Comparison of TreeBLOSSIM predictions with field measurements: FR121/4 (Tairua) and FR121/7 (Huanui)

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Executive Summary

TreeBLOSSIM is an integrated tree and branch growth model for radiata pine. Given the limited database used to develop TreeBLOSSIM, it is important to determine the performance of the model for a wide range of sites throughout New Zealand. To this end a non-destructive, ground-based photogrammetric method (PhotoMARVL / TreeD) is being used to provide data for comparison with TreeBLOSSIM predictions.

This report documents the performance of TreeBLOSSIM for two SGMC trials in the FR121 series:

- FR121/4 was planted in Tairua Forest in 1990 to be representative of a high site index in the Auckland Clays Growth Modelling Region.
- FR121/7 was planted in Huanui Forest in 1990 to be representative of a high basal area site on the East Coast of the North Island.

The performance of TreeBLOSSIM in predicting branch diameter and number of branch clusters has been examined for a range of tree sizes from different silviculture treatments and different seedlots in these two trials.

- There were no obvious trends in the model predictions with respect to tree position within the DBH distribution.
- There were negligible differences between the GF14, GF16 and GF25 seedlots considered.
- For many trees, the predicted branch diameters were realistic. The major factor leading to poor prediction of branch diameter were instances of stem damage where the tree had a large branch that was not representative of the general branching pattern of that tree.
- While TreeBLOSSIM appeared to perform better for plots at higher final crop stockings, this may be an artefact of the higher number of trees with stem damage at the lower stockings.

Comparison of PhotoMARVL / TreeD data with TreeBLOSSIM predictions for a range of site qualities, silviculture treatments, and different seedlots for all the growth modelling regions will provide a comprehensive data set to determine where TreeBLOSSIM performs well and for model improvement.

Comparison of TreeBLOSSIM predictions with field measurements:
FR121/4 (Tairua) and FR121/7 (Huanui)

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INTRODUCTION

TreeBLOSSIM is an integrated tree and branch growth model for radiata pine. The branching functions in Version 3 (see SGMC Report No. 125) are specifically for GF14 seedlots and were developed from destructively sampling a few radiata pine trees at a limited number of sites throughout New Zealand.

Given the limited database used to develop TreeBLOSSIM, it is important to determine the performance of the model for a wide range of sites throughout New Zealand. To this end a non-destructive, ground-based photogrammetric method (PhotoMARVL / TreeD) is being used to provide data for comparison with TreeBLOSSIM predictions.

Two strategies are being used for data collection. One approach is to use SGMC trials. This allows TreeBLOSSIM to be tested across a range of silvicultural treatments and genetically improved seedlots at one site. The second approach is to use individual PSPs within a growth modelling region. This allows TreeBLOSSIM to be tested across a wider range of site conditions.

This report examines the performance of TreeBLOSSIM for two SGMC trials in the FR121 series, which were planted in 1990 / 1991:

- FR121/4 was planted in Tairua Forest in 1990 to be representative of a high site index in the Auckland Clays Growth Modelling Region.
- FR121/7 was planted in Huanui Forest in 1990 to be representative of a high basal area site on the East Coast of the North Island. Recently, Ross Wade (pers. comm.) has indicated that the site is not considered to be representative of the surrounding forest.

Further details on the design and layout of these two trial series are given in SGMC Reports Nos. 100 and 103.

METHODS

<u>Ground-based photogrammetric method (PhotoMARVL / TreeD)</u>

The ground-based photogrammetric method, used to obtain quantitative measurements of stem and branching characteristics, requires a clear view of the approx. lower 20 m of the stem in question. To obtain this view it may be necessary to clear ground vegetation and dead branches obscuring the stem. A hanging pole of known length provides a scale for the image. The system was originally developed to use film and named PhotoMARVL (Firth *et al.*, 2000). The system has now been upgraded to work with digital images and renamed as TreeD (Brownlie *et al.*, submitted).
The data from FR121/4 was collected in mid October 2004 using PhotoMARVL, while the data from FR121/7 was collected in early November 2005 using TreeD. The change of system should not have had any impact on the measurements.

Treatments selected

Within the FR121 series, there were generally only 2 PSPs planted with a GF14 seedlot, with the following silviculture treatments:

- Planted at 500 stems/ha and thinned to 200 stems/ha
- Planted at 1000 stems/ha and left unthinned and unpruned

The unthinned / unpruned treatment was not assessed because it was not considered to be representative of likely forest practice. Additionally it would have taken time to prune the dead branches to obtain a good view of the stem.

The plots selected were chosen to determine the performance of TreeBLOSSIM for:

- GF14, GF16 and GF25 seedlots with a common silvicultural treatment
- GF25 seedlot across a range of silvicultural treatments

The treatments selected at each site are shown in Table 1. An additional two treatments were measured in FR121/7 because these treatments were assessed destructively at FR121/11 (Shellocks, Canterbury) in September 2005.

Table 1. Plot number for treatments assessed in FR121/4 and FR121/7.

GF rating	Thinning Treatment	FR121/4 Tairua	FR121/7 Huanui
14	500⇨200 stem/ha, pruned	6_12	3_12
16	500⇨200 stem/ha, pruned	5_12	5_12
25	500⇨200 stem/ha, pruned	4_12	6_12
25	250⇨100 stems/ha, pruned		1_11
25	1000⇨400 stem/ha, pruned	8_13	8_13
25	1000⇨600 stem/ha, unpruned		14_16

Tree Selection

As in previous PhotoMARVL/ TreeD studies, all the trees in a given PSP were ranked according to DBH (at last measurement), i.e:

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

The number of trees sampled and the percentage ranks selected has varied between studies. For one plot 10 sample trees were selected in the office. These were trees whose percentage rank was closest to:

- 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 100%.

For the rest of the plots, 6 sample trees were selected in the office. These were trees whose percentage rank was closest to:

- 10%, 30%, 50%, 70%, 90%, 100%.

In addition the tree should not have had a defect code assigned at the last measurement.

In the field, a selected sample tree was occasionally replaced if the tree was badly damaged. The sample trees, for which images were taken, are shown in Appendix 1 (Table 7 and Table 8).

<u>Image analysis</u>

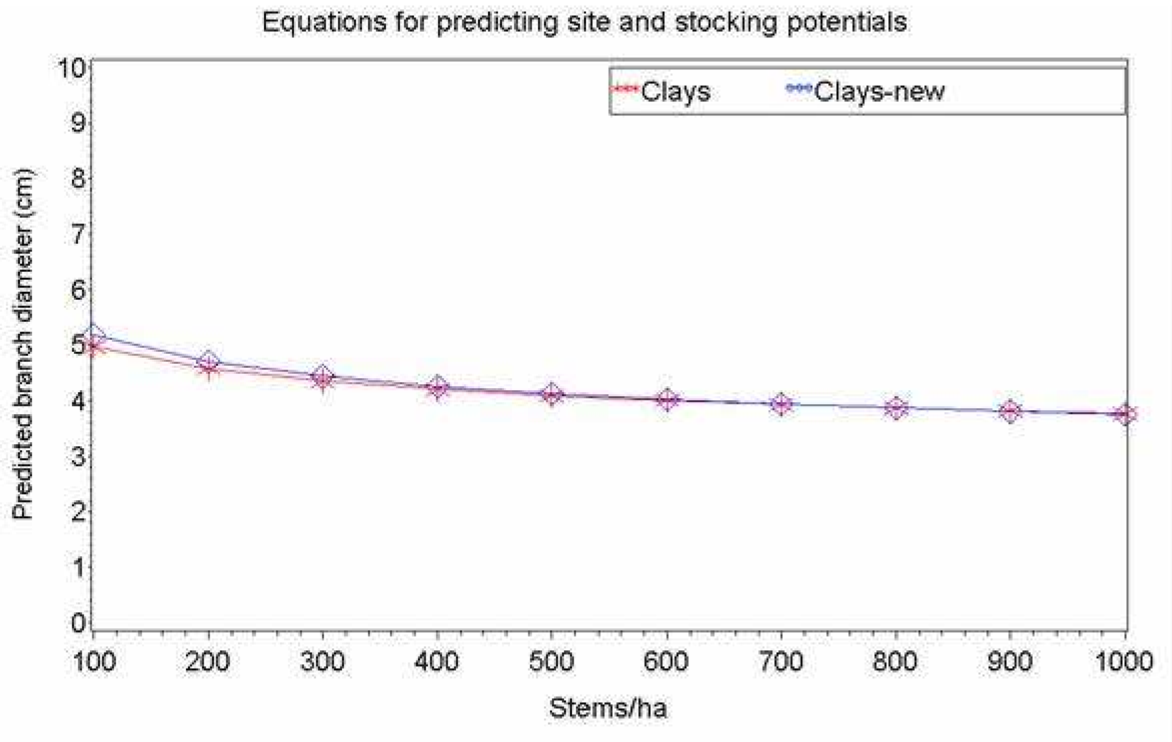
The following measurements were extracted from the images using the PhotoMARVL system (Tairua) or the TreeD system (Huanui):
- stem diameter below the cluster,
- height to base and top of the cluster,
- diameter of the largest branch in the cluster that was visible on the image (*BDI)*.

<u>TreeBLOSSIM simulations</u>

For each selected sample plot, the latest PSP measurements were imported into the most recent version of TreeBLOSSIM available at the time of analysis:
- For FR121/4, Tairua, it was Version 3.0
- For FR121/7, Huanui, it was Version 3.1

The site and stocking potentials were the only functions modified between these two versions of TreeBLOSSIM. There are regional coefficients for these two potentials, and the change in these coefficients for the Clays Growth Modelling region between Version 3 and Version 3.1 was very minor (Figure 1).

Figure 1. Site and Stocking potentials for the Clays Growth Modelling region in Version 3 and Version 3.1 of TreeBLOSSIM.



Note: The curve Clays is in Version 3.0. The curve Clays-new is the curve in Version 3.1.

The fact that the PSP data from Tairua was run through TreeBLOSSIM V3.0 rather than 3.1 is considered to be of negligible consequence to the results and conclusions.

