# Comparison of TreeD measurements of branching with TreeBLOSSIM predictions: Westland

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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: This is an unpublished report and must not be cited as a literature reference.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


TreeD images were collected from 14 PSPs located in 8 different forests on the West Coast. Measurements of branching taken from the images were compared with predictions from the integrated tree and branch growth model, TreeBLOSSIM.

An initial examination of the images showed that the crown structure varied between forests. Trees from Paporoa and Victoria Forest Park tended to have narrower and lighter crowns than the other forests, similar to trees previously measured in Golden Downs forest, Nelson. Trees from the other forests had heavier crowns, similar to trees previously measured in Longwood forest, Southland.

As a consequence, TreeBLOSSIM was run in two ways, once using the default model for the Westland region (combination of the stem growth model for the Nelson region and branching functions for the Westland region) and once using the model for the Southland model (stem growth and branching model for the Southland region).

Comparing TreeBLOSSIM predictions with measurements from the images indicated that:

- The Southland model was more appropriate as a predictor of branch diameter for all forests other than Paparoa and Victoria Forest Park.
- There was little difference in the prediction of number of branch clusters between the Westland and Southland model, but the Westland model was considered to be better.
- TreeBLOSSIM performed equally well for a range of tree sizes within most plots.

None of the trees selected had been recorded as having stem damage, but examination of the images indicated that some trees had received stem damage, and some were edge trees. Examination of measured branch diameters, and the differences between measured and predicted branch diameters, with respect to assigned stem damage classes indicated that large branch diameters and large differences associated with stem damage / edge effects.

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## INTRODUCTION

TreeD is a system that allows tree characteristics to be measured from digital images, and is the successor to PhotoMARVL (which used photographic film).
TreeD is being used within the Stand Growth Modelling Cooperative to determine how well the branching module within TreeBLOSSIM (an integrated stem and branch growth model) performs for sites throughout New Zealand.

This report documents the results of a comparison between TreeD measurements and TreeBLOSSIM predictions for trees within Permanent Sample Plots (PSPs) on the West Coast of the South Island.

## METHODS

### Selection of PSPs

The Stand Growth Modelling Cooperative does not have any trials on the West Coast, so this study utilised PSPs from the WD460 series that are owned by Timberland West Coast.
The PSPs were selected so that the impact of varying amount of stem damage between otherwise similar PSPs could be investigated.

Potential PSPs were selected taking into account:

- the forest,
- the mean top height of the trees (should be greater than 25 m to obtain a clear view of a reasonable length of stem for measuring branch diameters),
- the stocking,
- the percentage of trees that had been noted as having a defect (in any remeasurement).

These potential PSPs were discussed with Ross Jackson (Timberlands West Coast representative on the Stand Growth Modelling Cooperative), from which fourteen PSPs (Table 1 and Table 2) were selected for measurement, allowing TreeBLOSSIM performance to compared for PSPs with:

- similar stocking but varying percentage of trees damaged within the same forest
- similar percentage of damage and similar stocking between forests.

The current stocking in these plots varied between 160 and 410 stems/ha. The percentage of trees with defects varied from 11% to 59%. The age of the trees, at the last re-measurement, varied between 16 and 21 years (plots measured in either 2003 or 2004).

## Selection of sample trees

As in previous PhotoMARVL studies, all the trees in a given PSP were ranked according to DBH (at last re-measurement) and sample trees selected at given percentage ranks, i.e:

- if there are n trees in the plot, then the ranks are 1….n
- the percentage rank for $j^{th}$ tree is $100 \times j/n$

For this study, undamaged trees whose percentage rank was close to 10, 30, 50, 70, 90, and 100 were selected in the office. In the field, if any selected tree was unsuitable to image, it was replaced by the next most suitable tree of a similar percentage rank. The sample trees and image numbers are listed in Appendix 1.

## Image Analysis

Each image was imported into the TreeD system and the following recorded for each branch cluster visible on the image:

- stem diameter immediately below the cluster
- height to the base of the cluster
- height to the top of the cluster
- diameter of the largest branch visible in the cluster (*BDI*)

From examining the images, it was clear that there were large differences in crown structure between different forests (Appendix 2). In some of the forests, the tree crowns were quite light (i.e. low amounts of foliage, like 1978 Genetic Gain Trial in Golden Downs), whereas in other forests the crowns were heavier (more like the 1978 Genetic Gain Trial in Longwood, Southland).

As a consequence it was decided to run TreeBLOSSIM in two ways:

- by selecting Westland as the region
- by selecting Southland as the region

## Functions within TreeBLOSSIM for Westland Region

### Individual Tree Growth Model

The SGMC has not developed an individual tree growth model for the Westland Region, consequently another Individual Tree Growth Model needed to be assigned as a default. The Nelson Region model was implemented as the default.

### Branching Functions

The site and stocking potentials within the branching model were developed using branch measurements, collected at the time of pruning, from SGMC trials. As there are no SGMC trials in Westland, the site and stocking potentials for the Nelson region were assigned as defaults.

Other branch functions for the Westland Region were derived using data collected from 8 trees in Mawhera forest, Westland. There was quite a lot of hardwood shrub at this site, but its impact on branching is not known. This study will indicate whether these functions are generally applicable to forests within the Westland Region.

**Functions within TreeBLOSSIM for Southland Region**

Individual Tree Growth Model

The individual tree growth model for the Southland Region is implemented.

Branching Functions

The site and stocking potentials for the Southland Region are implemented.
Other branch functions for the Southland Region were derived using data collected from 8 trees in Taringatura forest, Southland.

**Comparison of differences between Southland and Westland branch models**

The functions that were considered to have the most impact on model predictions were:

- site and stocking potentials (Figure 1)
- number of branch clusters in an annual shoot (
- Figure **2**)

The curves in Figure 1 indicate that branch diameters will be larger in the Southland region compared to the Nelson, and hence the Westland regions.
The curves in
Figure **2** indicate that the number of branch clusters in a 1.5 m annual shoot length will be slightly less for the Southland Region compared to the Westland region.
A 1.5 m annual shoot length was chosen as a realistic annual shoot length from current height and age of PSPs (Table 1).

**TreeBLOSSIM runs**

For each PSP, the latest re-measurement data were imported into TreeBLOSSIMv3.1. The thinning and pruning history were added. Mortality was set to zero percent, and any tree mortality was included as a thinning event.
TreeBLOSSIMv3.1 was run twice, once using the Westland model and once using the Southland model.

**Comparison of TreeD measurements with TreeBLOSSIM predictions**

For each tree, the TreeBLOSSIM branching pattern for the section of stem measured by TreeD was extracted. The position of each cluster and the diameter of the largest branch in that cluster (*BDTB)* were retained.

The data for each tree was then summarised to give:

$BDI_{max}$: the maximum branch diameter measured on the TreeD image (i.e. maximum value of *BDI* for the tree)

$BDTB_{max}$: the maximum branch diameter predicted by TreeBLOSSIM for the relevant stem section (i.e. the maximum value of *BDTB* for the stem section)

$BDI_{av}$: the mean branch diameter measured by TreeD (i.e. average value of *BDI* for the tree)

$BDTB_{av}$: the mean branch diameter predicted by TreeBLOSSIM for the relevant stem section (i.e. average value of *BDTB* for the stem section)

*CLI*: number of branch clusters on the stem section measured by TreeD

*CLTB*: number of branch clusters on the same stem section in the TreeBLOSSIM prediction
*zonelength*: height to base of highest cluster – height to base of lowest cluster, both measured from the image

The following differences were then calculated for each tree:

$DIFF_{max} = BDI_{max} - BDTB_{max}$

$DIFF_{av} = BDI_{av} - BDTB_{av}$

$DIFF_{CL} = (CLI - CLTB) / zonelength$

These differences were then plotted against the relative position of the tree in the DBH distribution (equivalent to percentage rank) for each plot.

**Examination of errors with respect to stem damage**

As with other studies, there were a few trees with large values of $DIFF_{max}$ and $DIFF_{av}$. The effect of stem damage on these values was examined by classifying individual trees into "defect classes":

0: no record of stem defects in PSP system and no obvious damage visible in image
2: stem damage visible on image
3: image indicates tree is either an edge tree or in a large gap.

