, were marked. In a clockwise direction these were labelled A, B, C, and D. These strips were 4 cm wide to allow for spiral grain measurements.

Fibre length samples were saved from discs: E16/30, E17/41, D11/37, D13/20, A24/37, A16/41, C9/37.

For the other discs in a straight tree:
- a bark to bark strip through the pith was cut. This strip was orientated the same way with respect to the "north line" as the A-C strip in the bottom discs. The pith to bark strips were labelled A and C. These strips were 4 cm wide to allow for spiral grain measurements.

For all strips:
- the lowest 2 cm was cut off and saved for measuring ring widths
- the next 2 cm was cut off and saved for SilviScan
- the next 6 cm was saved for spiral grain measurements and shrinkage measurements
- any spare was waste

Note: For most discs, the **longitudinal** direction of the growth rings was approximately at right angles to the base of the strips. For a few samples, the growth rings were at an obvious angle to the base of the strip. In these cases, the strips were marked making the growth rings perpendicular to the direction of the samples.

All SilviScan samples were re-cut to be 2 cm wide centred around the stem pith.

Images were taken of the strips saved for measuring ring width.

In future: it would be best to take an image of the whole disc before samples are cut so that the circumferential variation in wood colour is recorded

Internode wedges

The internode below the branch was marked with a reference line extending downwards from the centre of the branch to the base of the internode. The objective was to examine how internode properties varied with distance from the branch.

To avoid carrying out a heavy disc, the position of the sample branch and an adjacent small branch were marked with respect to the "north line" and a wedge cut through the disc. The disadvantage of the wedge was that one did not have a feel for the within-disc variation in colour /compression wood.

The wedges were cut in the following manner:
- top 2 cm waste

then the following was repeated to the base of the internode
- next 2cm for SilviScan
- next 4 cm waste

For bent tree C11, the wedges cut showed obvious signs of compression wood. The compression wood appeared to be related to stem form, rather than branching patterns. These were not cut.

Sample branches

In the office a 2cm bark to bark strip through the branch pith was marked. The direction was through the most obvious compression wood. A sample 2cm deep was then cut from the side of the disc nearest to the stem.

In future: it would have been useful to mark the top and the bottom side of the branch in the field. It would also have been useful to note exact distance of branch disc from the stem.

Stem discs from swept trees

For the lowest disc:
- 4 strips, at right angles, were marked. In a clockwise direction these were labelled A, B, C, and D. These strips were 4 cm wide to allow for spiral grain measurements. For A5, the A strip matched the underside of the lean. For C11, the A strip matched the outside of the lean.

For the other disc in a tree:
- a bark to bark strip through the pith was cut. This strip was orientated the same way with respect to the "north line" as in the bottom discs. The pith to bark strips were labelled A and C. These strips were 4 cm wide to allow for spiral grain measurements.

For all strips:
- the lowest 2 cm was cut off and saved for measuring ring widths
- the next 2 cm was cut off and saved for SilviScan
- the next 6 cm was saved for spiral grain measurements
- any spare was waste

Note: For most discs, the **longitudinal** direction of the growth rings was approximately at right angles to the base of the strips. For a few samples, the growth rings were at an obvious angle to the base of the strip. In these cases, the strips were marked making the growth rings perpendicular to the direction of the samples.

The SilviScan samples were re-cut to be 2cm wide centred around the stem pith.

Long internodes

The reference line was not continued on the other three bent trees (a combination of being overlooked and bad weather at the time the trees were cut into discs). Two of these trees B24 and E22 had at least one very long internode and one complete long internode was bought back for each of these trees in order to examine how compression wood distribution varied through the internode.

They were cut assuming that the stem form overrides any influence of the branching pattern. This appeared to be occurring on the branch wedge cut from a bent tree (samples cut, examined but not measured).

The plane of maximum sweep was determined visually using a string.