TreeBLOSSIM was set up so that there was no tree mortality (i.e. mortality equations in the individual tree growth model were not used). Any mortality that had occurred in the PSP was accounted for by assuming a thinning at that age. This approach allows the actual stocking of the plot to be maintained.

The branching pattern was then estimated for each tree, and then (where necessary) the plot grown forward to the age at which the images were taken.

- For FR121/4, the 2003 PSP measurement was imported and the data grown forward one year as the PhotoMARVL data were collected in October 2004.
- For FR121/7, the 2005 PSP measurement was imported, but it was not considered necessary to grow the data forward as the TreeD data were collected in early November 2005.

Comparisons

For each tree, the TreeBLOSSIM branching pattern for the section of stem measured by PhotoMARVL / TreeD was extracted. The position of each cluster and the diameter of the largest branch in that cluster were retained. A graph was plotted showing both the TreeBLOSSIM prediction for diameter of the largest branch in a cluster (*BDTB)* and the image measurement of the largest visible branch in a cluster (*BDI)* versus the height of the cluster (see Appendix 2, Figure 2 to Figure 11). This approach gives a good visual impression of how the model performs for each tree.

The data for each tree was then summarised to give:

- BDI_{max} The maximum branch diameter measured on the PhotoMARVL / TreeD image (i.e. maximum value of *BDI* for the tree)
- $BDTB_{max}$ The maximum branch diameter predicted by TreeBLOSSIM for that stem section (i.e. the maximum value of *BDTB* for the stem section)
- BDI_{av} The mean branch diameter measured by PhotoMARVL / TreeD (i.e. average value of *BDI* for the tree)
- $BDTB_{av}$ The mean branch diameter predicted by TreeBLOSSIM for that stem section (i.e. average diameter *BDTB* for the stem section)
- *CLI* Number of branch clusters on the stem section measured by PhotoMARVL / TreeD
- *CLTB* Number of branch clusters on the same stem sections 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 (see Appendix 3, Figure 12 - Figure 15).

RESULTS

Determining what is an acceptable performance for a complex model, like TreeBLOSSIM, is a matter of judgement. In this study TreeBLOSSIM 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 there is error in measuring branch diameters from PhotoMARVL / TreeD (measured values 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.

The graphs, Appendix3, Figure 12 and Figure 14 show that there were no obvious trends in with respect to the relative position of the tree in the DBH distribution, indicating that TreeBLOSSIM performs equally well for a range of tree sizes within a plot.

For some individual trees, the model has performed well, i.e. the absolute values of $DIFF_{max}$ and $DIFF_{av}$ are less than 20 mm; but there are trees for which $DIFF_{max}$ is very large, particularly in Huanui (see graphs Appendix 2, Figure 2- Figure 11).

Images for trees, where the model has not performed well, were examined in more detail to understand why the model has not performed well. Images for two of these trees are shown in Appendix 4.

At FR121/4 (Tairua) the values of $DIFF_{max}$ were less than 60 mm. Four trees with high values of $DIFF_{max}$ were examined (Table 2). For two of the trees there were no obvious reasons for the large branch, while for the other two trees there were slight indications that the tree might have been damaged at some stage.

At FR121/7 (Huanui) the values of $DIFF_{max}$ were much larger, up to 300 mm. Trees with high values of $DIFF_{max}$ were examined (Table 3). From examining the images, it was obvious that the large values of $DIFF_{max}$ were generally associated with stem damage. In some instances the tree appeared to be in a large gap.

Table 2. Comments on trees in FR121/4 (Tairua) with large values of $DIFF_{max}$.

Plot	Tree	Relative Position	$DIFF_{max}$ (mm)	Comment
4_12	15	89	49	No obvious anomalies in the vicinity of the largest branch.
4_12	17	68	51	The large branch is angled up very steeply, which suggests that it might have been a competing leader at one stage.
6_12	2	74	53	Slight kink in the stem at the position of the largest branch, but it difficult to say whether stem had previously been damaged at this point.
8_13	56	50	52	No obvious anomalies in the vicinity of the largest branch (see Appendix 4).

Table 3. Comments on trees in FR121/7 (Huanui) with large values of $DIFF_{max}$.

Plot	Tree	Relative Position	$DIFF_{max}$ (mm)	Comments
3_12	45	31	71	This tree contains a steeply angled branch and one record of damage in PSP system.
3_12	18	50	192	This was a particularly ugly tree with 3 records of damage in PSP system (see Appendix 4).
3_12	15	69	222	This tree contains a steeply angled branch and 2 records of damage in PSP system.
3_12	1	100	93	This tree contains a steeply angled branch and one record of damage in PSP system.
5_12	16	20	74	Tree contains steely angled branches.
5_12	10	53	69	At least 2 steeply angled branches and records of stem damage in PSP system.
5_12	7	67	123	At least one steeply angled branch and 3 records of stem damage in PSP system.
5_12	37	93	62	Tree in an obvious gap
5_12	31	100	94	Tree contains at least one steeply angled branch, and appears to be in a gap.
1_11	25	29	93	Steeply angled branches indicating change in leader.
1_11	11	43	97	Swept stem leaning into a gap with large branches on one side of the crown.
1_11	45	50	154	Tree contains a fork.
1_11	32	93	70	Tree in an obvious gap.
1_11	49	100	285	Tree contains a ramicorn.
6_12	29	72	69	Tree appears to be in a gap.
6_12	18	100	195	Tree contains at least one steeply angled branch and 1 record of stem defect in PSP system.
8_13	44	8	62	4 records of stem defects in PSP system.
8_13	5	88	61	No obvious sign of damage.
8_13	43	96	81	1 record of stem damage in PSP system.
14_16	33	10	63	Appear to be some steeply angled branches

There were no obvious trends in $DIFF_{CL}$ with relative position in the plot (Appendix 3, Figure 13 and Figure 15), indicating that TreeBLOSSIM is performing equally well for a range of trees sizes.

The SAS procedure PROC GLM was used (with plot as a class variable, and relative position of the tree as a continuous variable) to calculate “least square mean” values for for $DIFF_{max}$, $DIFF_{av}$, and $DIFF_{CL}$ on an individual plot basis (Table 4, FR121/4, Tairua and Table 5, FR121/7, Huanui). Least square means are estimates of the means that would have been expected from a “balanced design”.

There were no trends in $DIFF_{max}$, $DIFF_{av}$, and $DIFF_{CL}$ with respect to relative position in the DBH distribution.

The least square mean values of $DIFF_{max}$ and $DIFF_{av}$ were always positive and generally significantly different from zero. The values were higher for FR121/7, Huanui. A major reason is considered to be the poor performance of the model for trees that have been damaged in some way.

To quantify the effect of stems being damaged, the trees from Huanui were classified as:

- no obvious sign of damage,
- record in PSP system indicating the stem had been damaged at some stage and /or obvious indication of stem damage on the image,
- tree appears to be in an obvious gap.

The mean values of $DIFF_{max}$ and $DIFF_{av}$ were calculated for each of these classes (Table 6), indicating that the model predictions were much poorer for trees with damage and trees in gaps. The values of 30 mm ($DIFF_{max}$) and 14 mm ($DIFF_{av}$) for the trees with no obvious signs of damage are comparable to the values for Tairua (Table 4) where there was little sign of stem damage.

The plot least square mean values for $DIFF_{CL}$ were small and non-significant at Huanui (Table 5). The values were positive and sometimes significantly different from zero at Tairua (Table 4).

The following conclusions can be drawn:

With respect to the prediction of branch diameter:

- The main factor leading to poor performance of TreeBLOSSIM is stem damage, a feature that has not been accounted for in TreeBLOSSIM.
- TreeBLOSSIM has performed better at Tairua compared to Huanui – due to less trees with stem damage at Tairua;
- TreeBLOSSIM has performed slightly better for the plots at higher stockings – this may because fewer of the trees sampled had obvious stem defects;
- There are negligible differences between the different seedlots;

With respect to the prediction of the number of branch clusters:

- $DIFF_{CL}$ was generally not significantly different from zero.

Table 4. Least square mean values for $DIFF_{max}$, $DIFF_{av}$ and $DIFF_{CL}$ at Tairua

Plot	Seedlot	Silviculture	$DIFF_{max}$ Mean (mm)	$DIFF_{av}$ Mean (mm)	$DIFF_{CL}$ (m^{-1})
6_12	GF14	500⇨200 stem/ha, pruned	10	12*	0.2
5_12	GF16	500⇨200 stem/ha, pruned	31*	16*	0.1
4_12	GF25	500⇨200 stem/ha, pruned	35*	15*	0.3*
8_13	GF25	1000⇨400 stem/ha, pruned	18*	6*	0.3*

Note: * indicates value significantly different from zero (p<0.02)

Table 5. Least square mean values for $DIFF_{max}$, $DIFF_{av}$ and $DIFF_{CL}$ at Huanui

Plot	Seedlot	Silviculture	$DIFF_{max}$ Mean (mm)	$DIFF_{av}$ Mean (mm)	$DIFF_{CL}$ (m^{-1})
0312	GF14	500⇨200 stem/ha, pruned	111*	32*	-0.02
0512	GF16	500⇨200 stem/ha, pruned	74*	32*	-0.06
0612	GF25	500⇨200 stem/ha, pruned	65*	24*	-0.1
0111	GF25	250⇨100 stems/ha, pruned	122*	30*	0.05
0813	GF25	1000⇨400 stem/ha, pruned	45	19*	-0.2
1416	GF25	1000⇨600 stem/ha, unpruned	31	6	0.05

Note: * indicates value significantly different from zero (p<0.02)

Table 6. Mean values for $DIFF_{max}$, $DIFF_{av}$ for Huanui when trees are classified according to stem characteristics

Stem Class	Number of trees	$DIFF_{max}$ Mean (mm)	$DIFF_{av}$ Mean (mm)
No obvious signs of damage	13	30	14
Obvious signs of damage	18	106	29
Tree in a gap	5	78	32

DISCUSSION

PhotoMARVL / TreeD data were collected for individual trees from specific plots within SGMC experiments FR121/4 (Tairua) and FR121/7 (Huanui). Examination of these data indicated that TreeBLOSSIM predicted realistic branch diameters for some trees. For other trees, there were some extremely large branches that were not well predicted by TreeBLOSSIM. Many of these large branches appeared to be associated with stem damage at some stage in the tree's life. Five of the trees with large branches appeared to be in gaps.

