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Suitability of Disc Images to Test Applicability of Taper Equations at Different Ages

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Growth models predict stem diameter at breast height through time. Taper equations provide estimates of stem diameter under bark at different heights within a tree, giving stem form. The stem form through time becomes important when one wishes to predict wood property distributions within the stem. However taper equations are derived using data collected towards the end of the rotation. The question is whether such taper equations are equally applicable at younger ages.

This problem is important to the development of integrated growth and quality models and simulating product performance.

This project was designed to determine the feasibility of using disc images to reconstruct stem taper through time.

Stem forms at different ages were derived by digitising growth rings from previously collected disc images from 33-year-old trees of average DBH from a range of silvicultural treatments.

The dataset obtained for this project was very small as it was difficult to digitise all growth rings on discs due to the small width of later growth rings and the chain-saw cut surface.

The two main conclusions from this study were:

1. It is feasible to develop stem profiles and test taper equations using data from digitised discs, but a chain-saw cut surface did limit the amount of data that could be extracted from an image.
2. While only a very small dataset was available to compare with taper equations, it appears that the difference of "actual" (digitised) minus predicted diameter under bark is more negative for younger trees, i.e., the taper equations tested may not be equally applicable at all ages.

Further research is required to determine whether these differences in diameter under bark and the fact that taper equations ignore nodal swelling are of significance to product performance. It is recommended that a simulation study be carried out to address these questions and to determine the importance of random events in a tree's life on product performance. The answers to these questions are needed prior to any further development and/or testing of taper equations.

An alternative approach to using taper equations is to develop growth models that directly predict stem form. This would be achievable by developing an integrated growth, branching and wood property model.

INTRODUCTION

An overall aim of the FFR radiata theme is to be able to develop computer simulation models covering the value chain from seed to product. One component of this chain will be models of wood property distributions within tree stems, as the property distributions will influence performance.

An important consideration is the independent variables used to predict the wood property distributions. For example wood properties could be modelled as a function of:

- distance from pith
- ring number from pith
- ring width at a given position in the tree.

Using ring number or ring width will require functions that predict tree taper at any tree age. However tree taper equations are generally derived for rotation-aged trees. Previous attempts at modelling wood property distributions (e.g., within TreeBLOSSIM) have assumed that such taper equations are equally applicable at younger ages.

This project is an initial investigation of the validity of the assumption that current taper equations are equally applicable at younger ages. Specifically it investigates whether it is feasible to estimate stem taper through time by digitising the growth rings on previously collected disc images.

This approach is different from the traditional procedures for developing and testing taper equations[(1)]. Specific points to note are:

- Tree volume and taper equations are usually produced for an individual species or species group for a particular forest or region. For increased accuracy, equations can be derived for stands grown under specific tending regimes.
- To test an equation with reasonable confidence, a sample size of approximately 50 felled trees is required.
- Bark thickness and stem diameter are recorded at 3-m intervals above the ground.
- Where a measured point falls on a branch cluster or nodal swelling, a measurement above and below this portion must be made and the average of these recorded.

METHODS

As part of the data collection procedures in the 1975 Final Crop Stocking Trials at Woodhill (AK1056), and Golden Downs (NN529/1), trees that represented the "average" tree in each silvicultural treatment were selected[(2)]. For these trees, stem discs were cut below branch clusters and imaged. These images were primarily collected to determine whether the discs contained compression wood and whether it could be related to the diameter of branches.

The disc was cut below the initiation point of the cluster, as determined by the patterns in the stem bark. A visual examination of images of the felled stems at Golden Downs indicated that there was very little nodal swelling and that any swelling around branches was contained within the branch cluster, i.e., above the point of branch initiation and the position of the stem disc. Thus it appears that these discs satisfy the criteria to avoid nodal swelling[(1)].

In the field, the number of growth rings below and above each branch cluster were counted. The ring count below the cluster will be equivalent to that on the disc image.

The Scion software (G2Ring) was used to map the growth rings. Profiles of stem taper at different ages were then developed to provide confidence that the generated taper profile was logical. Initially, discs at breast height and at every two metres between the prune height and 20 m were digitised. Some additional discs were added once initial profiles had been generated.

These profiles were then compared with profiles generated using PSP measurements of tree height and diameter at breast height using three different volume and taper equations:

- No. 182
    - This volume and taper equation was derived for all New Zealand forests managed to a direct sawlog regime[(3)].
- No. 237
    - This volume and taper equation was derived for transition crops using data from Kaingaroa[(3)] and is considered to adequately represent the shape of radiata pine (A. Gordon pers comm.)
- No. 460
    - This is a 3-point taper equation that requires estimates of prune heights[(4)]. A mean pruned height of 6 m was simulated for the following reason:
        - Documentation in the PSP system indicates that the Golden Downs trial had been pruned to a mean crop height of 4.2 m. Measurement of height to lowest cluster for the sample trees indicated that the mean prune height was 5.5 m, suggesting that a 3rd lift, probably to 6 m, had occurred but not been recorded.