Bar charts were then plotted showing:
maximum branch diameter visible on image ($BDI_{max}$)
$DIFF_{max}$
average branch diameter ($BDI_{av}$)
$DIFF_{av}$
$BDI_{max} - BDI_{av}$

## RESULTS

Determining what is an acceptable performance for a complex model, like TreeBLOSSIM, is a matter of judgement. In this study the model is considered to have performed well for predicting branch diameters on an individual tree if the absolute values of $DIFF_{max}$ and $DIFF_{av}$ are less than or equal to 20 mm. This was based on the fact that measured branch diameters from TreeD are assumed to be within 10 mm of the true value; and that a model prediction within 10 mm of the true value would be reasonable.
As well as performing well for individual trees, the model should perform equally well for all trees in a plot.

### $DIFF_{max}$, and $DIFF_{av}$

Individual tree values of $DIFF_{max}$, and $DIFF_{av}$, from running TreeBLOSSIM v3.1 for the two different regions are shown in **Figure 3** to Figure 10. From examining these figures, it can see seen that there is generally no trend between either $DIFF_{max}$, or $DIFF_{av}$ and the relative position of the tree it the DBH distribution. They also show that the Southland model has performed better than the Westland model for most plots.

Analyses of the data confirmed these visual assumptions. For an individual plot the correlation, between either $DIFF_{max}$, or $DIFF_{av}$ and the relative position of the tree in the DBH distribution, was generally not significantly different from zero (p=0.05).

The SAS procedure PROC GLM was used (with plot as a class variable and relative position as a continuous variable) to calculate least square mean values for $DIFF_{max}$, and $DIFF_{av}$ at the plot level (Table 3). A least square mean is similar to a mean value, but is estimated to account for any imbalances in the design of an experiment. Comparison of the least square means for the Westland and Southland model, indicate that the Southland model has performed better for all forests except Paparoa and Victoria Forest Park (plots WD 460 34/09, WD 460 51/21 and WD460 51/35).

### $DIFF_{CL}$

The SAS procedure PROC GLM was also used (with plot as a class variable and relative position as a continuous variable) to calculate least square mean values for $DIFF_{CL}$ (Table 4) from running both the Westland and Southland models. The least square mean values were generally not significantly different from zero (p=0.05), but the Westland model appeared to be slightly better. The individual tree values of $DIFF_{CL}$ when running the Westland are shown in Figure 11.

**Influence of stem damage**

Several pairs of PSPs were selected in order to compare errors in model predictions for "undamaged trees" between PSPs with varying amounts of stem damage as estimated from data in the PSP system (Table 2). According to the PSP system none of the trees selected had stem damage. However from examining the images, 15 of the trees had some form of stem damage, and 7 trees could be considered as edge trees. This means that the initial comparisons proposed are not valid.

As an initial attempt to understand how stem damage and branch size are interrelated , bar charts were produced showing the values of :

- maximum branch diameter visible on image ($BDI_{max}$)
- $DIFF_{max}$
- Average branch diameter ($BDI_{av}$)
- $DIFF_{av}$
- $BDI_{max}$ - $BDI_{av}$

with respect to "damage class" (Figure 12). These indicate that the proportion of trees that have received stem damage vary with these measures of branching. From examining these graphs, it is considered that a tree in these plots is likely to have received stem damage if:

- maximum branch diameter visible on image ($BDI_{max}$) > 140 mm
- $DIFF_{max}$ > 80 mm
- $BDI_{max}$ - $BDI_{av}$ > 60 mm

## DISCUSSION

TreeD images were collected for 14 PSPs on the West Coast. Measurements of branching taken from the images were compared with TreeBLOSSIM predictions.

An initial examination of the images showed that the crown structure varied between forests (Appendix 2). Visually the tree in some forests were similar trees from the Nelson region, and trees from other forests were similar to trees from the Southland region.

As a consequence, TreeBLOSSIM was run in two ways, once using the default model for the Westland region and once using the model for the Southland model.

Comparing TreeBLOSSIM predictions with measurements from the images indicated that:

- The Southland model was more appropriate as a predictor of branch diameter for all forests other than Paparoa and Victoria Forest Park.
- There was little difference in the prediction of number of branch clusters between the Westland and Southland model, but the Westland model was considered to be better.
- TreeBLOSSIM performed equally well for a range of tree sizes within most plots.
- There are interactions between stem damage and branch diameter, with many of the larger branches being attributable to some form of stem damage.

### Future research

The default growth model for Westland forests will need to be modified in the next version of TreeBLOSSIM.
There will definitely need to be two sub-regions, but some further testing is required to determine the appropriate functions for each region.
Sub-region 1 – forests where the crown structure is similar to Southland forests:

- Determine whether it would be more appropriate to combine the branching functions from Westland Region with Southland Growth Model, rather than use the current Southland model.

Sub-region 2 – forests where the crown structure is similar to Nelson forests:

- Determine whether it would be more appropriate to use the Nelson branch functions, rather that the current Westland functions.

Another possible direction is to investigate whether the errors from running TreeBLOSSIM are related to environmental variables available in the Land Environments of New Zealand (Leathwick *et al.*, 2003). If this were the case, then TreeBLOSSIM could be revised to account for such variables.

At present it is suggested that the Southland model be used for most forests. The Westland model should be used for Paparoa, Victoria Forest Park and any other forest with similar looking trees.

## REFERENCES

Leathwick, J. *et al.* 2003: Land environments of New Zealand. Ministry of Environment, Wellington.

## ACKNOWLEDGEMENTS

Thanks are due to Ross Jackson and his staff (Timberlands West Coast) for providing access to the forests and helping clear understory vegetation.

**Table 1. PSPs for which TreeD images have been obtained.**

| Forest Code | Plot Id. | Age (years) at last measure. | Current age (years) | Stems/ha | Mean top height (m) | % trees with defects |
|---|---|---|---|---|---|---|
| MAHN | WD460/17 5/0 | 18.5 | 20 | 360 | 25.1 | 11 |
| MAHN | WD460/17 7/0 | 19 | 22 | 360 | 27.5 | 49 |
| | | | | | | |
| KINR | WD460/19 4/0 | 16.4 | 19 | 250 | 25.1 | 36 |
| KINR | WD460/19 8/0 | 20.15 | 22 | 300 | 27.6 | 16 |
| | | | | | | |
| HOCH | WD460/26 25/0 | 17.15 | 20 | 160 | 26.9 | 56 |
| HOCH | WD460/26 27/0 | 17.15 | 20 | 210 | 25.4 | 59 |
| | | | | | | |
| NEMO | WD460/31 50/0 | 19.4 | 22 | 410 | 26.3 | 54 |
| NEMO | WD460/31 66/0 | 19.4 | 22 | 310 | 31.9 | 28 |
| | | | | | | |
| MWRE | WD460/33 34/0 | 21.1 | 24 | 260 | 32.1 | 35 |
| MWRE | WD460/33 42/0 | 20.1 | 23 | 260 | 34.0 | 15 |
| | | | | | | |
| PPRO | WD460/34 9/0 | 21.1 | 24 | 250 | 30.2 | 32 |
| | | | | | | |
| WMWD | WD460/43 18/0 | 17.25 | 20 | 270 | 22.8 | 26 |
| | | | | | | |
| VTFP* | WD460/51 21/0 | 17.15 | 20 | 310 | 25.3 | 16 |
| VTFP | WD460/51 35/0 | 18.1 | 21 | 310 | 28.5 | 26 |

*: this is the only one of these PSPs that is recorded as containing GF14 trees.