Overall TreeBLOSSIM performed better in FR121/4 where there was little evidence of stem damage (both from images and PSP system) compared to FR121/7 (Huanui) where many of the trees showed stem damage. There was little evidence that TreeBLOSSIM performance varied between the three seedlots considered (GF14, GF16 and GF25) – the current version (version 3) of TreeBLOSSIM being based on data from GF14 seedlots. TreeBLOSSIM appeared to perform better for plots with nominal final crop stockings higher than 200 stems/ha.

The prediction of number of branch clusters was generally acceptable (i.e. difference between actual and predicted number of branch clusters was generally not significantly different from zero). TreeBLOSSIM calculates the number of branch clusters in an annual shoot from region, tree age and annual height growth. Further data from more sites within a region will be needed to determine whether and how this function could be improved.

ACKNOWLEDGMENTS

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APPENDIX 1. Trees measured in FR121/4 and FR121/7.

Table 7. Trees measured in FR121/4 (Tairua)

Plot No.	Nominal Final Stems/ha	GF rating	% rank	Quad_row	treeno	treekey	dbh_cm
6_12	200	14	15.8	0	14	14	31.5
6_12	200	14	31.6	0	45	45	37.3
6_12	200	14	57.9	3	32	32	42.2
6_12	200	14	73.7	0	2	2	44.2
6_12	200	14	89.5	0	48	48	46.8
6_12	200	14	100.0	0	5	5	54.6
5_12	200	16	10.5	0	5	5	37
5_12	200	16	31.6	0	1	1	42.3
5_12	200	16	52.6	0	13	13	43.4
5_12	200	16	57.9	4	24	24	43.5
5_12	200	16	68.4	0	15	15	44.9
5_12	200	16	89.5	0	22	22	47.2
4_12	200	25	15.8	0	43	43	33.4
4_12	200	25	31.6	0	8	8	41.6
4_12	200	25	52.6	0	29	29	44.1
4_12	200	25	68.4	1	17	17	47.2
4_12	200	25	89.5	0	15	15	51.4
4_12	200	25	100.0	2	40	40	51.7
8_13	400	25	10.7	4	33	33	28.3
8_13	400	25	21.4	4	26	26	29.4
8_13	400	25	28.6	3	49	49	30.6
8_13	400	25	39.3	0	63	63	33
8_13	400	25	50.0	2	56	56	34.3
8_13	400	25	60.7	0	61	61	35.3
8_13	400	25	71.4	0	7	7	36.4
8_13	400	25	78.6	4	13	13	36.7
8_13	400	25	89.3	0	10	10	38.1
8_13	400	25	100.0	0	69	69	44.2

Table 8. Trees measured in FR121/7 (Huanui)

Plotno	Nominal Final Stems/ha	GF rating	% rank	Quad_row	Treeno	Treekey	Image No.
FR121070312	200	GF14	19	0	43	43	3740
FR121070312	200	GF14	31	0	45	45	3738
FR121070312	200	GF14	50	1	18	18	3734
FR121070312	200	GF14	69	0	15	15	3732
FR121070312	200	GF14	88	0	41	41	3736
FR121070312	200	GF14	100	0	1	1	3730
FR121070512	200	GF16	20	1	16	16	3700
FR121070512	200	GF16	33	1	11	11	3698
FR121070512	200	GF16	53	4	10	10	3696
FR121070512	200	GF16	67	0	7	7	3694
FR121070512	200	GF16	93	0	37	37	3704
FR121070512	200	GF16	100	2	31	31	3702
FR121070612	200	GF25	17	0	4	4	3671
FR121070612	200	GF25	33	0	41	41	3679
FR121070612	200	GF25	72	0	29	29	3677
FR121070612	200	GF25	83	1	16	16	3681
FR121070612	200	GF25	89	4	10	10	3673
FR121070612	200	GF25	100	1	18	18	3675
FR121070111	100	GF25	14	0	16	16	3714
FR121070111	100	GF25	29	3	25	25	3712
FR121070111	100	GF25	43	1	11	11	3716
FR121070111	100	GF25	50	0	45	45	3708
FR121070111	100	GF25	93	3	32	32	3706
FR121070111	100	GF25	100	0	49	49	3710
FR121070813	400	GF25	8	0	44	83	3690
FR121070813	400	GF25	27	0	58	99	3692
FR121070813	400	GF25	46	0	27	62	3687
FR121070813	400	GF25	85	4	17	52	3685
FR121070813	400	GF25	88	1	5	38	3683
FR121070813	400	GF25	96	0	43	82	3742
FR121071416	600	GF25	10	4	33	41	3726
FR121071416	600	GF25	31	1	23	31	3718
FR121071416	600	GF25	48	0	50	66	3722
FR121071416	600	GF25	72	3	55	71	3724
FR121071416	600	GF25	90	4	34	42	3728
FR121071416	600	GF25	97	0	51	67	3720

APPENDIX 2. Graphs of actual and predicted branch diameters.

Figure 2. **Graph showing PhotoMARVL measurements and TressBLOSSIM predictions of branch diameter versus height of cluster for individual trees in FR121/4, plot 4_12 (GF25 seedlot).**

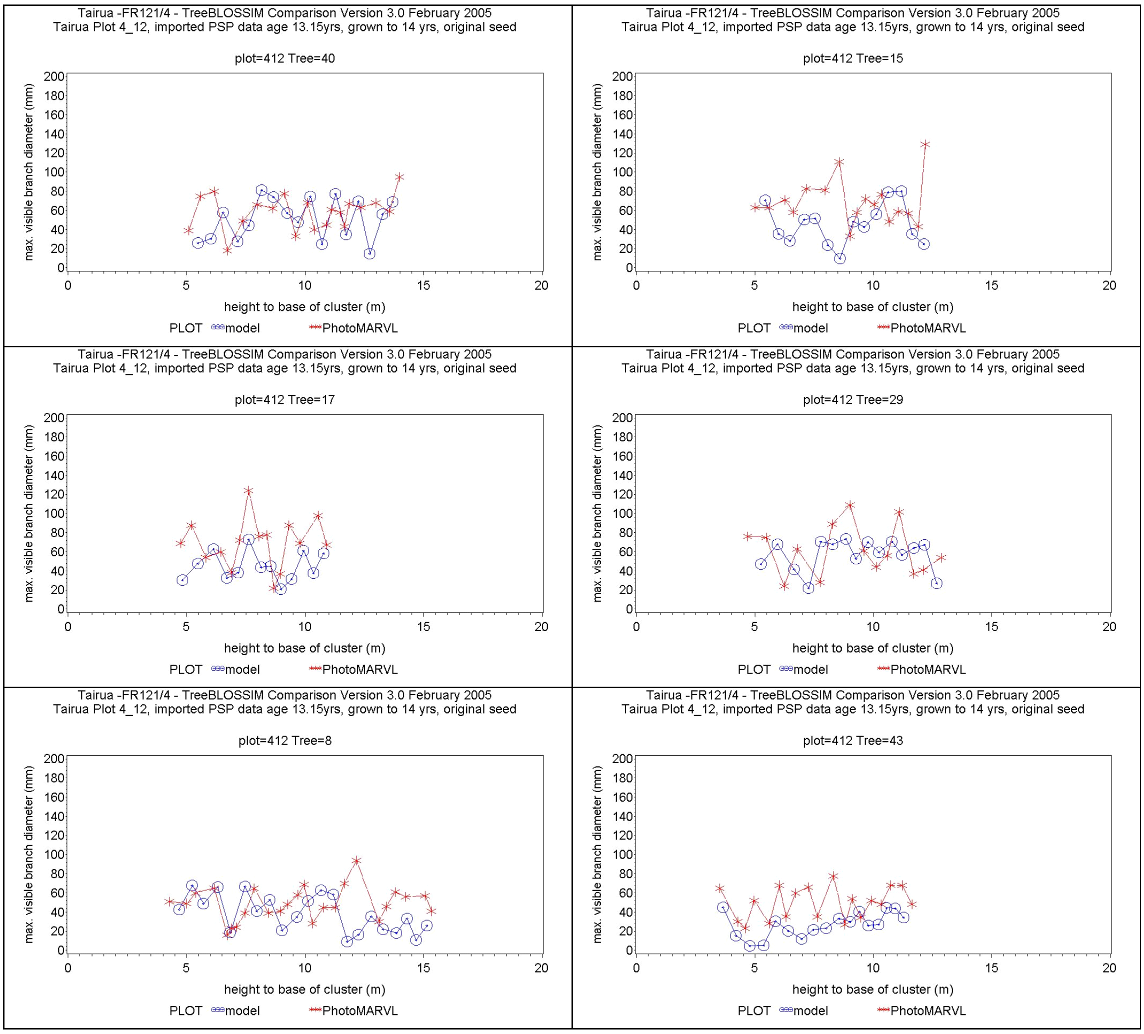


Figure 3. Graph showing PhotoMARVL measurements and TressBLOSSIM predictions of branch diameter versus height of cluster for individual trees in FR121/4, plot 5_12 (GF16 seedlot).