Lack of PSP height measurements at different ages for the sample trees limited the number of comparisons that could be made.

RESULTS

Golden Downs

It was feasible to digitise growth rings on the Golden Downs discs, but it was not feasible to digitise rings all the way out to the bark due to the narrow growth rings and the image surface (a chain-saw cut). It was therefore necessary to use the field ring count estimate to assign the tree age to each growth ring. The field ring counts were collected in sequence from the top of the tree, taking particular note of the size of the innermost growth ring to determine when the ring count increased. Even so, determining the number of growth rings in a particular disc is not easy. Consequently it was important to check that the generated profiles were logical.

The first profiles of stem radius with height above ground contained some “blips”, but the profiles for the different ages rarely crossed, indicating that the use of ring counts to determine ring age was satisfactory. The disc images were further examined to determine whether there were any obvious reasons (e.g., disc with obvious nodal swelling, missed growth rings). Ring counts were adjusted where the inner ring was not digitised, but the “blips” remained
Figure 1). It is suggested that these “blips” are real. Reasons for these blips are not known and should be further investigated, They may be related to the dimensions of the stem pith which has been noted to swell towards the end of annual shoots.

The difference (digitised diameter under bark – predicted diameter under bark), was calculated for each taper equation and plotted against height in the tree for each tree, with curves labelled by tree-age. For clarity, only selected ages are shown (Appendices - Figures 2 to 6). Visually the graphs indicate that for each tree the errors are similar for each taper equation. The mean error for these selected ages (Table 1) is always negative, and tends to be more negative at younger ages. Given the small sample size it is not logical to say one equation is better or worse than any other.

Table 1. Mean values of digitised diameter under bark – predicted diameter under bark (cm)

Tree-age (years)	Taper Eqn. 182	Taper Eqn. 237	Taper Eqn. 460
12	-3.9	-4.9	-4.1
16	-3.9	-4.8	-5.2
27	-0.7	-0.7	-4.0
32	-0.7	-0.5	-3.4

Woodhill

The operator charged with digitising growth rings from the Woodhill discs considered that the task was not practical. David Pont, who developed the G2Ring software, has commented that the ease of using G2ring varies between trees.

Discussion

This small study was designed to determine whether it would be feasible to use digitised disc images to test the performance of taper equations at younger ages. Even though the sample size was extremely small, the consistent trend for the prediction of stem form to be poorer at young ages provides an answer to the initial question. Further studies are needed to determine whether this result is generally applicable. In addition we need to determine how much error is acceptable in predicted stem diameter when it comes to product performance. This would best be determined by a simulation study. For example, a simulation exercise was carried out to determine the impact of branching characteristics on visual timber grades[5].

For this study, the disc surface was that produced by a chainsaw. A “skim saw” (a modified “Petterson skill mill” portable sawmill) has since been developed and installed at Scion. This produces a much smoother surface. This should improve the ability to digitise rings if used in future studies.

The advantage of using disc images is that it allows the prediction of the change in taper through time for individual trees. An alternative approach would be to fell a sample of trees at different ages through the rotation. It needs to be decided whether this approach would provide sufficiently realistic within-tree profiles.

In this study PSP height and diameter measurements were used as input to the taper equations. Lack of height measurements limited the number of comparisons that could be made. As the height to each branch cluster and the ring counts below each branch cluster is recorded in destructive sampling studies, it would be feasible to develop a height profile though time which could be used instead of the PSP height measurements. PSP diameter overbark would still need to be used.

CONCLUSION

Taper equations complement growth models in providing an estimate of the form of the stem. This study was designed to investigate whether it was feasible to use digitised disc images to test whether taper equations, generally derived using near-rotation-aged trees, were applicable at all tree ages. This knowledge is important if one wishes to use ring width or ring number from the pith in predicting wood property distributions within the stem.

The two main conclusions from this study were:

1 It is feasible to develop stem profiles and test taper equations using data from digitised discs, but a chain-saw cut surface did limit the amount of data that could be extracted from an image.

2 While only a very small dataset was available to compare with taper equations, it appears that the difference of "actual" (digitised) minus predicted diameter under bark is more negative for younger trees, i.e., the taper equations tested may not be equally applicable at all ages.