**Table 2. Comments on plots selected and comparisons**

| Forest Code | Comment |
|---|---|
| MAHN | 2 plots selected have the same stocking but different percentage trees of with defects |
| KINR | 2 plots selected have a similar stocking but different percentage of trees with defects |
| HOCH | 2 plots selected have similar stocking and percentage of trees with defects. |
| NEMO | 2 plots selected have a similar stocking but different percentage of trees with defects |
| MWRE | 2 plots selected have the same stocking but different percentage trees of with defects |
| PPRO | Only 1 plot selected. The stocking and percentage trees with defects is similar to plots in KINR and MWRE that will allow for comparisons across forests |
| WMWD | Only 1 plot selected. Stocking and percentage trees with defects similar to other forests. Conditions closest to those in PPRO |
| VTFP | 2 plots have been selected. They have the same stocking, but different percentage damage. One plot is recorded as being a GF14 seedlot. This is worth measuring as TreeBLOSSIM is based on GF14 data. Based on similar stocking and percentage defect, one plot maybe compared with a plot in KINR and the other plots may be compared with a plot in NEMO |

**Table 3. Least Square Mean values of *DIFF*$_{max}$.**

| Plot | *DIFF*$_{max}$ (mm) Westland model | *DIFF*$_{max}$ (mm) Southland model | *DIFF*$_{av}$ (mm) Westland model | *DIFF*$_{av}$ (mm) Southland model |
|---|---|---|---|---|
| WD460/17 5/0 | 35 | 0 | 16 | -8 |
| WD460/17 7/0 | 29 | -4 | 11 | -11 |
| WD460/19 4/0 | 46 | 8 | 19 | -5 |
| WD460/19 8/0 | 54 | 15 | 21 | -2 |
| WD460/26 25/0 | 50 | 5 | 33 | 6 |
| WD460/26 27/0 | 55 | 9 | 31 | 1 |
| WD460/31 50/0 | 28 | -6 | 18 | -6 |
| WD460/31 66/0 | 27 | -11 | 13 | -8 |
| WD460/33 34/0 | 54 | 9 | 36 | 10 |
| WD460/33 42/0 | 46 | 5 | 29 | 5 |
| WD460/34 9/0 | 18 | -24 | 7 | -18 |
| WD460/43 18/0 | 44 | 3 | 19 | -6 |
| WD460/51 21/0 | 22 | -15 | 19 | -6 |
| WD460/51 35/0 | 18 | -20 | 10 | -16 |

**Table 4. Least Square Mean values of *DIFF*$_{CL}$.**

| Plot | *DIFF*$_{CL}$ Westland model | *DIFF*$_{CL}$ Southland model |
|---|---|---|
| WD460/17 5/0 | -0.03 | 0.15 |
| WD460/17 7/0 | -0.05 | 0.19 |
| WD460/19 4/0 | 0.63 | 0.89 |
| WD460/19 8/0 | 0.28 | 0.52 |
| WD460/26 25/0 | -0.11 | 0.06 |
| WD460/26 27/0 | 0.03 | 0.27 |
| WD460/31 50/0 | 0.01 | 0.24 |
| WD460/31 66/0 | -0.12 | 0.16 |
| WD460/33 34/0 | -0.38 | -0.13 |
| WD460/33 42/0 | 0.13 | 0.39 |
| WD460/34 9/0 | 0.02 | 0.28 |
| WD460/43 18/0 | 0.11 | 0.45 |
| WD460/51 21/0 | 0.09 | 0.31 |
| WD460/51 35/0 | 0.41 | 0.65 |

**Figure 1. Equations for predicting site and stocking potentials for Westland region (Nelson-new) and Southland region (Southland-new) in TreeBLOSSIM v3.1.**

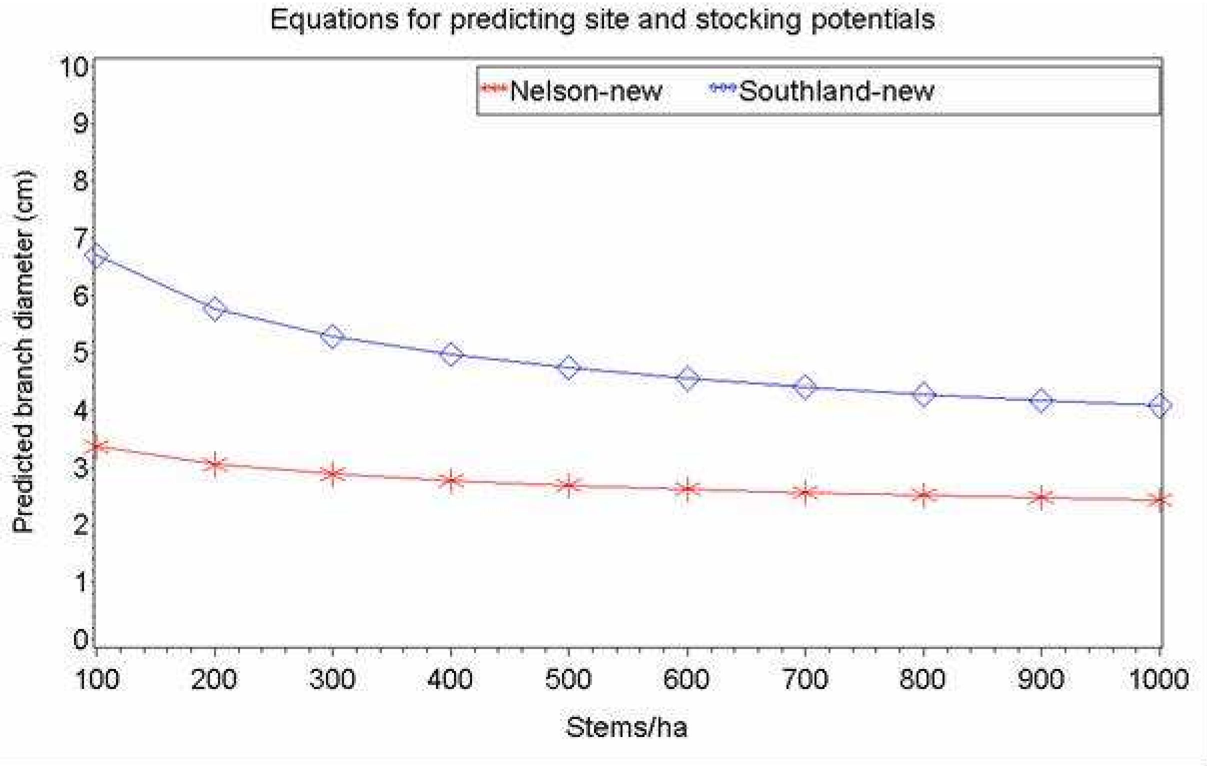


**Figure 2. Equations for predicting number of branch clusters in an annual shoot for Westland and Southland growth modelling region.**