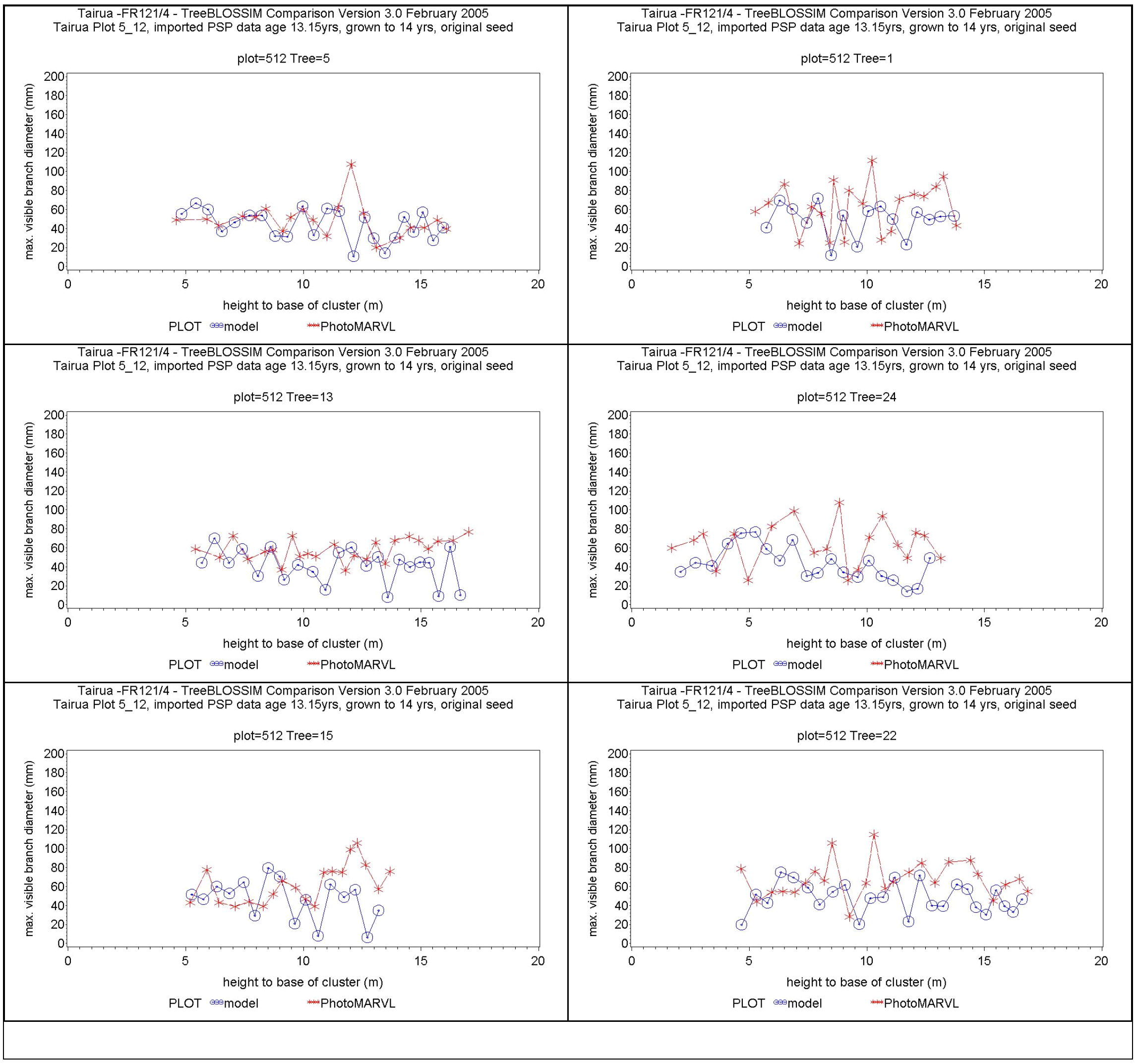


Figure 4. **Graph showing PhotoMARVL measurements and TressBLOSSIM predictions of branch diameter versus height of cluster for individual trees in FR121/4, plot 6_12 (GF14 seedlot).**

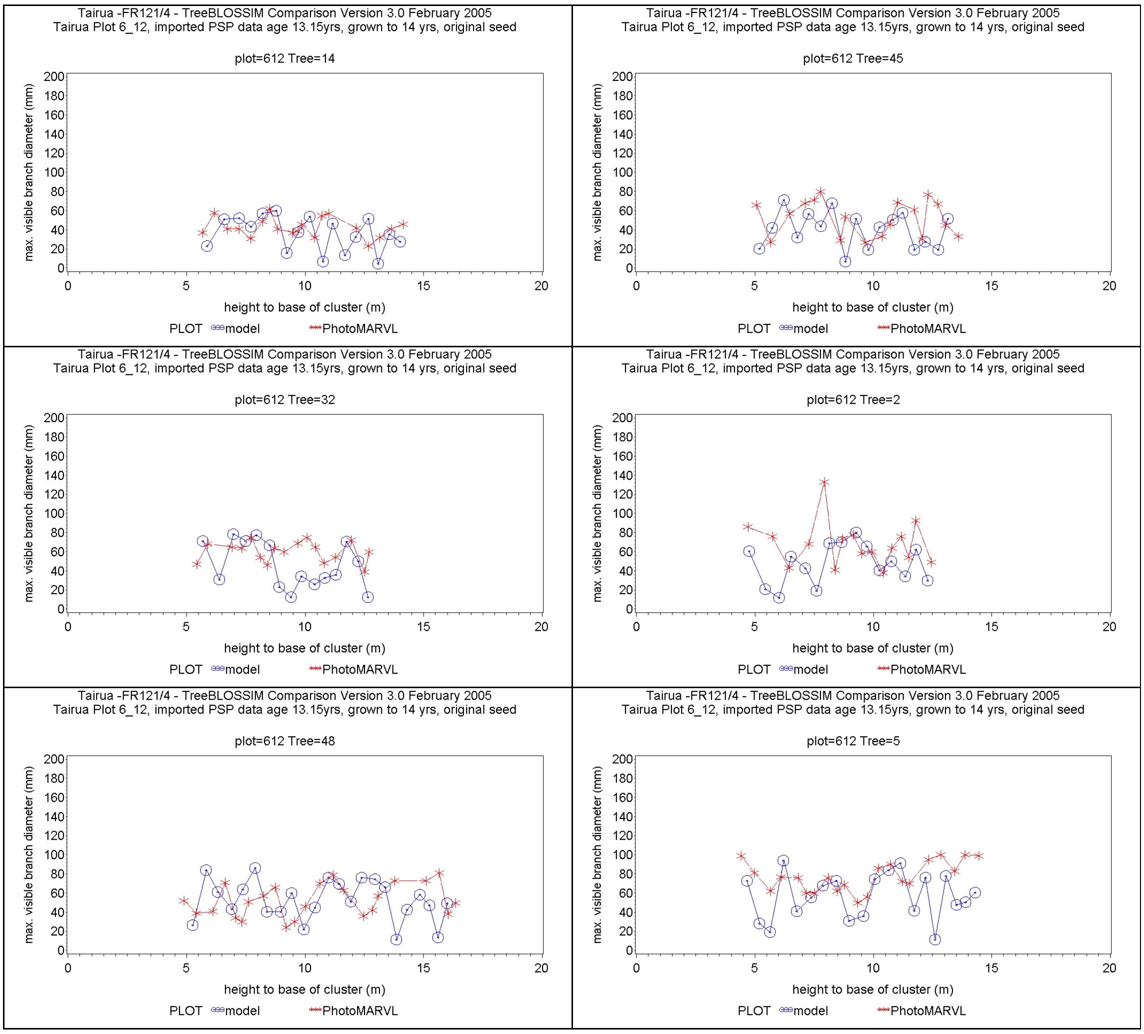


Figure 5. **Graph showing PhotoMARVL measurements and TressBLOSSIM predictions of branch diameter versus height of cluster for individual trees in FR121/4, plot 8_13 (GF25 seedlot).**

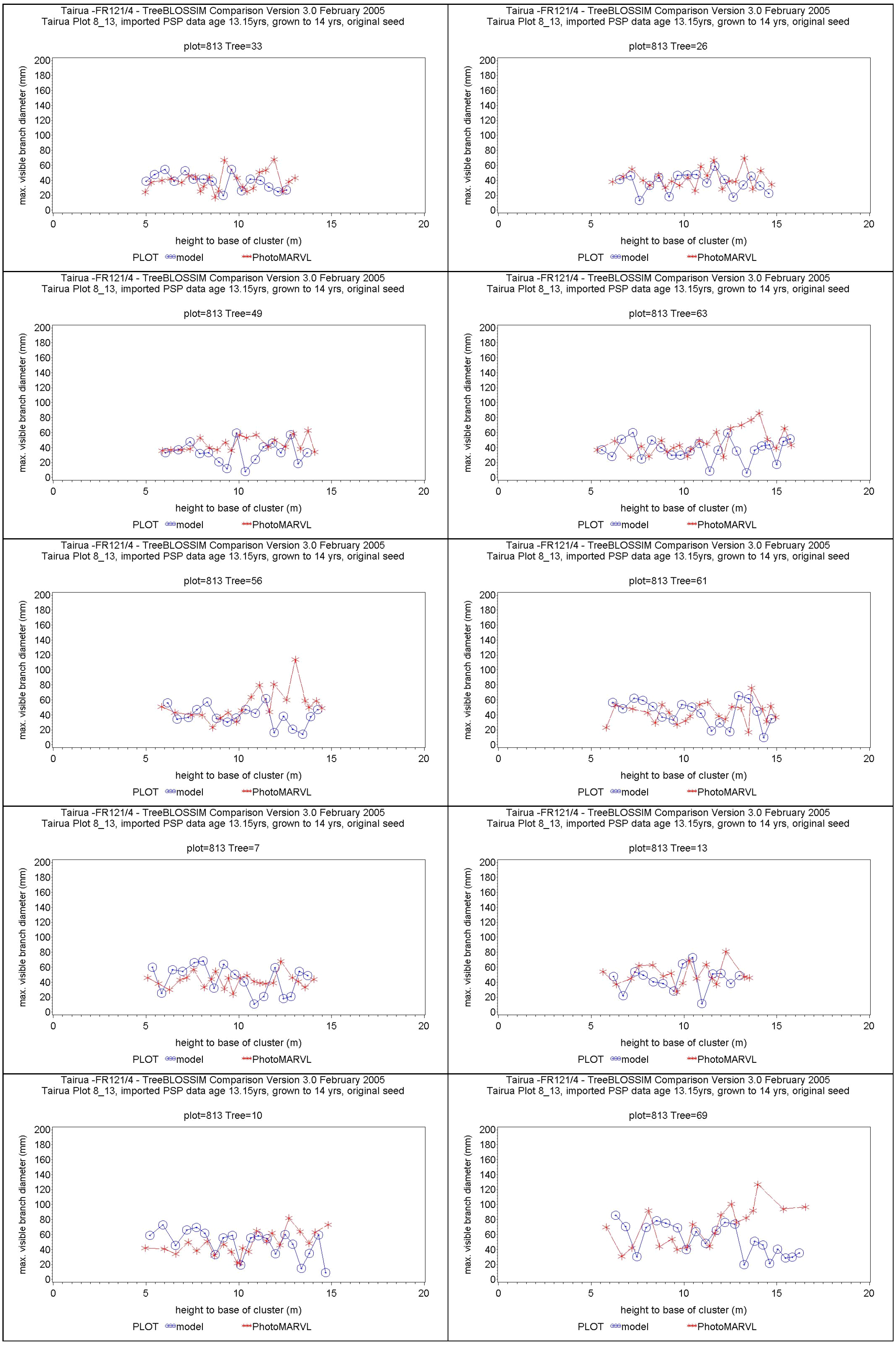


Figure 6. Graph showing TreeD measurements and TressBLOSSIM predictions of branch diameter versus height of cluster for individual trees in FR121/7, plot 3_12 (GF14 seedlot).