The development of new taper equations that are equally applicable at all ages will be an expensive, non-trivial exercise, given the sample size recommended for taper equation development.

Prior to any further data collection there are three important but related questions that need to be addressed:

1. Are these differences in stem taper important in terms of product performance?
2. Are taper equations appropriate for developing models that allow product performance to be evaluated? A taper equation provides only a general average stem form. The actual stem form, including swelling and any sweep may be more important in determining product performance.
3. What are the most important factors influencing product performance (for example, how much influence do random versus regular events in a tree's life have on the performance of products cut from that tree?) This would best be determined by a simulation study.

An alternative approach to using taper equations is to develop growth models that directly predict stem form. This would be achievable by developing an integrated growth, branching and wood property model.

In addition it is recommended that:

- A small study be carried out to determine whether it is any easier to digitise small growth rings on discs whose surface has been prepared using the "skim saw" developed at Scion.

ACKNOWLEDGEMENTS

Thanks to Andrew Gordon for estimating tree taper using equation 460 and for providing comments on the initial draft.

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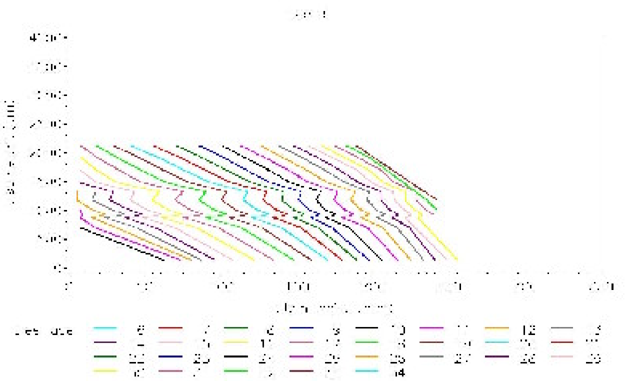
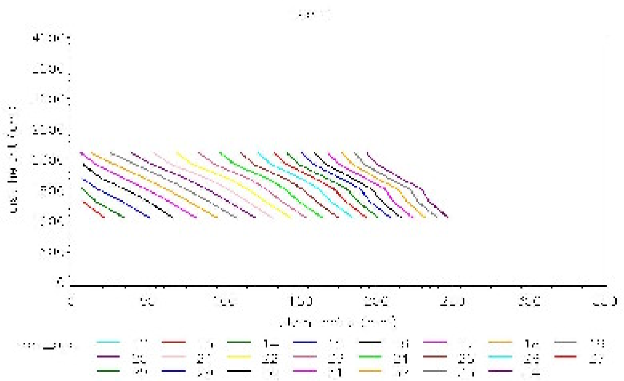
1. Gordon, A.; Penman, J. 1987. Sampling and measuring procedure for tree volume and taper equation construction and testing. FRI Bulletin 138.
2. Grace, J.C.; McKinley, R.; Cown, D.; Lee, J. 2009. 1975 Final crop stocking Trials: Assessment of crown and wood properties for trees from different silvicultural treatments. FFR Report R020.
3. Eggleston, N. 1992. Comparing the range of regional volume and taper equations. Stand Management Cooperative Report No. 26.
4. Gordon, A.D.; Budianto, M. 1999. A 3-point stem volume and taper equation for radiata pine. Forest and Farm Plantation Management Cooperative Report No. 66.
5. Pont, D.; Grace, J.C.; Todoroki, C. 1999. Modelling the influence of radiata pine branching characteristics on visual timber grades. Stand Growth Modelling Cooperative Report No. 82.