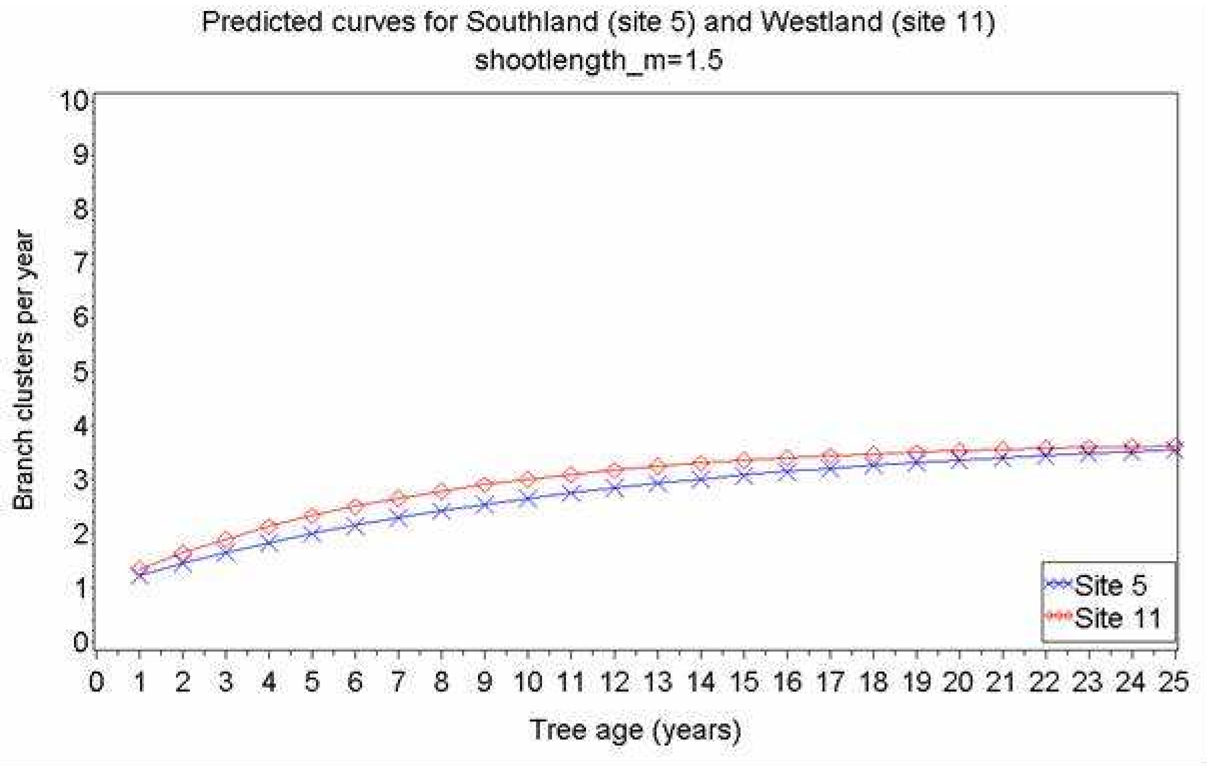

**Figure 3.** Individual tree values of $DIFF_{max}$ (maximum) and $DIFF_{av}$ (average) from running TreeBLOSSIM Version 3.1 for plots from Mahinapua.

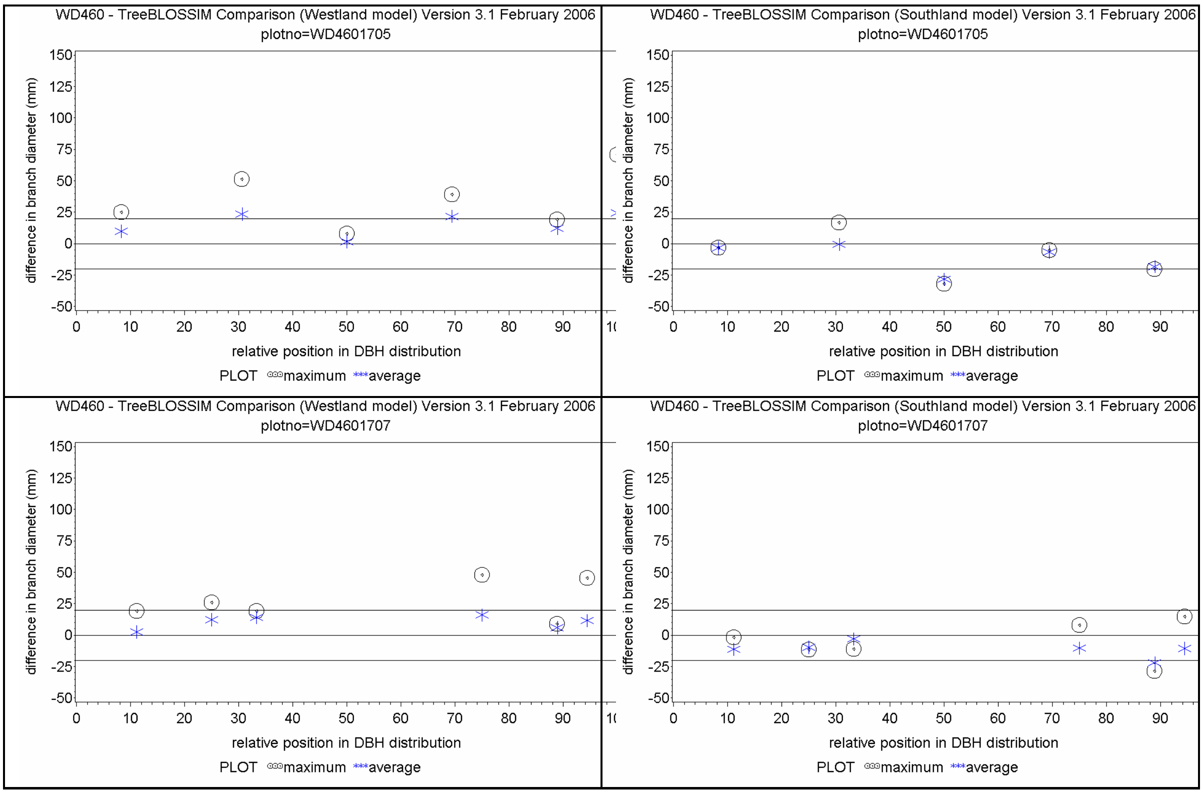


**Figure 4. Individual tree values of $DIFF_{max}$ (maximum) and $DIFF_{av}$ (average) from running TreeBLOSSIM Version 3.1 for plots from Kaniere.**

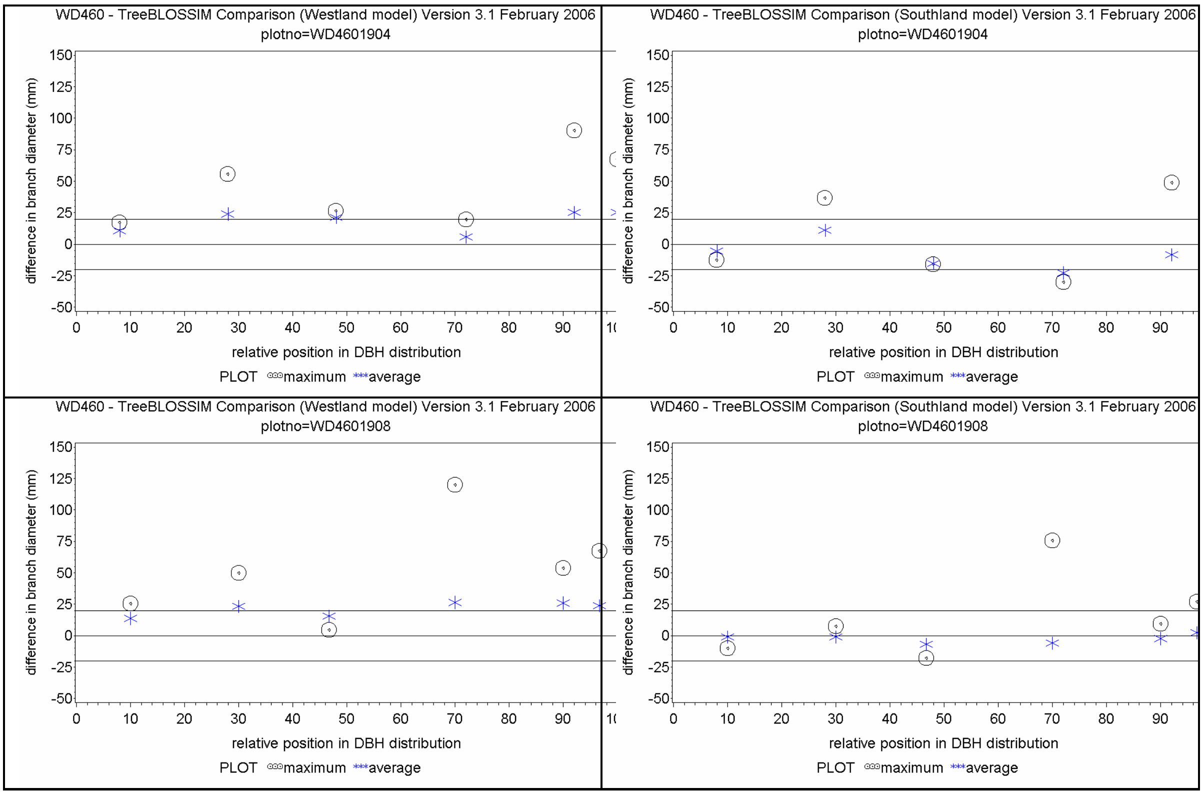

**Figure 5. Individual tree values of $DIFF_{max}$ (maximum) and $DIFF_{av}$ (average) from running TreeBLOSSIM Version 3.1 for plots from Hochstetter.**