Growth Unit E22/10 contained an almost complete wave. Four samples were marked across one half of the wave. Growth Unit B24/13 contained half a wave and four samples were cut across this (*Appendix 3, Figure 3*).

2. Laboratory data – Longitudinal shrinkage for bent trees

One disc was saved from each of the bent trees for determining longitudinal shrinkage using 'the pin method' previously used by Dr. Rolf Booker (pers. comm.). It measures, on an annual ring basis, the longitudinal shrinkage of wood fibres along the direction that the fibres are orientated.

The pin method is considered to provide a more accurate measurement of longitudinal shrinkage than the 'block' method since it corrects for the grain angle. Block measurements of longitudinal shrinkage not only have the problem of grain angle variation, but measurements can also be affected by the surface smoothness of the transverse surfaces, and the problem of fibre rise during drying (T. Jones, pers comm.).

The measurements required were:

- spiral grain angle
- initial distance between two known points along fibre direction
- initial sample width in tangential (circumferential) direction
- distance between two known points along fibre direction after equilibrating sample to a known moisture content
- sample width in tangential (circumferntial) direction after equilibrating sample to a known moisture content
- sample weight after equilibrating sample to a known moisture content
- sample weight after oven - drying

It is important that any samples saved for longitudinal shrinkage measurements do not lose any moisture prior to samples being prepared. All discs were stored in a cool store prior to being cut. The discs from trees C11 and D9 were stored in plastic bags, while the discs from trees E22 and B24 were stored with top and bottom surfaces either covered by a plastic bag or another disc. It was not noted how the disc from tree A05 was stored. The samples from this tree were used for training only.

For each disc, a bark to bark strip through the pith and two side strips were cut. These strips were orientated the same way as the strips saved for SilviScan and were given the same label as the corresponding SilviScan strip. These strips were approximately 2 cm wide and stored in plastic bags, in the cool store, until required for further processing.

The following methods were used to prepare the individual samples:

- The height of the sample strip was measured at both ends, the centre point of these two measurements was marked and a line drawn along the centre of the strip joining these two points.

- Each sample strip was cut into annual ring sections through the latewood, using a chisel and mallet starting from the pith. The year of growth ring formation, plot number, cluster (whorl) number and strip number was then marked onto the sample (e.g., 99/C/24/C) using a black marker pen.

- Each ring was scribed along the grain direction on the outer growth layer, (i.e., all strips were measured on the same side) using a swinging arm scribe to mark grain angle. The grain line indentation is highlighted using a black marker pen (*Appendix 3, Figure 4*).

- Grain angle was measured in relation to the lower surface of the disc by using a Perspex protractor. The protractor is centered on the bottom of the spiral grain line and then the measurement is read off the protractor at the top of the grain, reading in 1 degree intervals. For example if the spiral grain was straight at 90 degrees the angle would be recorded as 0, so left of 90^0 is a negative value and right of 90^0 is a positive value (*Appendix 3, Figure 5*).

- Pins were then placed on two points of the marked grain line, and the distance between these two points measured using Mitutoyo digital callipers, measuring to 0.01mm. The arms of the callipers were placed at the point where pins have been inserted into the sample. It is important to place the calliper arms very gently against the pins in order to avoid moving the pins. The callipers were calibrated before use and randomly during the process of measuring all samples. The distance between the pins was recorded before and after samples had spent time in the EMC laboratory (*Appendix 3, Figure 6*).

- Tangential width of the samples were measured using a Digital Dial Gauge that records to 0.01mm. The point of measurement was marked at the centre of the reference line, which is drawn at the time of sample preparation. Prior to commencing the measurements the gauge is calibrated to zero and randomly calibrated throughout the process. The tangential width of the samples was recorded before and after samples had spent time in the EMC laboratory (*Appendix 3, Figure 7*).

After the initial measurements, the samples were the stored in the EMC room (equilibrium moisture content room) in Timber Engineering Laboratory, which was set to bring samples to 12% moisture content. This took several weeks.