APPENDICES

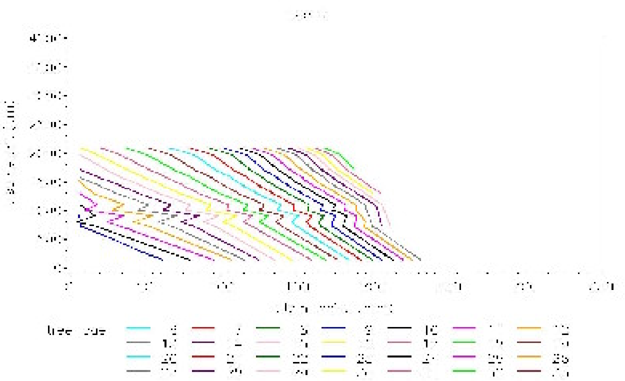
Thinning: 100 stems/ha at age 11 years



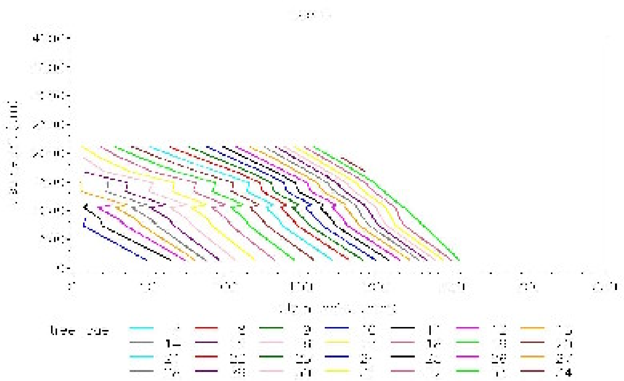
Thinning: 100 stems/ha at age 14 years



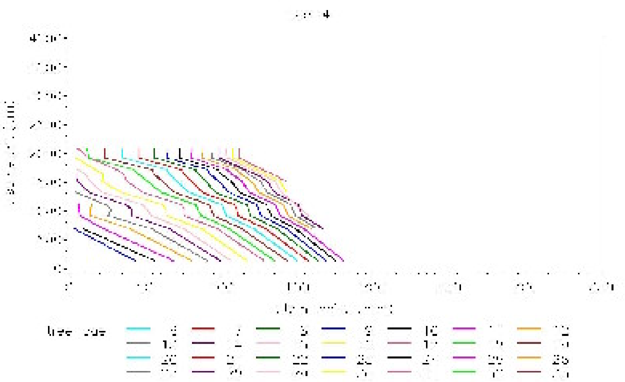
Thinning: 200 stems/ha at age 11years



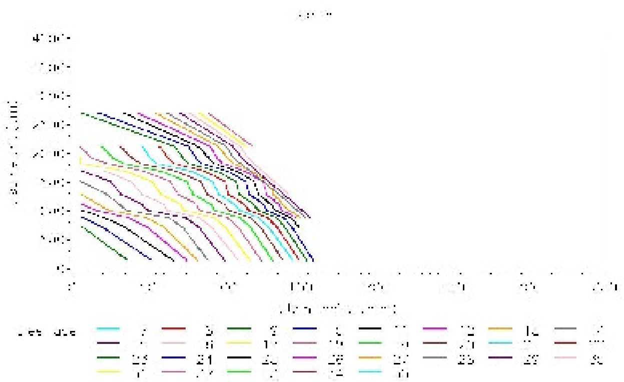
Thinning: 200stems/ha at age 14 years



Thinning: 400 stems/ha at age 11 years



Thinning: 400 stems/ha at age 14 years



Thinning: no thinning

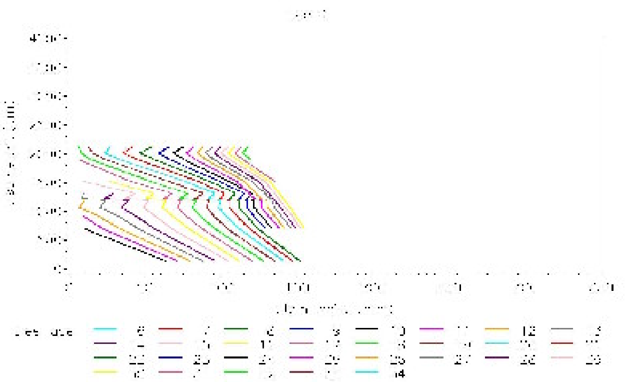


Figure 1. Digitised stem form for trees of average DBH from each treatment in the 1975 Final Crop Stocking Trial at Golden Downs.