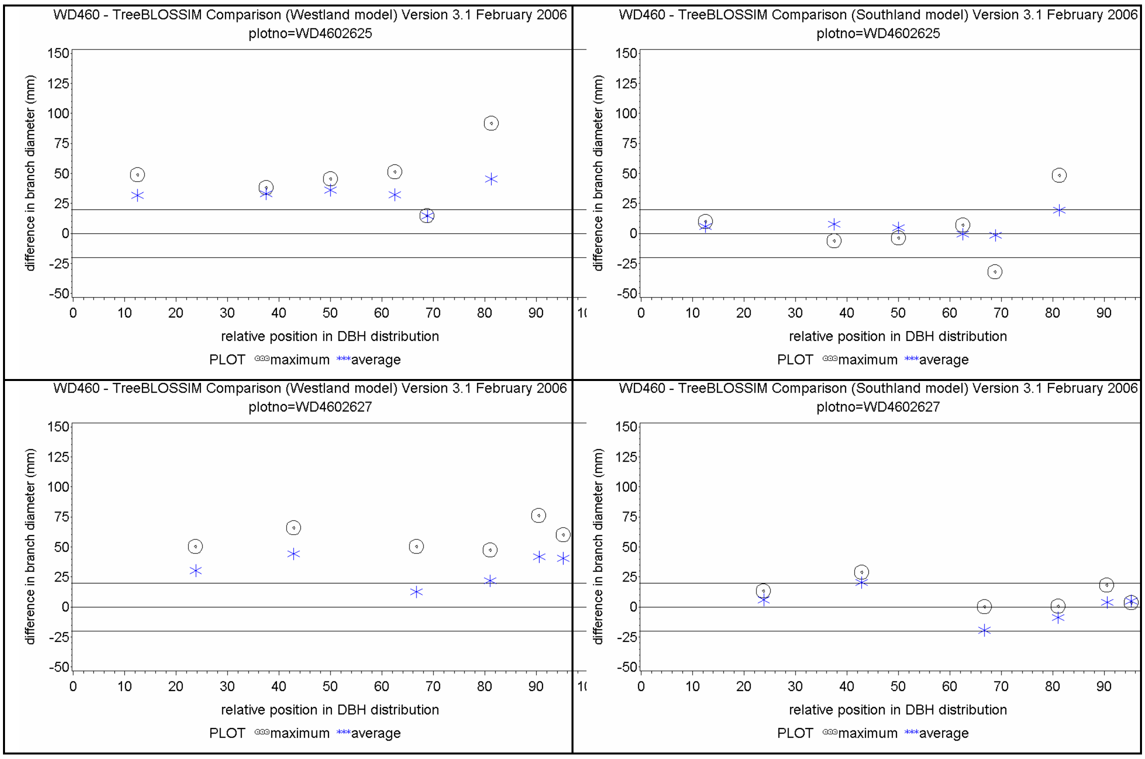


**Figure 6. Individual tree values of $DIFF_{max}$ (maximum) and $DIFF_{av}$ (average) from running TreeBLOSSIM Version 3.1 for plots from Nemona.**

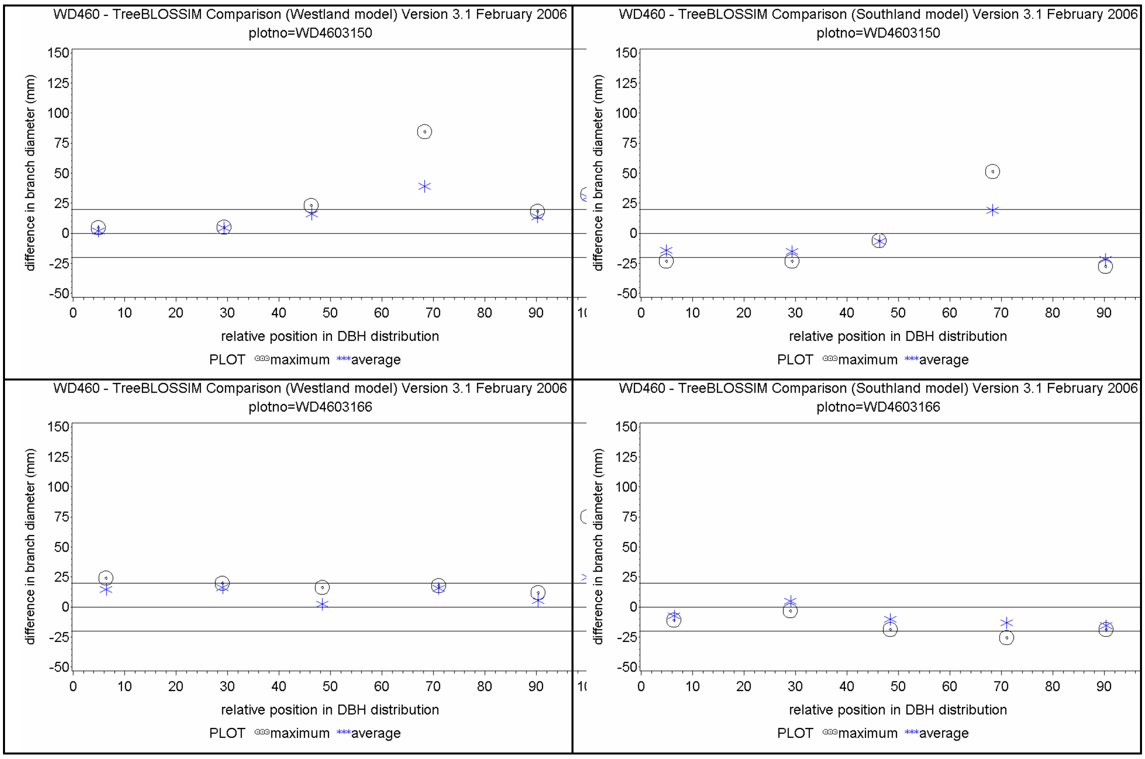

**Figure 7.** **Individual tree values of $DIFF_{max}$ (maximum) and $DIFF_{av}$ (average) from running TreeBLOSSIM Version 3.1 for plots from Mawhera.**

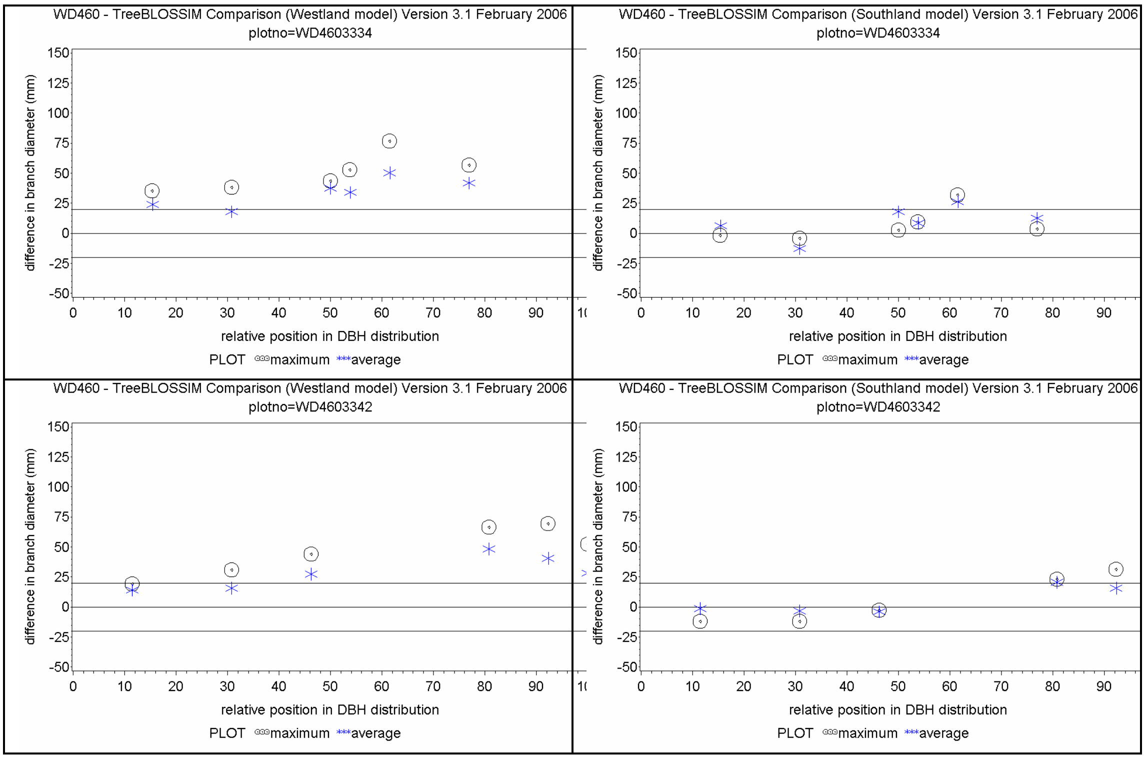


**Figure 8.** **Individual tree values of $DIFF_{max}$ (maximum) and $DIFF_{av}$ (average) from running TreeBLOSSIM Version 3.1 for plots from Paparoa.**