Prior to the samples being removed from the EMC room for the second set of measurements, plastic bags were stored there to reach the same temperature as the samples. Samples were then placed into the plastic bags so that there was an equilibrium whilst transferring them to the Wood Quality dry laboratory.

After the samples had been removed from the EMC laboratory and the above distances had been measured, the pins were removed, and their weight recorded (to nearest 0.1gm) using a Mettler Toledo electronic scale. The samples were then oven dried overnight at 104°C and re-weighed immediately on removal from the oven (*Appendix 3, Figure 8*). This allowed precise determination of the moisture content.

3. Laboratory data – Spiral Grain

Spiral grain (using the method outlined above) was recorded for all other samples saved for spiral grain measurements.

4. Laboratory data - Ring Width

Stem radius to the end of each growth ring was measured on the samples saved for ring width measurement. Ring width is calculated as the difference between adjacent measurements.

5. Laboratory data - SilviScan

SilviScan is a tool, developed by CSIRO, that measures various wood properties.
Three processes are used to provide data:

- X-ray to provide data on wood density
- Diffraction to provide data on microfibril angle
- Image analysis to provide data on cell properties

Various other properties can be estimated from these data, for example, modulus of elasticity.

<u>Data available</u>

For this study:

- Density was measured at 50 micron radial steps
- MFA was measured at 5mm radial steps
- MOE was estimated at 5 mm radial steps
- Cell properties were measured at 50 micro radial steps

To investigate how crown structure influences wood properties:

- Density, MFA, MOE and cell properties are available for 84 strips (10 to 14 strips from each straight tree) Samples are listed in *Appendix 2, Table 2*.

To investigate how stem form influenced wood properties:

- Density, MFA, MOE and cell properties are available for 20 strips (4 strips from the base of the each bent tree). Samples are listed in *Appendix 2, Table 3*.
- Density, MFA, and estimated MOE available for 12 strips (6 strips from each of 2 bent trees). Samples are listed in *Appendix 2, Table 4*.

To investigate how wood properties varied within an internode

- Density, MFA, and estimated MOE available for 74 strips (6 – 12 strips from one internode from each straight tree). Samples are listed in *Appendix 2, Table 5.*
- Density, MFA, and estimated MOE available for 16 strips (8 strips from one swept internode for two of the bent trees). Samples are listed in *Appendix 2, Table 6*.

To investigate how wood properties vary within a branch

- Density, MFA, and estimated MOE available for 26 strips (2 strips from each of 13 branches). Samples are listed in *Appendix 2, Table 7*.

Discussion

The objective of the Internal Stem Modelling theme within the Stand Growth Modelling Cooperative 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.

The aim is to be able to predict the variation of wood properties vertically, radially and circumferentially as a function of crown structure, stem form, genetic stock, silvicultural treatment and site variables.

A pilot data collection study was carried out in abandoned plots from Experiment FR172/3 in order to develop cost-effective data collection procedures for the internal stem modelling theme.

In order to provide data considered necessary for model development, data were collected in the following categories:

- Stem form
- Amount of foliage in crown
- Crown structure
- Wood properties of stem and branches

The data collection strategy was essentially an extension to that currently used to collect crown data for TreeBLOSSIM development.

The following points were noted:

- PhotoMARVL images should be taken of all sample trees to provide quantitative information on stem form.
- It is not cost-effective to attempt to age branches using the botanical structure of the branch. Selecting branches based on position in the crown should be sufficient.
- Whole discs should be cut in order to see how the distribution of visual compression wood varies circumferentially.
- Images should be taken of all wood samples to provide a visual image for comparison with quantitative wood properties.
- Each sample tree should be given a simple unique number. Using a combination of plot and tree was harder to remember in the field than one number.
- As noted in other studies it is difficult to label damp/wet wood.