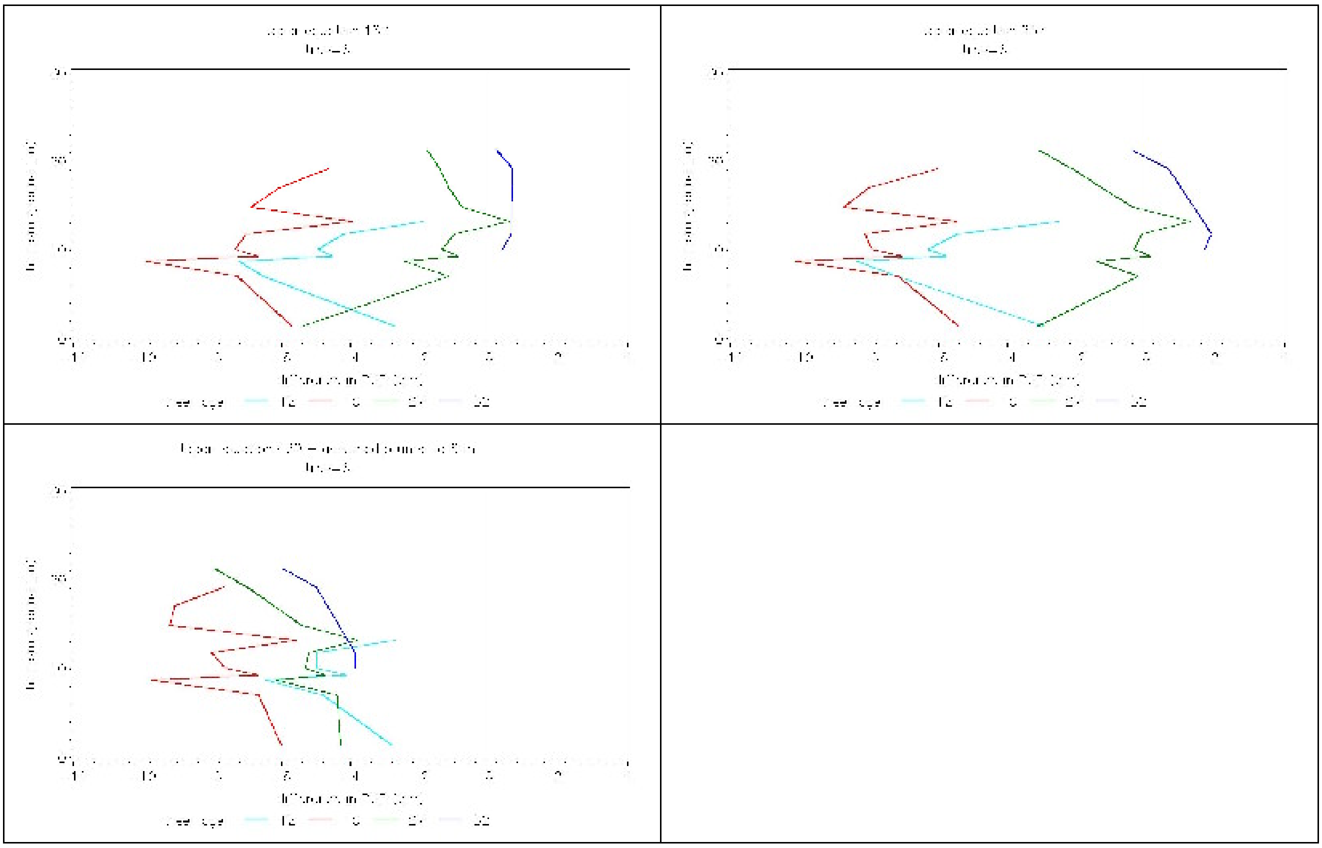


Figure 2. Digitised – predicted diameter under bark at selected ages for tree 6, Thinning: 100 stems/ha at age 11 years.