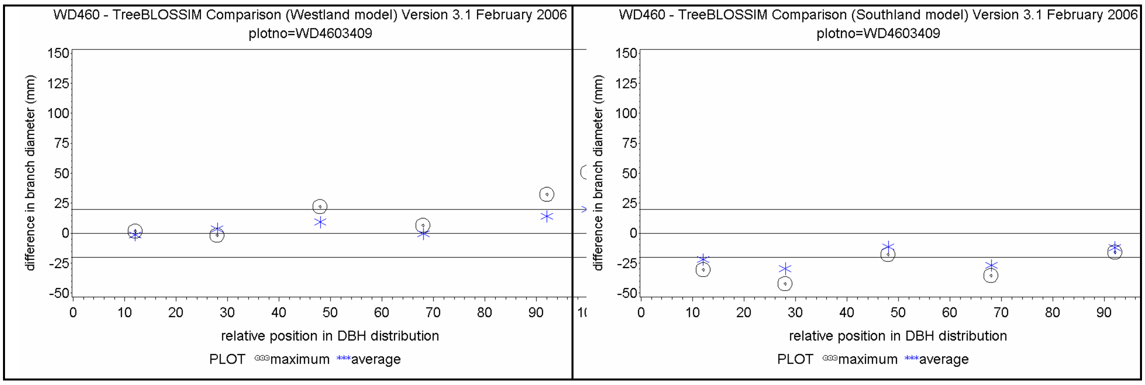

**Figure 9.** **Individual tree values of $DIFF_{max}$ (maximum) and $DIFF_{av}$ (average) from running TreeBLOSSIM Version 3.1 for plots from Waimea**

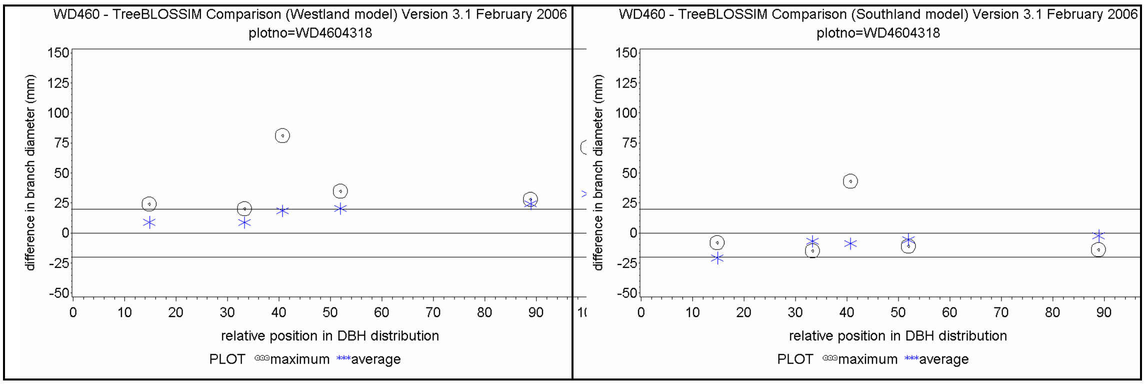


**Figure 10.** **Individual tree values of $DIFF_{max}$ (maximum) and $DIFF_{av}$ (average) from running TreeBLOSSIM Version 3.1 for plots from Victoria SFP.**