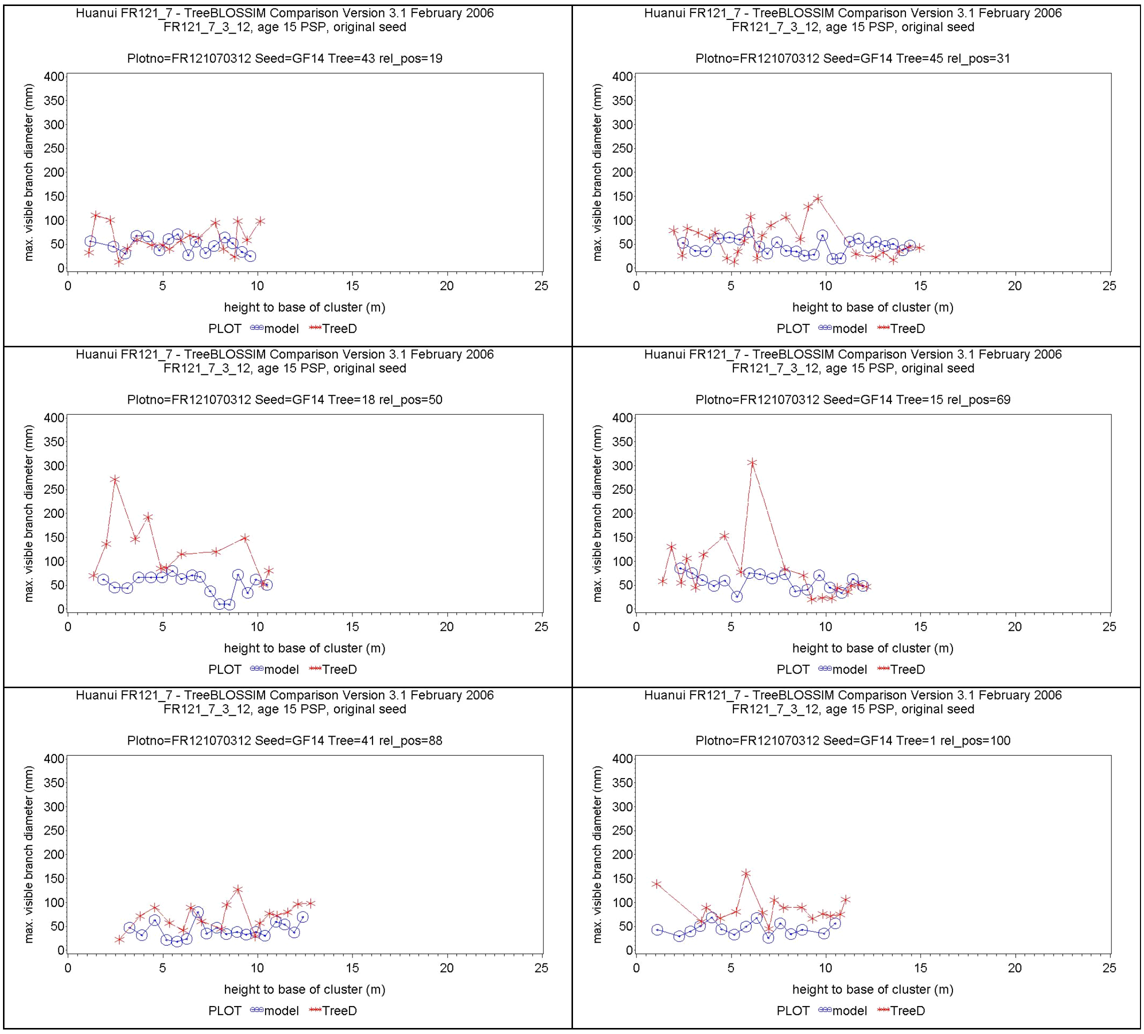


Figure 7. **Graph showing TreeD measurements and TressBLOSSIM predictions of branch diameter versus height of cluster for individual trees in FR121/7, plot 5_12 (GF16 seedlot).**

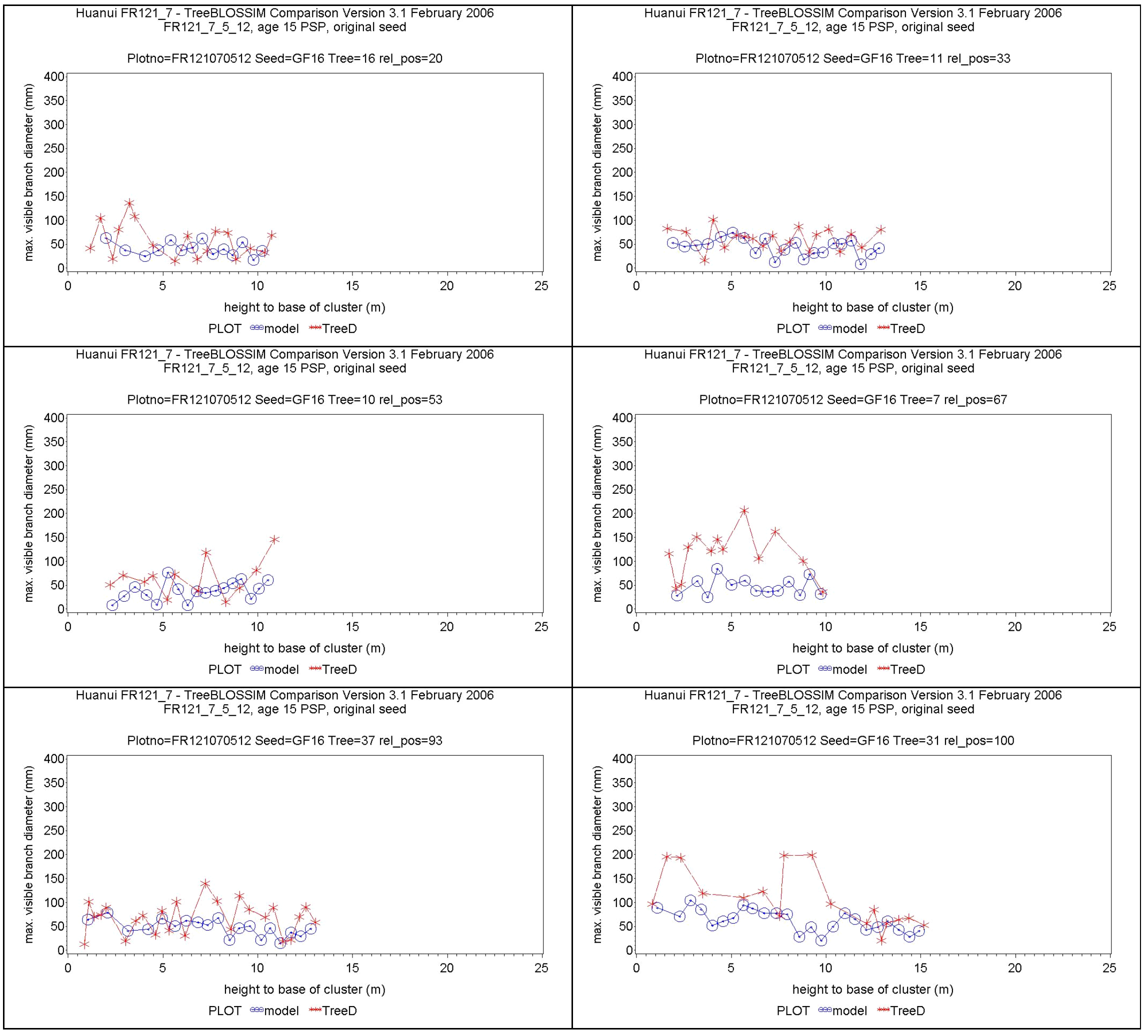


Figure 8. Graph showing TreeD measurements and TressBLOSSIM predictions of branch diameter versus height of cluster for individual trees in FR121/7, plot 1_11 (GF25 seedlot).