It is considered that this pilot study provided valuable knowledge for refining the proposed sampling strategy for rotation age trees. A summary and preliminary analysis of the data collected is provided in SGMC Report No. 127.

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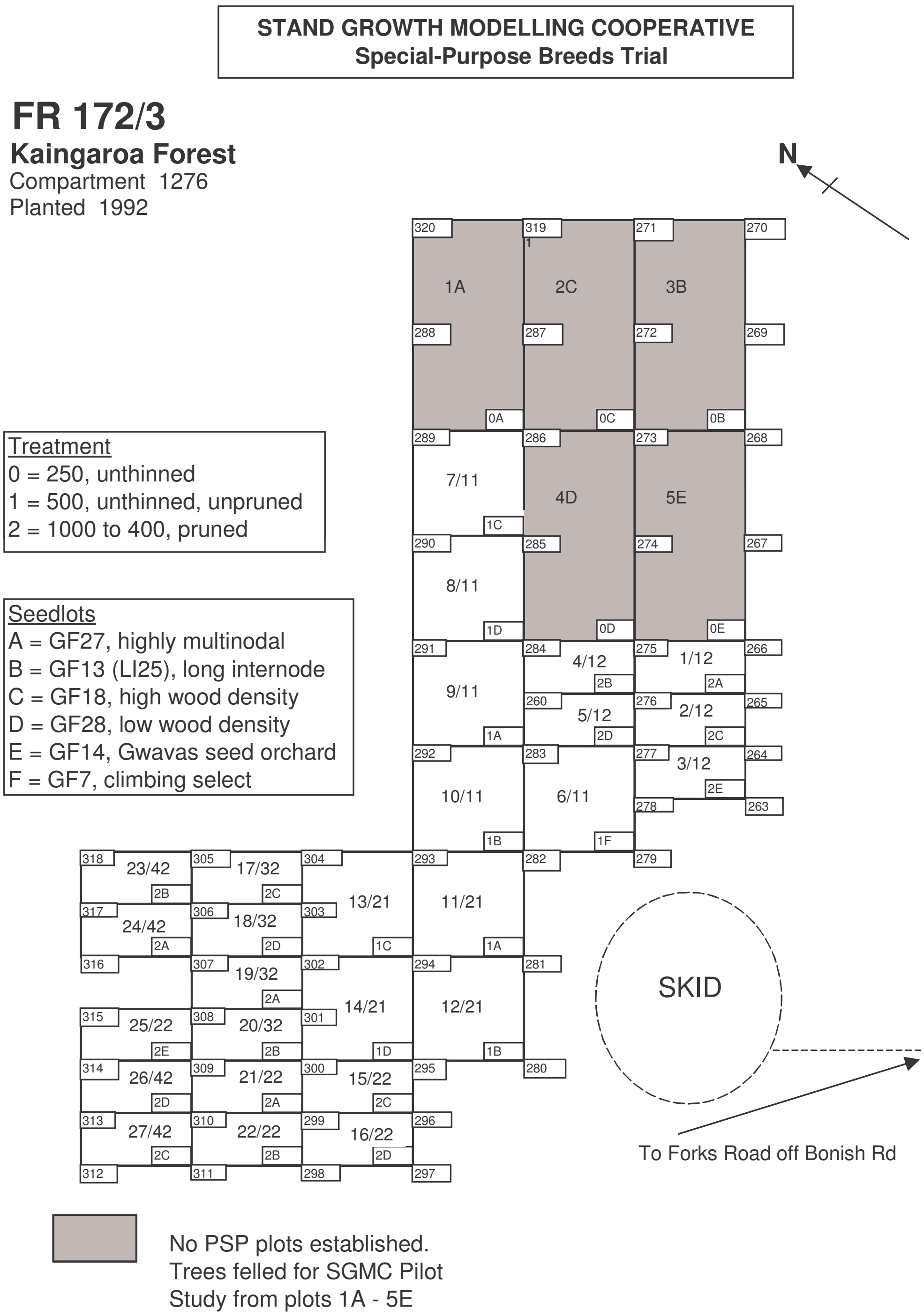
Map Trial FR172/3 showing location of plots used



Wood samples saved for further analysis.