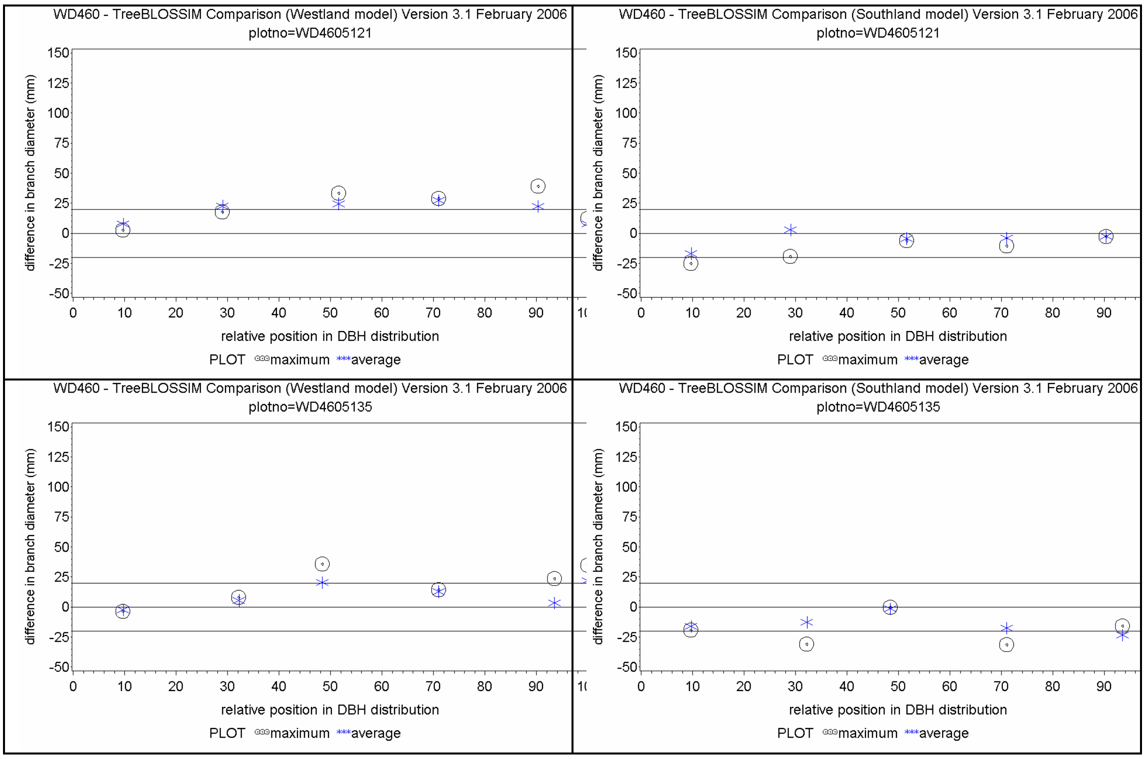

**Figure 11. Individual tree values of $DIFF_{CL}$ from running TreeBLOSSIM v3.1 using the Westland model.**

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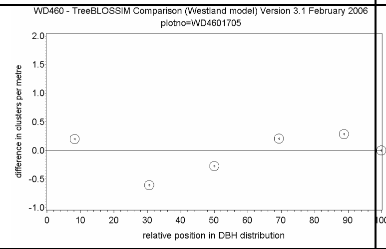
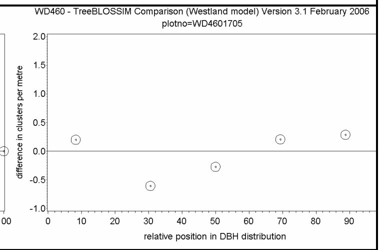
<tr><td>Forest</td><td></td><td></td></tr>
<tr><td>MAHN</td><td>
</td><td>
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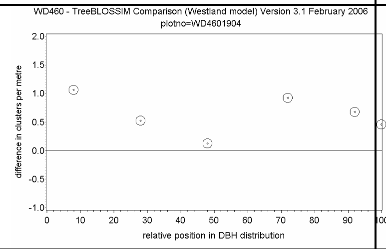
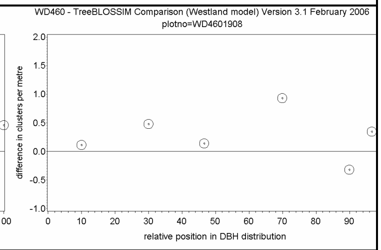
<tr><td>KINR</td><td>
</td><td>
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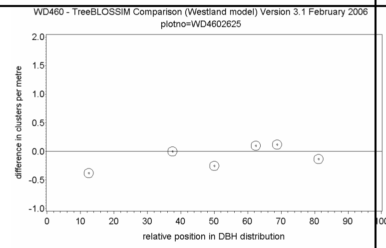
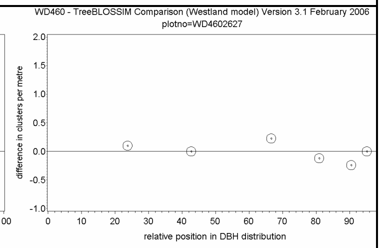
<tr><td>HOCH</td><td>
</td><td>
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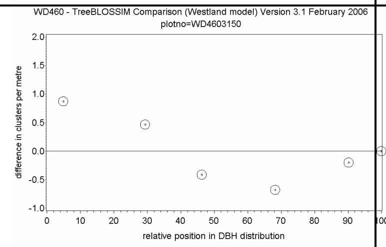
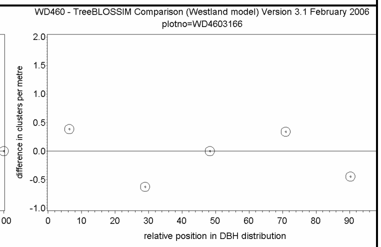
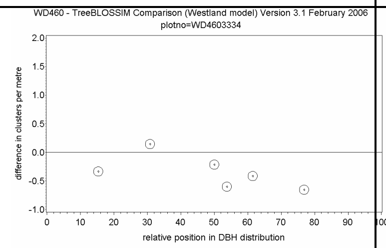
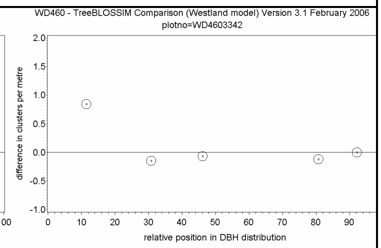
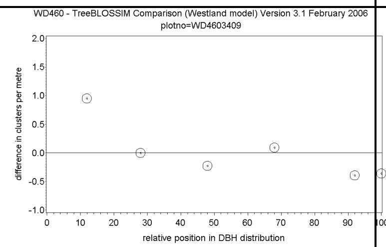
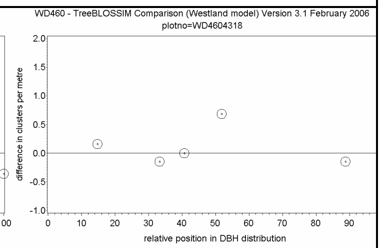
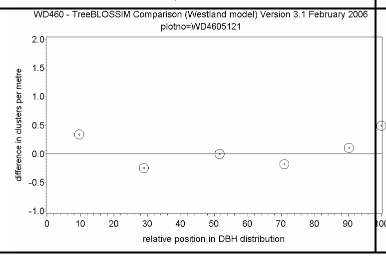
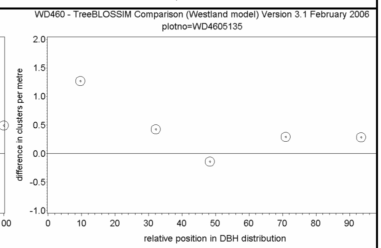
<tr><td>NEMO</td><td>
</td><td>
</td></tr>
<tr><td>MWRE</td><td>
</td><td>
</td></tr>
<tr><td>PPRO (left image)<br>WMWD (right image)</td><td>
</td><td>
</td></tr>
<tr><td>VTFP</td><td>
</td><td>
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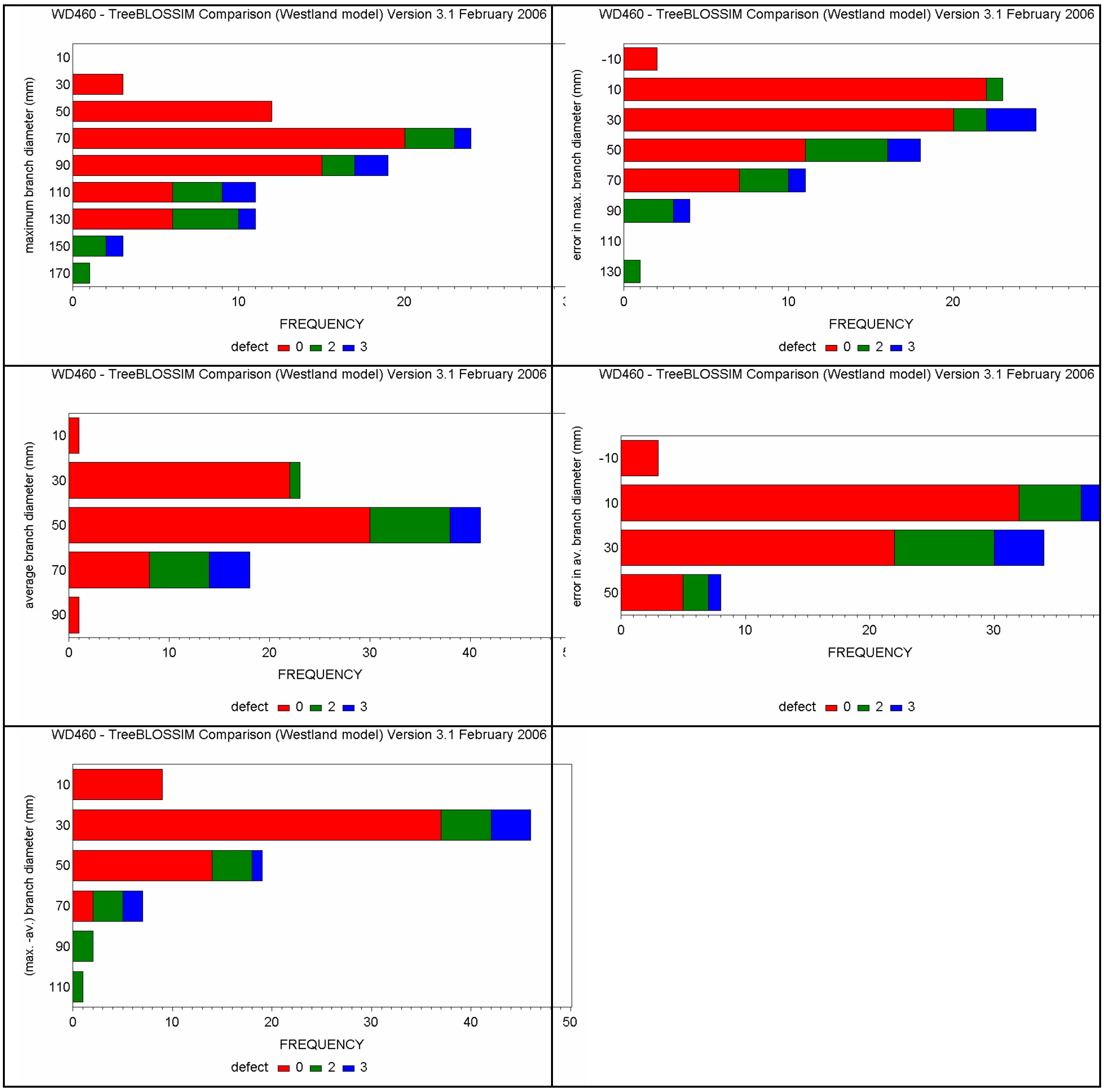
</table>