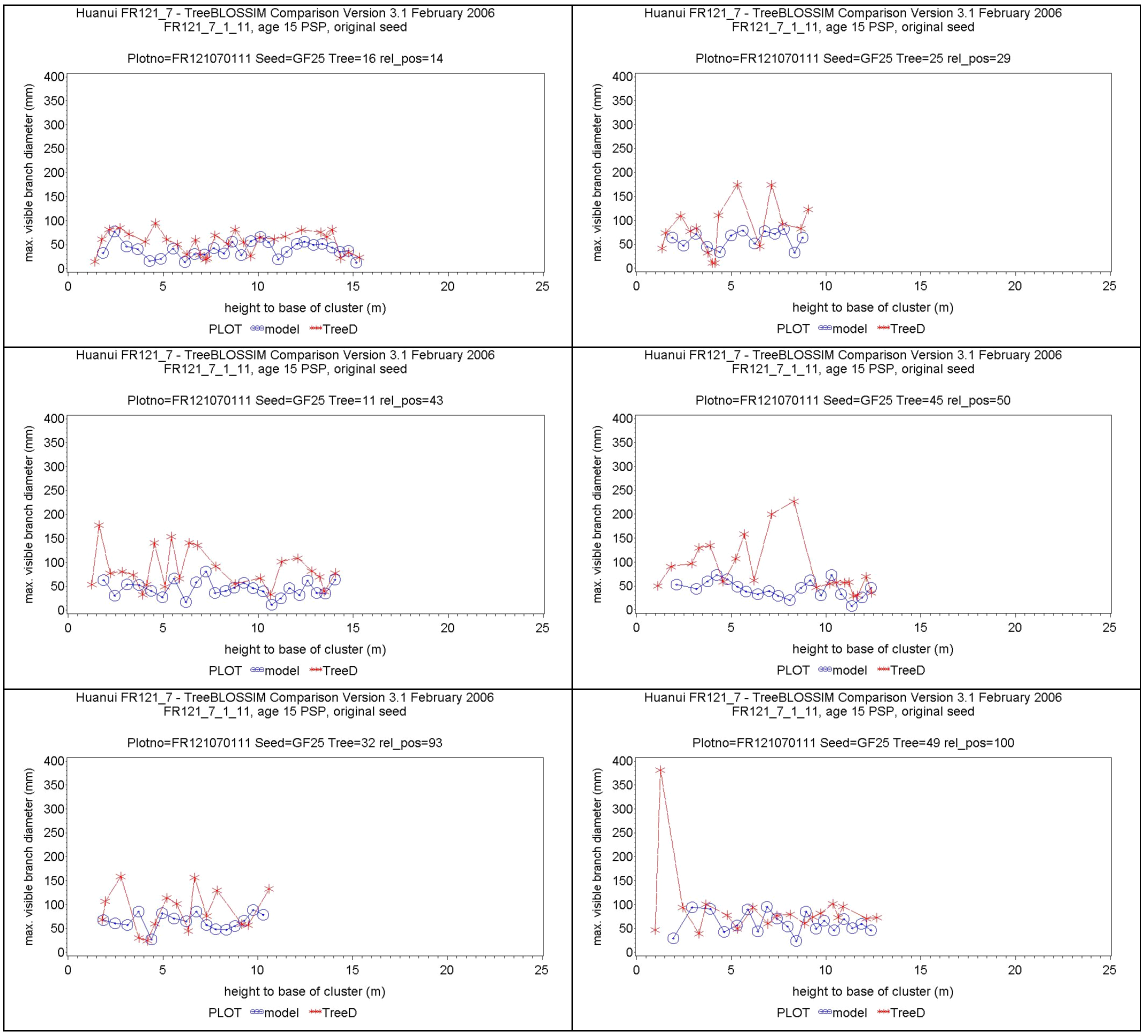


Figure 9. **Graph showing TreeD measurements and TressBLOSSIM predictions of branch diameter versus height of cluster for individual trees in FR121/7, plot 6_12 (GF25 seedlot).**

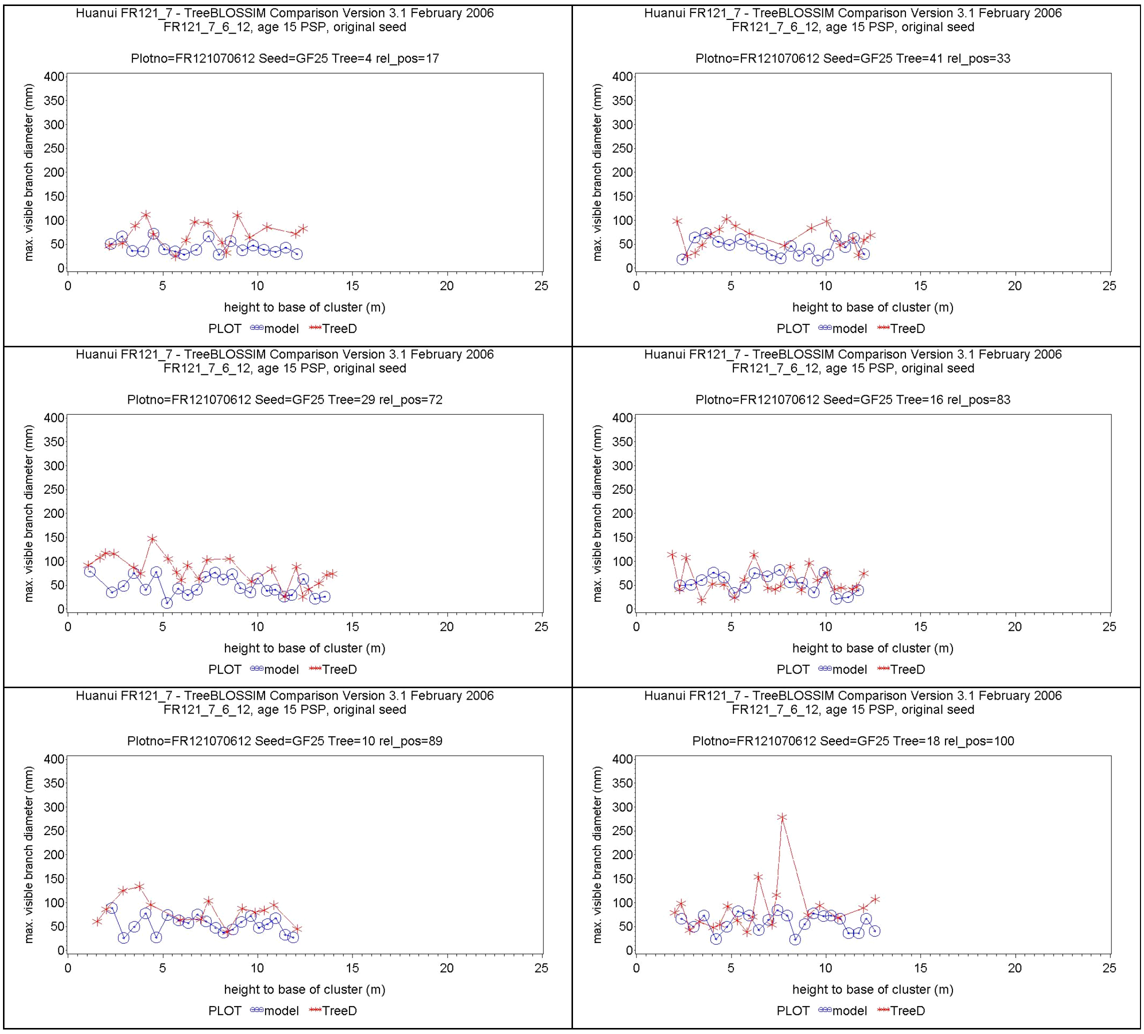


Figure 10. Graph showing TreeD measurements and TressBLOSSIM predictions of branch diameter versus height of cluster for individual trees in FR121/7, plot 8_13 (GF25 seedlot).