Table 2. Stem disc samples saved from straight trees for SilviScan, spiral grain and ring width assessment.

Plot Number	Tree Number	Cluster/ Growth Unit Number	Sample Label	Bearing wrt North line	Comment
E	16	9	E16/9A E16/9C	192º 12º	
		16	E16/16A E16/16C	192º 12º	
		20	E16/20A E16/20C	192º 12º	
		23	E16/23A E16/23C	192º 12º	
		30	E16/30A E16/30B E16/30C E16/30D	192º 282º 12º 102º	
E	17	9	E17/9A E17/9C	158º 338º	
		18	E17/18A E17/18C	158º 338º	
		25	E17/25A E17/25C	158º 338º	
		34	E17/34A E17/34B E17/34C E17/34D	158º 248º 338º 68º	
		41	E17/41A E17/41B E17/41C E17/41D	158º 248º 338º 68º	
D	11	9	D11/9A D11/9C	230º 50º	
		18	D11/18A D11/18C	230º 50º	
		25	D11/25A D11/25C	230º 50º	C: resin pocket in ring 5 from pith
		29	D11/29A D11/29C	230º 50º	
		37	D11/37A D11/37B D11/37C D11/37D	230º 320º 50º 140º	
D	13	6	D13/6A D13/6C	90º 270º	
		11	D13/11A D13/11C	90º 270º	
		16	D13/16A D13/16C	90º 270º	

Plot Number	Tree Number	Cluster/ Growth Unit Number	Sample Label	Bearing wrt North line	Comment
D	13	20	D13/20A D13/20B D13/20C D13/20D	90º 180º 270º 0º	
A	24	8	A24/8A A24/8C	25º 205º	
		17	A24/17A A24/17C	25º 205º	
		26	A24/26A A24/26C	25º 205º	
		30	A24/30A A24/30C	25º 205º	
		37	A24/37A A24/37B A24/37C A24/37D	25º 115º 205º 295º	A: Ring 5 from pith narrower on 1 side of sample due to damage to tree. B: Resin pocket ring 2 from pith
A	16	10	A16/10A A16/10C	45º 225º	
		21	A16/21A A16/21C	45º 225º	
		27	A16/27A A16/27C	45º 225º	
		33	A16/33A A16/33C	45º 225º	
		41	A16/41A A16/41B A16/41C A16/41D	45º 135º 225º 315º	D: hollow in stem in this direction
C	9	10	C9/10A C9/10C	118º 298º	
		18	C9/18A C9/18C	118º 298º	
		23	C9/23A C9/23C	118º 298º	
		32	C9/32A C9/32C	118º 298º	
		37	C9/37A C9/37B C9/37C C9/37D	118º 208º 298º 28º	

Table 3. Samples saved from near base of stem of the swept trees for SilviScan and longitudinal shrinkage measurements.

Plot Number	Tree Number	Disc Position (cm)	Cluster/ Growth Unit	Sample label	Bearing wrt magnetic North	Length (mm)
A	5	72-88	45	A5A		162
				A5B		192
				A5C		200
				A5D		195
B	24	63-80	23	B24A	135	157
				B24B	225	164
				B24C	315	154
				B24D	45	157
C	11	78-94	40	C11AJG	330	158
				C11BJG	60	153
				C11CJG	150	182
				C11DJG	240	168
D	9	184-202	35	D9AJG		158
				D9BJG		143
				D9CJG		154
				D9DJG		130
E	22	69-84	32	E22A	120	161
				E22B	210	155
				E22C	300	138
				E22D	30	125

Notes:
Disc position is height in tree and includes the sample saved for SilviScan, which was always at the base of the disc.
Trees A5 and D9, not possible to recreate bearings from information available. Bearings for other trees calculated from notes and diagrams. Bearings are not essential for comparing SilviScan and longitudinal shrinkage data.