**Figure 12. Comparison of branching variables with respect to stem damage.**



**Appendix 1. List of sample trees.**

| Image | Forest | PSP | Q_row | Treeno | Treekey | Rank (%) |
|---|---|---|---|---|---|---|
| 3759 | MAHN | WD4601705 | 0 | 2 | 3 | 8.3 |
| 3769 | MAHN | WD4601705 | 0 | 7 | 8 | 30.6 |
| 3763 | MAHN | WD4601705 | 0 | 15 | 15 | 50 |
| 3765 | MAHN | WD4601705 | 0 | 12 | 12 | 69.4 |
| 3767 | MAHN | WD4601705 | 0 | 18 | 18 | 88.9 |
| 3761 | MAHN | WD4601705 | 0 | 35 | 33 | 100 |
| 3747 | MAHN | WD4601707 | 2 | 11 | 12 | 11.1 |
| 3755 | MAHN | WD4601707 | 1 | 3 | 4 | 25 |
| 3757 | MAHN | WD4601707 | 4 | 27 | 30 | 33.3 |
| 3753 | MAHN | WD4601707 | 1 | 9 | 10 | 75 |
| 3749 | MAHN | WD4601707 | 2 | 13 | 14 | 88.9 |
| 3751 | MAHN | WD4601707 | 2 | 14 | 15 | 94.4 |
| 3779 | KINR | WD4601904 | 0 | 21 | 18 | 8 |
| 3771 | KINR | WD4601904 | 0 | 7 | 7 | 28 |
| 3777 | KINR | WD4601904 | 0 | 2 | 2 | 48 |
| 3775 | KINR | WD4601904 | 0 | 11 | 10 | 72 |
| 3773 | KINR | WD4601904 | 2 | 8 | 24 | 92 |
| 3781 | KINR | WD4601904 | 3 | 13 | 25 | 100 |
| 3788 | KINR | WD4601908 | 2 | 14 | 28 | 10 |
| 3790 | KINR | WD4601908 | 2 | 16 | 29 | 30 |
| 3783 | KINR | WD4601908 | 0 | 8 | 7 | 46.7 |
| 3792 | KINR | WD4601908 | 4 | 24 | 33 | 70 |
| 3785 | KINR | WD4601908 | 0 | 7 | 6 | 90 |
| 3794 | KINR | WD4601908 | 0 | 31 | 22 | 96.7 |
| 3847 | HOCH | WD4602625 | 1 | 5 | 7 | 12.5 |
| 3849 | HOCH | WD4602625 | 1 | 3 | 5 | 37.5 |
| 3845 | HOCH | WD4602625 | 1 | 2 | 4 | 50 |
| 3855 | HOCH | WD4602625 | 4 | 14 | 16 | 62.5 |
| 3853 | HOCH | WD4602625 | 3 | 10 | 12 | 68.8 |
| 3851 | HOCH | WD4602625 | 2 | 9 | 11 | 81.2 |
| 3863 | HOCH | WD4602627 | 2 | 8 | 10 | 23.8 |
| 3859 | HOCH | WD4602627 | 3 | 16 | 18 | 42.8 |
| 3869 | HOCH | WD4602627 | 2 | 9 | 11 | 66.7 |
| 3861 | HOCH | WD4602627 | 1 | 4 | 6 | 81 |
| 3857 | HOCH | WD4602627 | 4 | 18 | 20 | 90.5 |
| 3865 | HOCH | WD4602627 | 2 | 7 | 9 | 95.2 |
| 3827 | NEMO | WD4603150 | 4 | 33 | 34 | 4.9 |
| 3821 | NEMO | WD4603150 | 2 | 17 | 18 | 29.3 |
| 3823 | NEMO | WD4603150 | 2 | 18 | 19 | 46.3 |
| 3825 | NEMO | WD4603150 | 1 | 7 | 8 | 68.3 |
| 3829 | NEMO | WD4603150 | 4 | 34 | 35 | 90.2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 3831 | NEMO | WD4603150 | 3 | 30 | 31 | 100 |
| 3808 | NEMO | WD4603166 | 1 | 2 | 3 | 6.4 |
| 3812 | NEMO | WD4603166 | 3 | 18 | 19 | 29 |
| 3816 | NEMO | WD4603166 | 3 | 22 | 23 | 48.4 |
| 3810 | NEMO | WD4603166 | 2 | 11 | 12 | 71 |
| 3819 | NEMO | WD4603166 | 3 | 23 | 24 | 90.3 |
| 3814 | NEMO | WD4603166 | 3 | 21 | 22 | 100 |
| 3841 | MWRE | WD4603334 | 3 | 14 | 16 | 15.4 |
| 3833 | MWRE | WD4603334 | 3 | 18 | 19 | 30.8 |
| 3835 | MWRE | WD4603334 | 2 | 10 | 11 | 50 |
| 3843 | MWRE | WD4603334 | 3 | 19 | 20 | 53.8 |
| 3839 | MWRE | WD4603334 | 3 | 16 | 17 | 61.5 |
| 3837 | MWRE | WD4603334 | 2 | 11 | 12 | 76.9 |
| 3894 | MWRE | WD4603342 | 2 | 9 | 10 | 11.5 |
| 3886 | MWRE | WD4603342 | 4 | 24 | 25 | 30.8 |
| 3884 | MWRE | WD4603342 | 3 | 17 | 18 | 46.2 |
| 3888 | MWRE | WD4603342 | 3 | 18 | 19 | 80.8 |
| 3890 | MWRE | WD4603342 | 3 | 14 | 15 | 92.3 |
| 3892 | MWRE | WD4603342 | 1 | 2 | 3 | 100 |
| 3898 | PPRO | WD4603409 | 2 | 7 | 8 | 12 |
| 3896 | PPRO | WD4603409 | 2 | 5 | 6 | 28 |
| 3904 | PPRO | WD4603409 | 4 | 20 | 21 | 48 |
| 3906 | PPRO | WD4603409 | 4 | 25 | 26 | 68 |
| 3900 | PPRO | WD4603409 | 2 | 11 | 12 | 92 |
| 3902 | PPRO | WD4603409 | 3 | 15 | 16 | 100 |
| 3806 | WMWD | WD4604318 | 0 | 13 | 13 | 14.8 |
| 3802 | WMWD | WD4604318 | 0 | 4 | 5 | 33.3 |
| 3798 | WMWD | WD4604318 | 0 | 24 | 22 | 40.7 |
| 3804 | WMWD | WD4604318 | 0 | 11 | 11 | 51.9 |
| 3800 | WMWD | WD4604318 | 0 | 16 | 15 | 88.9 |
| 3796 | WMWD | WD4604318 | 0 | 26 | 24 | 100 |
| 3877 | VTFP | WD4605121 | 0 | 1 | 2 | 9.7 |
| 3873 | VTFP | WD4605121 | 0 | 3 | 4 | 29 |
| 3871 | VTFP | WD4605121 | 0 | 25 | 23 | 51.6 |
| 3881 | VTFP | WD4605121 | 0 | 21 | 20 | 71 |
| 3875 | VTFP | WD4605121 | 0 | 4 | 5 | 90.3 |
| 3879 | VTFP | WD4605121 | 0 | 10 | 10 | 100 |
| 3914 | VTFP | WD4605135 | 3 | 21 | 22 | 9.7 |
| 3912 | VTFP | WD4605135 | 3 | 23 | 24 | 32.2 |
| 3910 | VTFP | WD4605135 | 2 | 12 | 13 | 48.4 |
| 3916 | VTFP | WD4605135 | 1 | 4 | 5 | 71 |
| 3918 | VTFP | WD4605135 | 4 | 30 | 31 | 93.5 |
| 3908 | VTFP | WD4605135 | 2 | 7 | 8 | 100 |

**Appendix 2.** TreeD images showing differences in crown structure between forests in Westland: left hand image from Kaniere, right hand image from Paparoa