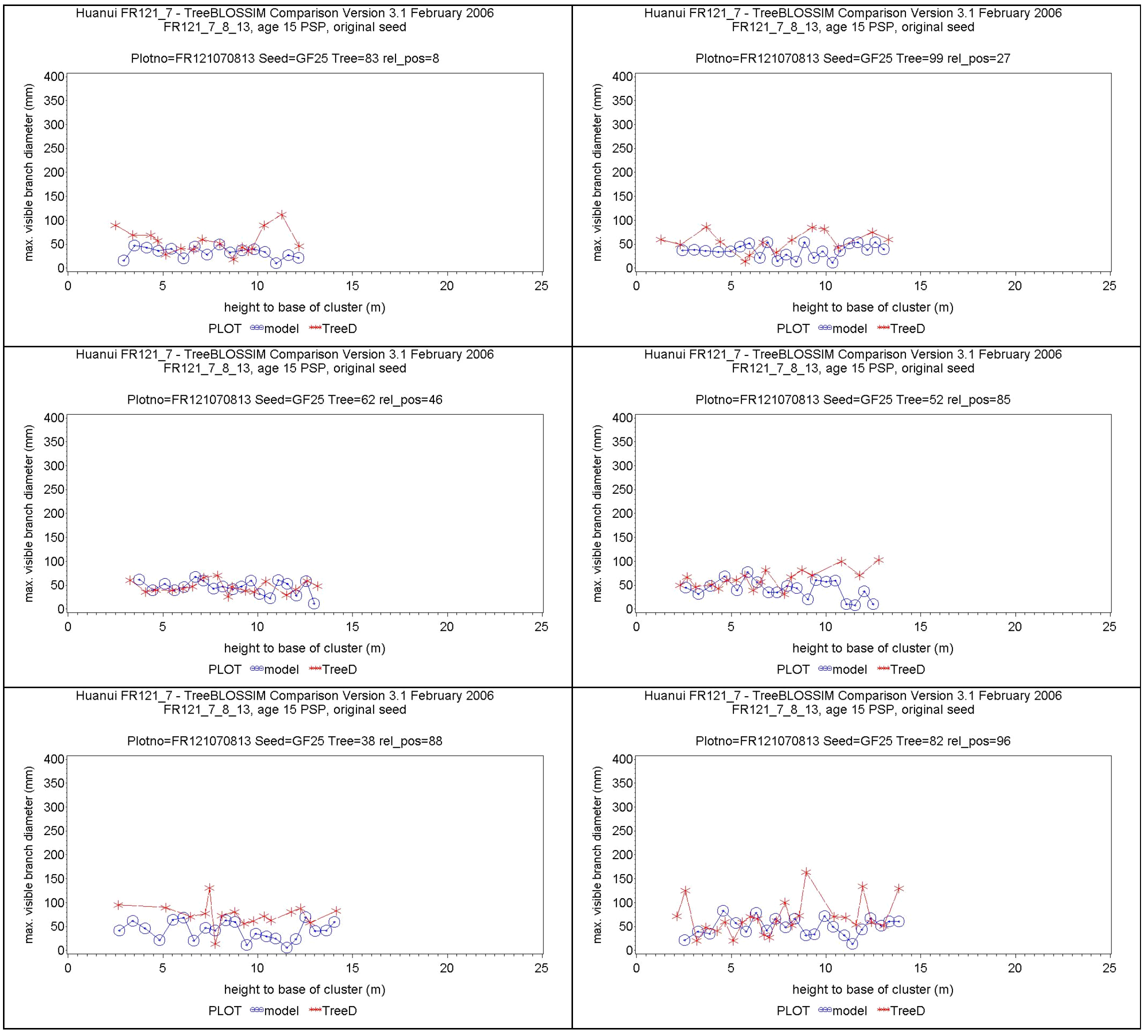
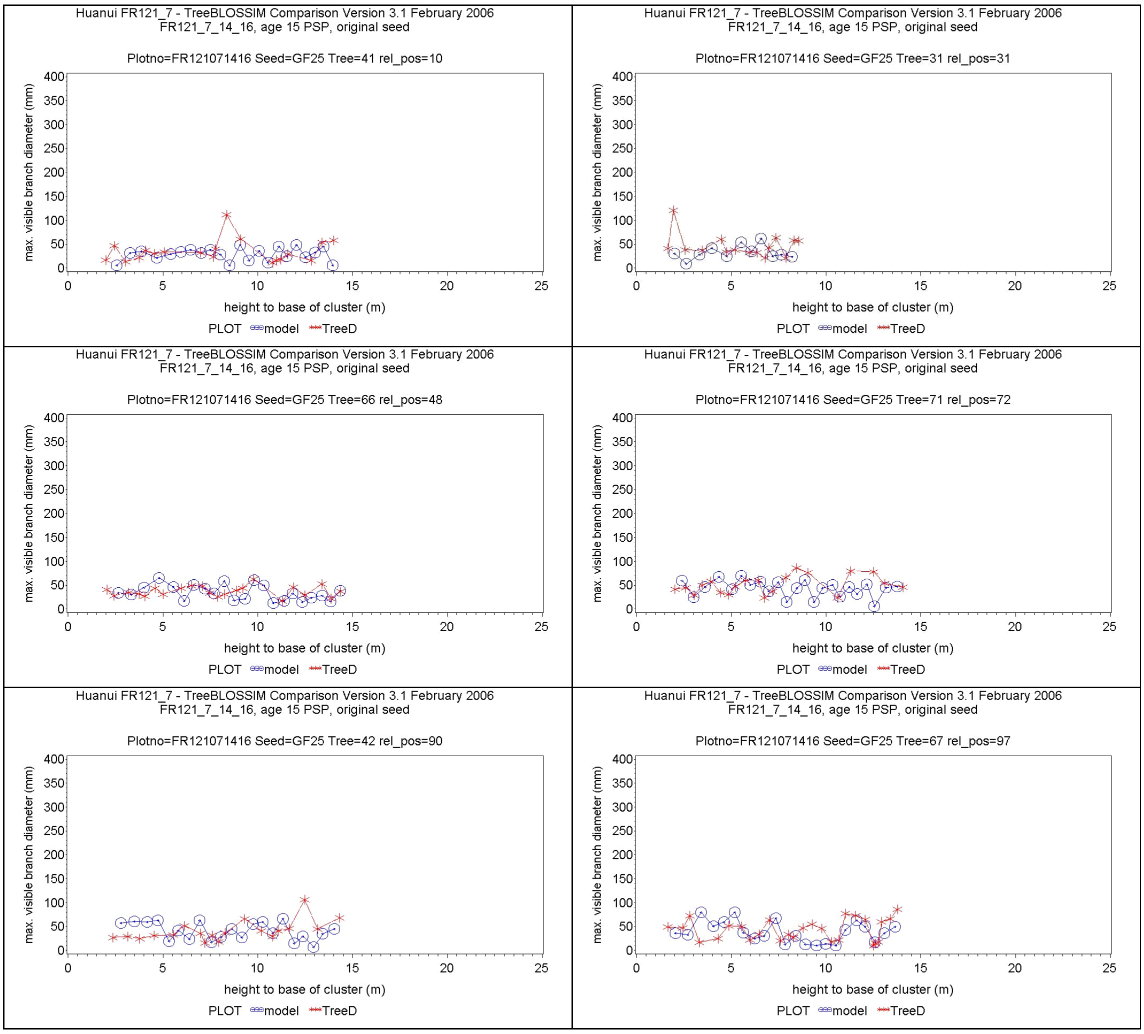
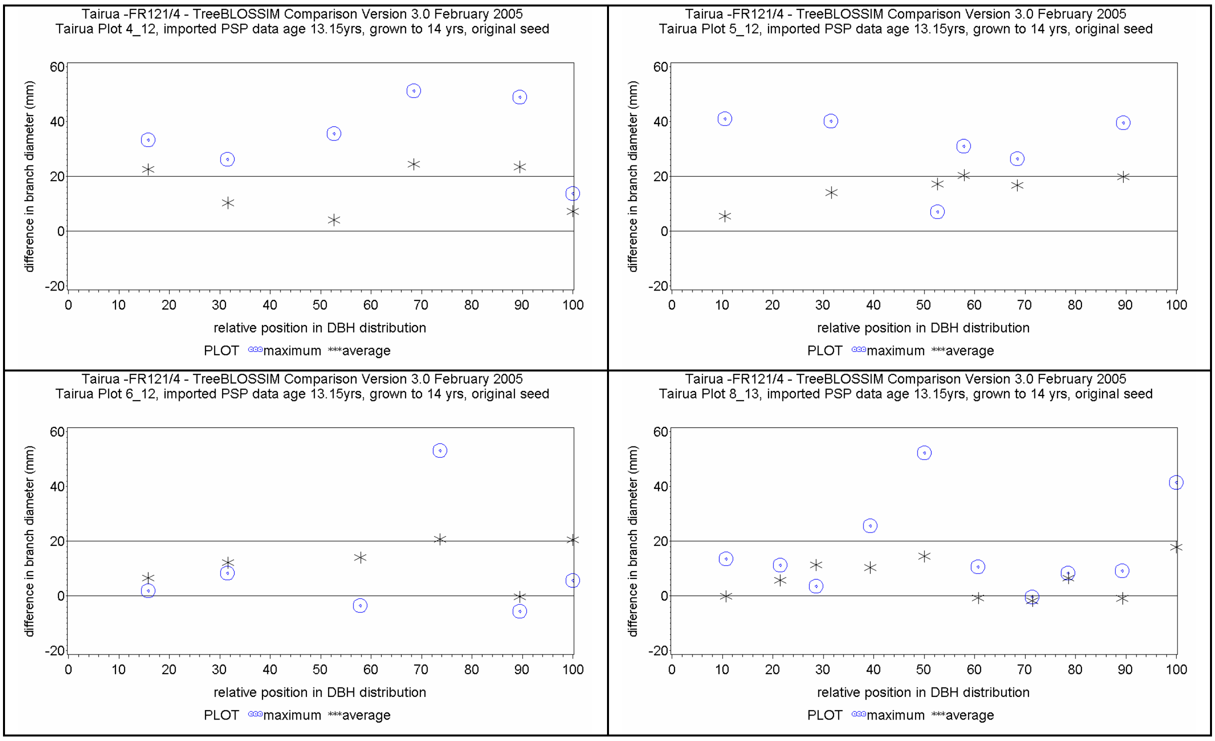


Figure 11. Graph showing TreeD measurements and TressBLOSSIM predictions of branch diameter versus height of cluster for individual trees in FR121/7, plot 14_16 (GF25 seedlot).



APPENDIX 3. Comparison of image data and TreeBLOSSIM predictions at a plot level.

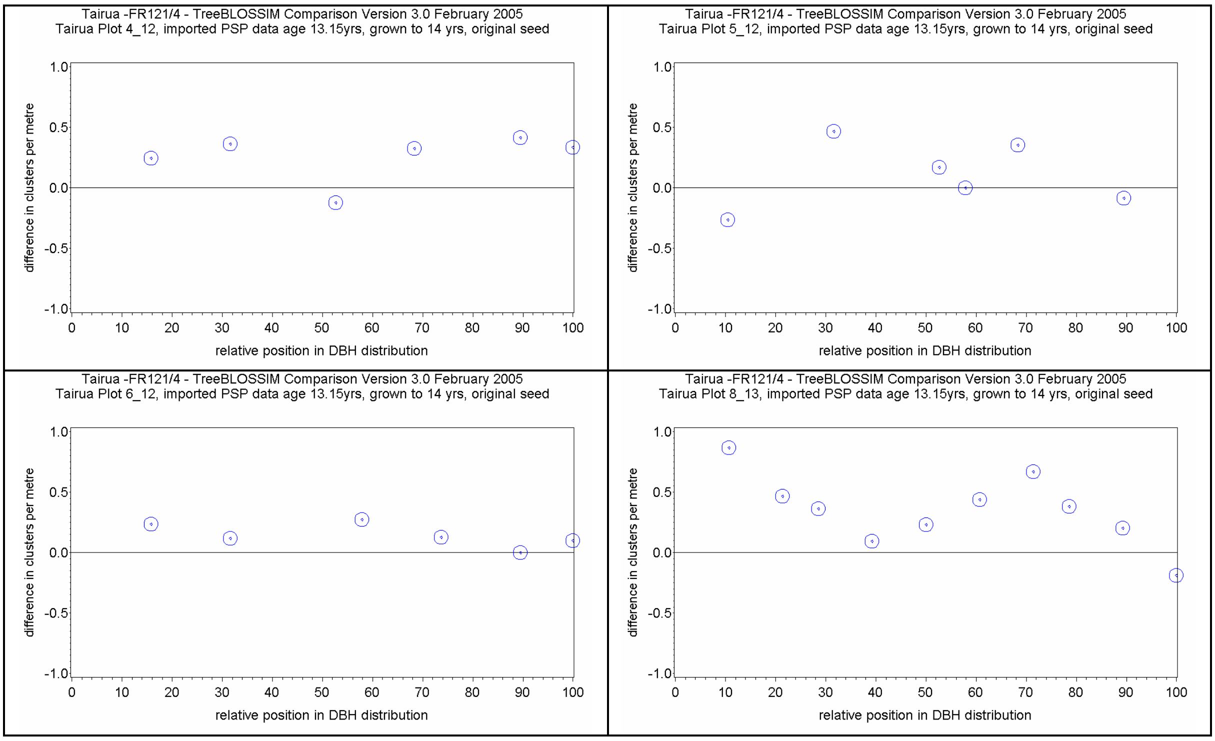
Figure 12. Graphs showing the difference in branch diameter (maximum =$DIFF_{max}$ and average = $DIFF_{av}$), between image measurements and TreeBLOSSIM predictions, for individual trees within PSPs in FR121/4 (Tairua).