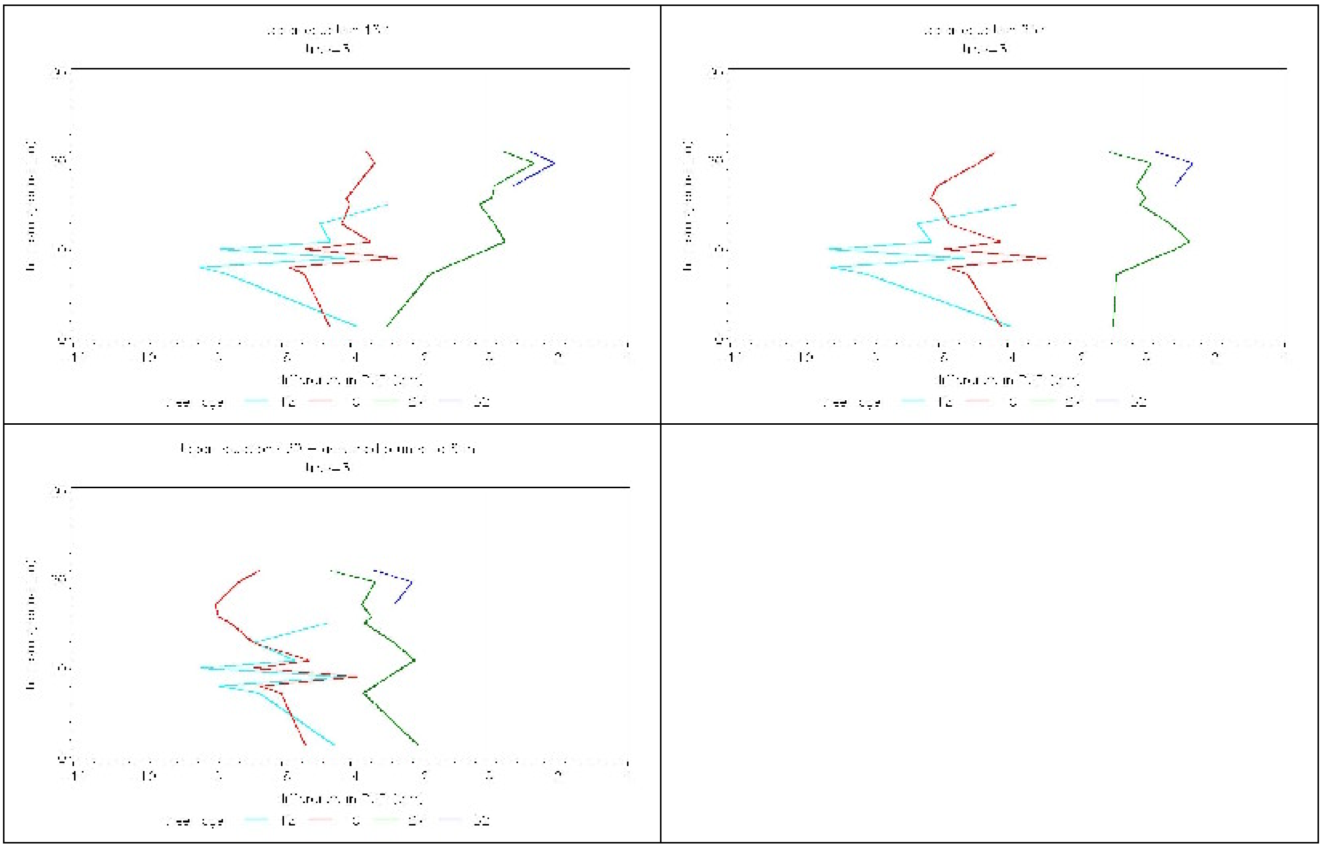


Figure 3. Digitised – predicted diameter under bark at selected ages for tree 3, Thinning: 200 stems/ha at age 11 years.