Table 4. Additional samples saved from the swept trees

Plot Number	Tree Number	Cluster/ Growth Unit Number	Sample Label	Bearing wrt North line	Comment
A	5	20	A5/20A A5/20C		
		32	A5/32A A5/32B A5/32C A5/32D		
C	11	16	C11/16A C11/16C	283º 103º	
		36	C11/36A C11/36B C11/36C C11/36D	283º 13º 103º 193º	Samples were not from growth unit 36 (based on number of growth rings). Samples were probably from cluster 26 (based on heights of samples for tree A05.

Note: Bearings for tree A5 not recorded.

Table 5. Samples to measure variation of wood properties within an internode

Sample Label	Sample Length (mm)
A16/30A	147
A16/30B	148
A16/30C	148
A16/30D	150
A16/30E	150
A16/30F	150
A24/33A	165
A24/33B	165
A24/33C	165
A24/33D	165
A24/33E	167
A24/33F	172
C9/26A	120
C9/26B	120
C9/26C	120
C9/26D	125
C9/26E	129
D11/30A	161
D11/30B	165
D11/30C	164
D13/17A	117
D13/17B	115
D13/17C	108
D13/17D	115
D13/17E	122
D13/17F	125
E16/24A	130
E16/24B	129
E16/24C	127
E16/24D	128
E16/24E	125
E16/24F	130
E17/31A	130
E17/31B	130
E17/31C	130
E17/31D	130
E17/31E	130

Sample Label	Sample Length (mm)
A16/30V	126
A16/30W	130
A16/30X	131
A16/30Y	133
A16/30Z	133
A16/30H	130
A24/33V	150
A24/33W	141
A24/33X	142
A24/33Y	142
A24/33Z	145
A24/33H	145
C9/26V	115
C9/26W	110
C9/26X	115
C9/26Y	110
C9/26Z	117
D11/30V	147
D11/30W	145
D11/30X	145
D13/17V	90
D13/17W	89
D13/17X	95
D13/17Y	101
D13/17Z	107
D13/17H	110
E16/24V	108
E16/24W	115
E16/24X	110
E16/24Y	115
E16/24Z	100
E16/24H	115
E17/31V	110
E17/31W	115
E17/31X	100
E17/31Y	113
E17/31Z	115

Table 6. Samples to measure variation in wood properties in a swept internode

Plot	Tree	Cluster	Sample Code	Sample Length (mm)
E	22	10	ELIAO	49
			ELIAI	51
			ELIBO	48
			ELIBI	53
			ELICO	52
			ELICI	49
			ELIDO	53
			ELIDI	49
B	24	13	BLIAO	97
			BLIAI	89
			BLIBO	96
			BLIBI	85
			BLICO	92
			BLICI	85
			BLIDO	89
			BLIDI	87

Table 7. Samples to measure variation in wood properties within a branch

Plot	Tree	Cluster	Sample Name	Sample Length (mm)
A	16	30	A16SBT	30
			A16SBB	47
C	9	20	C9SBT	19
			C9BBB	29
D	11	30	D11SBT	25
			D11SBB	36
D	13	17	D13/17SBT	28
			D13/17SBB	39
D	13	18	D13/18SBT	26
			D13/18SBB	39
E	16	not recorded	E16SBT	24
			E16SBB	32
E	17	31	E17SBT	14
			E17SBB	17
A	5	38	A5SBT	17
			A5SBB	25
B	24	16	B24/16SBT	31
			B24/16SBB	39
C	11	31	C11SBT	22
			C11SBB	27
D	9	28	D9/28SBT	17
			D9/28SBB	29
D	9	29	D9/29SBT	16
			D9/29SBB	27
E	22	27	E22/27SBT	18
			E22/27SBB	29