Note: The seedlot and treatment for each plot is shown below:

Plot	GF rating	Thinning Treatment
4_12	25	500⇨200 stem/ha, pruned
5_12	16	500⇨200 stem/ha, pruned
6_12	14	500⇨200 stem/ha, pruned
8_13	25	1000⇨400 stem/ha, pruned

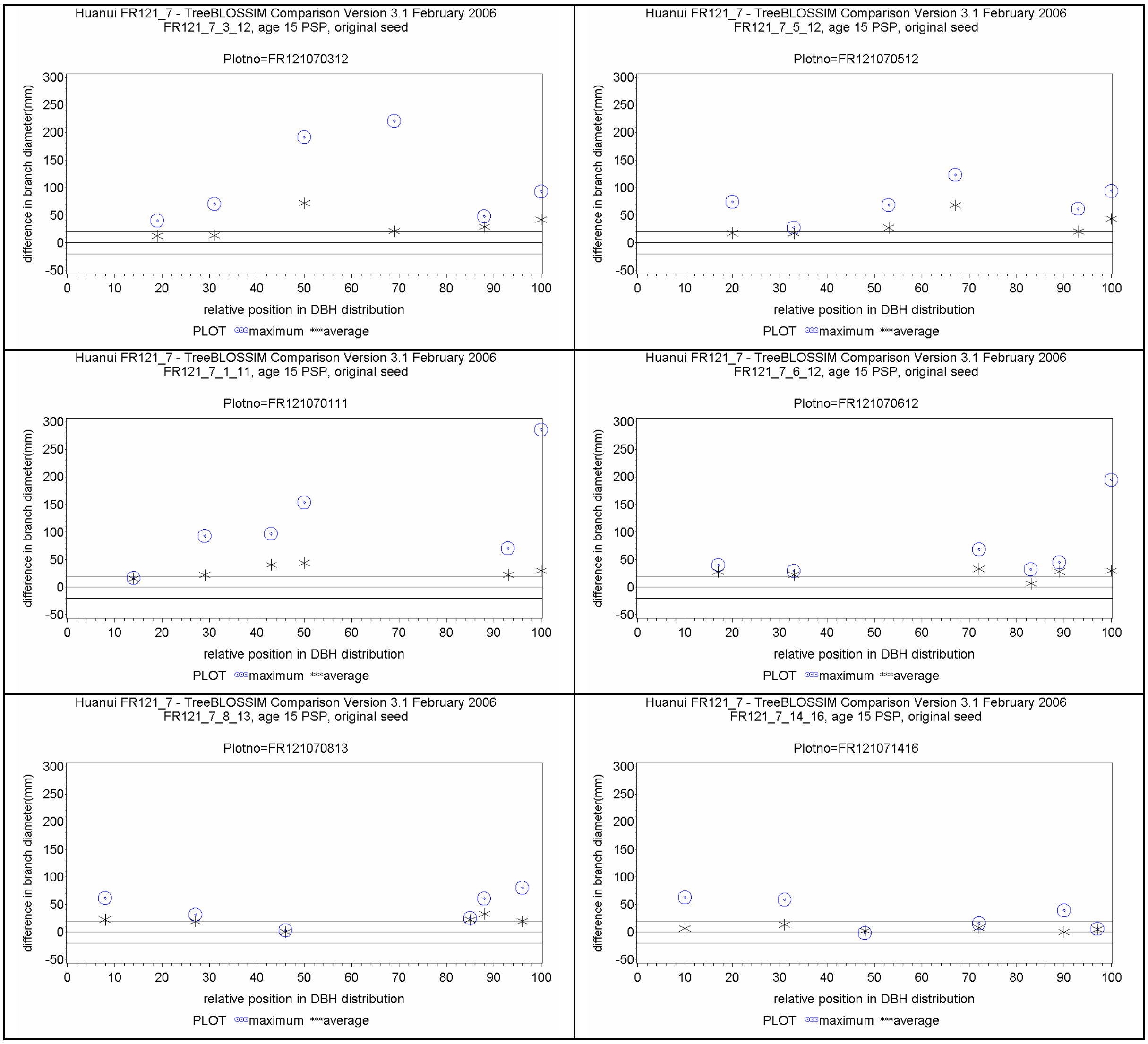
Figure 13. Graphs showing the difference between image and TreeBLOSSIM prediction of the number of branch clusters per metre ($DIFF_{CL}$) for FR121/4, Tairua.



Note: The seedlot and treatment for each plot is shown below:

Plot	GF rating	Thinning Treatment
4_12	25	500⇨200 stem/ha, pruned
5_12	16	500⇨200 stem/ha, pruned
6_12	14	500⇨200 stem/ha, pruned
8_13	25	1000⇨400 stem/ha, pruned

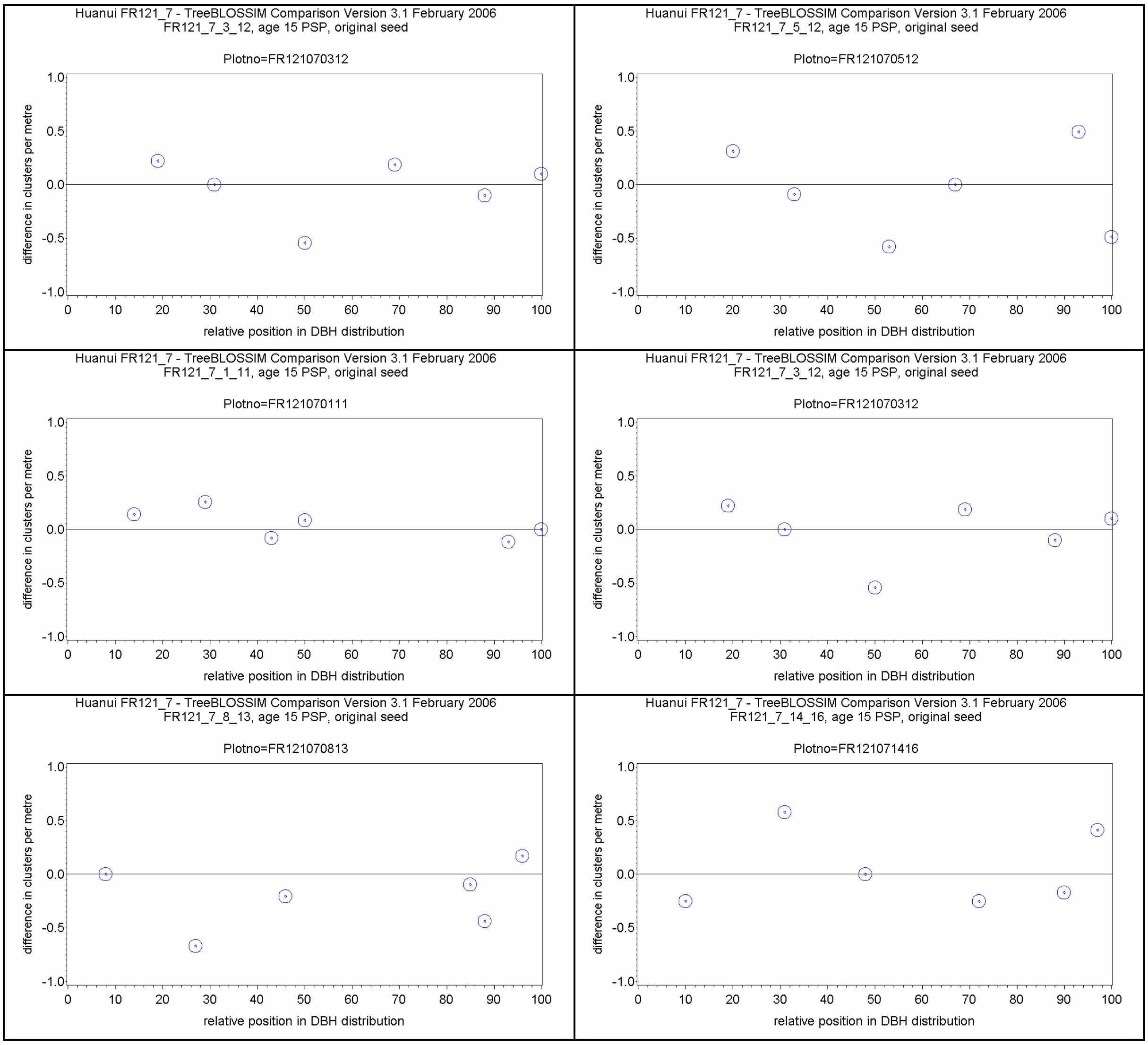
Figure 14. Graphs showing the difference in branch diameter (maximum =*$DIFF_{max}$* and average = *$DIFF_{av}$*), between image measurements and TreeBLOSSIM predictions for individual trees within PSPs in FR121/7 (Huanui).



Note: The seedlot and treatment for each plot is shown below:

Plotno	GF rating	Thinning Treatment
121070312	14	500⇨200 stem/ha, pruned
121070512	16	500⇨200 stem/ha, pruned
121070111	25	250⇨100 stems/ha, pruned
121070612	25	500⇨200 stem/ha, pruned
121070813	25	1000⇨400 stem/ha, pruned
121071416	25	1000⇨600 stem/ha, unpruned

Figure 15. Graphs showing the difference between image and TreeBLOSSIM prediction of the number of branch clusters per metre ($DIFF_{CL}$) for FR121/7, Huanui.



Note: The seedlot and treatment for each plot is shown below:

Plotno	GF rating	Thinning Treatment
121070312	14	500⇨200 stem/ha, pruned
121070512	16	500⇨200 stem/ha, pruned
121070111	25	250⇨100 stems/ha, pruned
121070612	25	500⇨200 stem/ha, pruned
121070813	25	1000⇨400 stem/ha, pruned
121071416	25	1000⇨600 stem/ha, unpruned

APPENDIX 4. Images of two trees with large values of *$DIFF_{max}$*

Note:
Left hand image is FR121/4, Plot 8/13, Tree 56.
Right hand image is FR121/7, Plot 3/12, Tree 18.