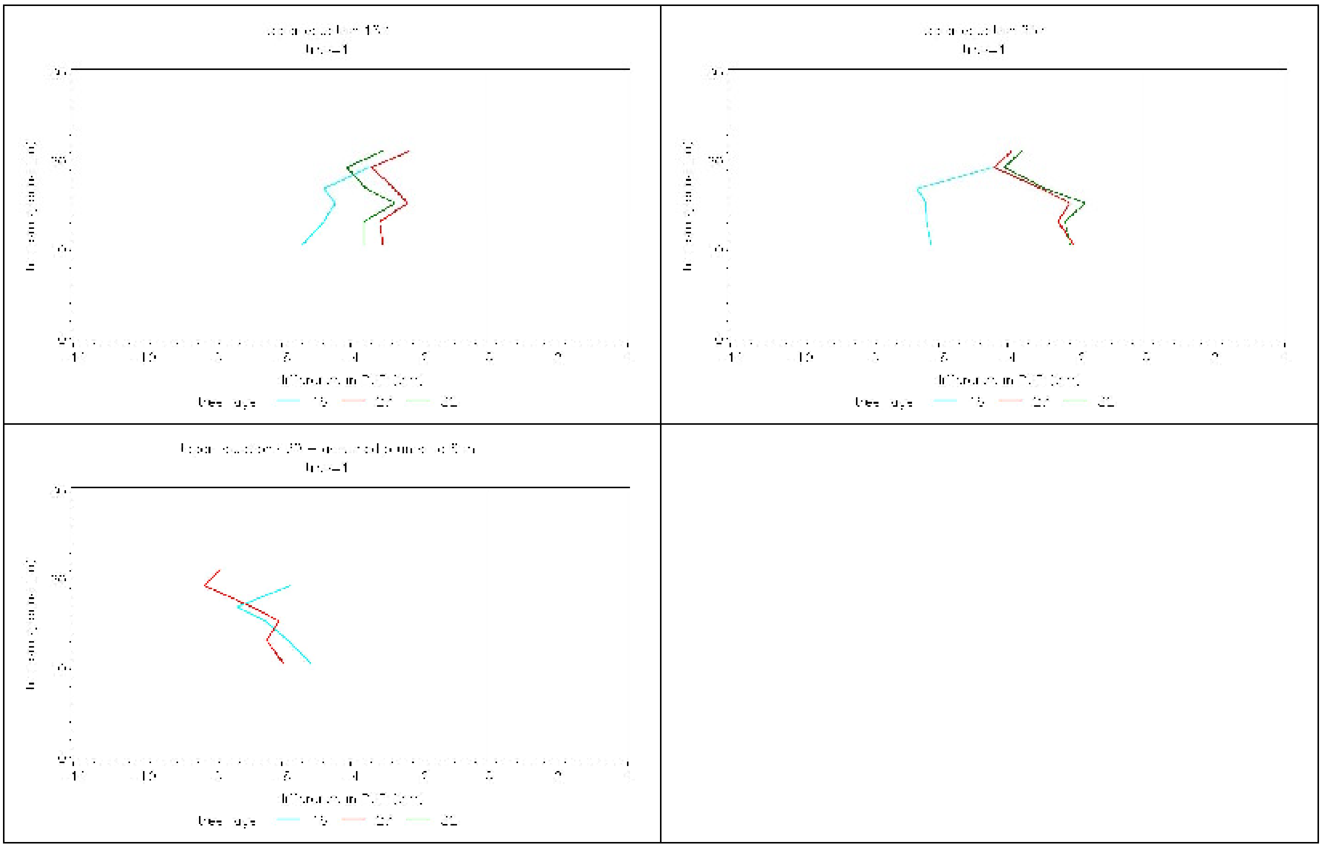


Figure 4. Digitised – predicted diameter under bark at selected ages for tree 1, Thinning: 100 stems/ha at age 14 years.

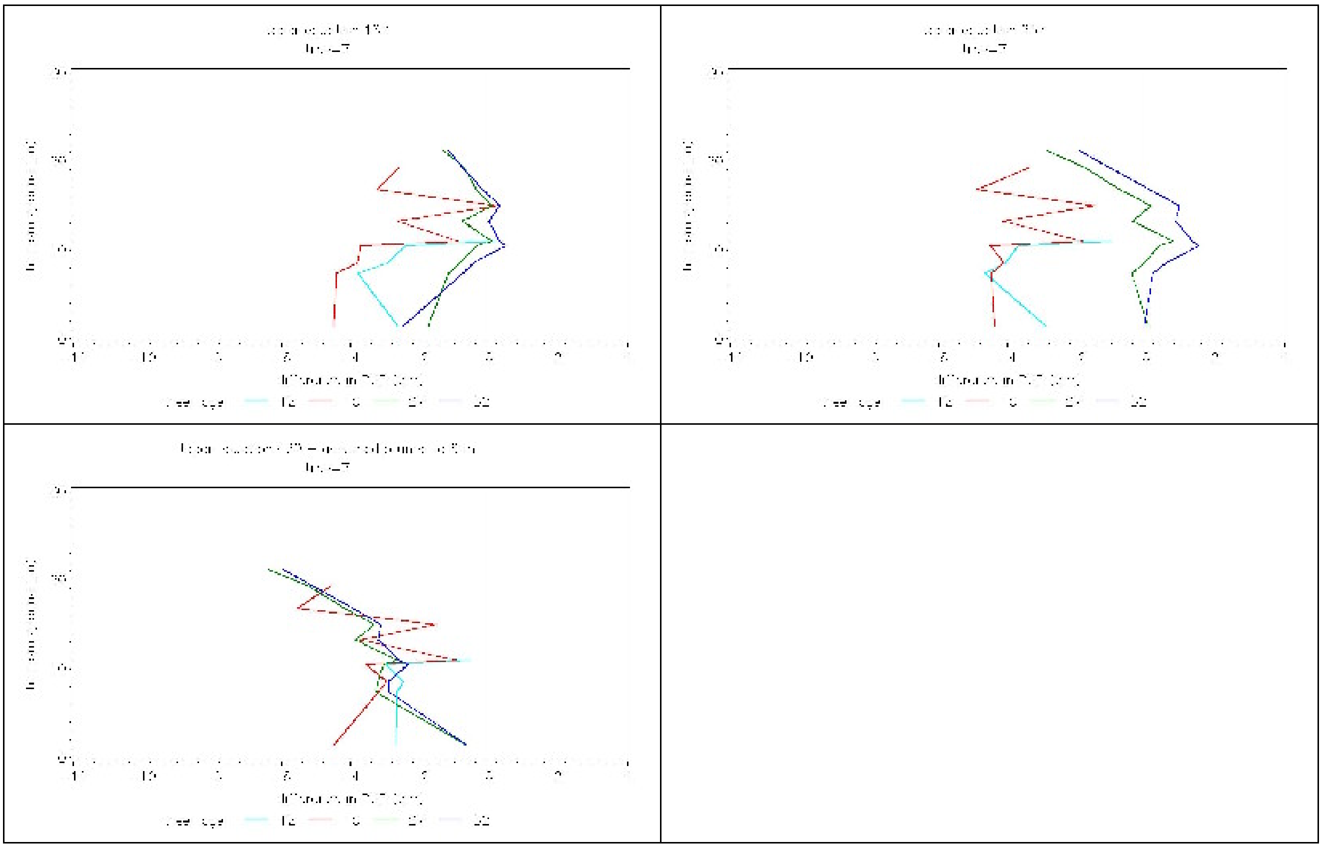


Figure 5. Digitised – predicted diameter under bark at selected ages for tree 7, Thinning: 200 stems/ha at age 14 years.

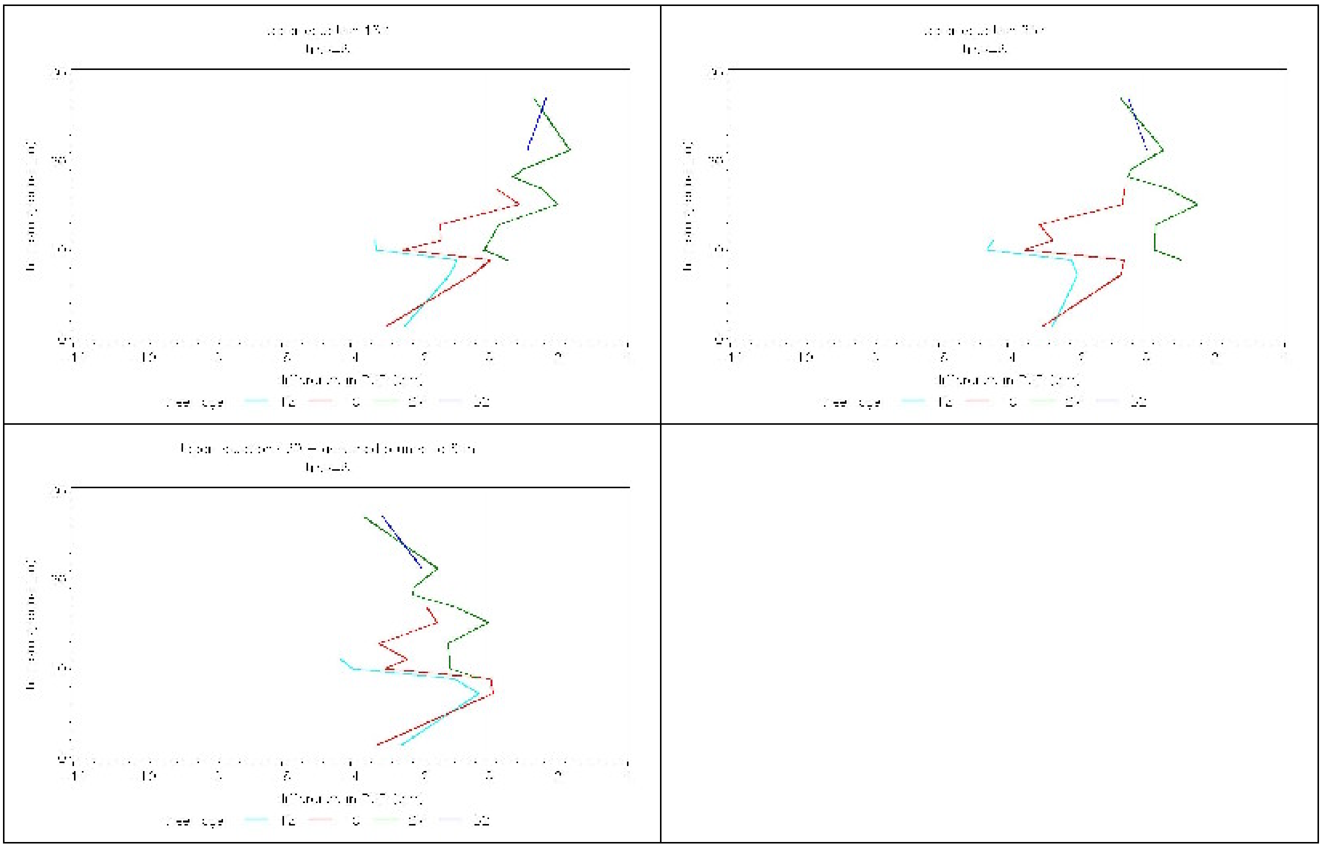


Figure 6. Digitised – predicted diameter under bark at selected ages for tree 8, Thinning: 400 stems/ha at age 14 years.