Comparison of TreeBLOSSIM predictions with PhotoMARVL/ TreeD data:
FR121/1 (Tungrove), FR121/3 (Gwavas) and FR121/13 (Golden Downs)

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EXECUTIVE SUMMARY

PhotoMARVL / TreeD studies were carried out for a range of silvicultural treatments and seedlots in the 1990/91 silviculture breed trials FR121/1 (Tungrove), FR121/3 (Gwavas), and FR121/13 (Golden Downs), between October 2006 and February 2007.

The main points to emerge from analysis of these data were:

- For branch diameter, TreeBLOSSIM performance was similar for the seedlots considered (GF14,GF16, GF25 and Long Internode) suggesting that branch diameters vary little between seedlots.
- The version of TreeBLOSSIM used for this study was developed using data from improved trees with a growth and form rating of 14. The number of branch clusters predicted for the Long Internode seedlot was higher than observed, noticeably different from the growth and form seedlots.
- TreeBLOSSIM performance tended to be poorer for the plots at lower final crop stocking indicating that the site and stocking potentials still need further modification.
- Stem damage has a major influence on branching with branch diameter being larger than predicted by TreeBLOSSIM.
- Further research is needed to determine how trees respond to stem damage, in particular the reasons for the larger than expected branch diameters and the consequent effects of stem damage on wood property distributions within the stem.

Comparison of TreeBLOSSIM predictions with PhotoMARVL/ TreeD data: FR121/1 (Tungrove), FR121/3 (Gwavas) and FR121/13 (Golden Downs)

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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 three SGMC trials in the FR121 series, which were planted in 1990 / 1991:

- FR121/1 (Tungrove) – is considered to be representative of a medium site index in the Clays growth modelling region
- FR121/3 (Gwavas) – is considered to be representative of a low site index in the Hawke's Bay growth modelling region
- FR121/13 (Golden Downs) – is considered to be representative of a high site index in the Nelson growth modelling region

These analyses will complement those previously completed for FR121/4 (Tairua) and FR121/7 (Huanui) (see SGMC Report No. 135). Further details on the design and layout of the FR121 series trials are given in SGMC Reports Nos. 100 and 103.

METHODS

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.

Apart from FR121/4 (Tairua) and FR121/7 (Huanui), trials within the FR121 series contained a long internode seedlot. Hence it was decided to sample the long internode seedlot in FR121/1, FR121/3 and FR121/13 in addition to the treatments previously sampled in FR121/4 and FR121/7.

The PSPs selected (Table 1) enable the performance of TreeBLOSSIM to be determined for:

- GF14, GF16,GF25 and Long Internode (LI) seedlots with a common silvicultural treatment
- GF25 seedlot across a range of silvicultural treatments
- Long Internode seedlot across a range of silvicultural treatments

Table 1. List of PSPs for which TreeD data has been collected

GF rating	Thinning Treatment	FR121/1 Tungrove	FR121/3 Gwavas	FR121/13 Golden Downs
		PSP Plot IDs		
14	500⇨200 stem/ha, pruned	4/12	5/12	7/12
16	500⇨200 stem/ha, pruned	5/12	6/12	8/12
25	500⇨200 stem/ha, pruned	8/12	4/12	4/12
13(LI)	500⇨200 stem/ha, pruned	7/12	11/12	5/12
25	250⇨100 stems/ha, pruned	-	3/11	1/11
13(LI)	250⇨100 stems/ha, pruned	-	1/11	3/11
25	1000⇨400 stem/ha, pruned	9/13	9/13	15/13
13(LI)	1000⇨400 stem/ha, pruned	11/13	8/13	16/13
25	1000⇨600 stem/ha, unpruned	24/16	16/15	19/16
13(LI)	1000⇨600 stem/ha, unpruned	23/16	12/15	20/16

Note:
Plots for treatment: 250⇨100 stems/ha, pruned, have been abandoned in FR121/1 and were not be assessed.

<u>Tree Selection</u>

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 these trials, 6 sample trees were selected in the office. These were trees whose percentage rank was closest to 10%, 30%, 50%, 70%, 90%, and 100%.
In addition the tree should not have had a defect code assigned at any PSP remeasurement.

In the field, a selected sample tree was occasionally replaced if the tree was badly damaged and had not been recorded on the database. The sample trees, for which images were taken, are shown in Appendix 1.

Ground-based photogrammetric method (PhotoMARVL / TreeD)

The ground-based photogrammetric method, used to obtain quantitative measurements of stem and branching characteristics, requires a clear view of the lower 20 m (approx.) 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.*, 2007). The data from FR121/1 and FR121/3 were collected using TreeD procedures. However, because the digital camera used for TreeD malfunctioned in FR121/13, it was necessary to fall back on the film camera and the earlier PhotoMARVL procedures for the image analysis for FR121/13. Measurement accuracy is the same for both systems.

Site Conditions

Some plots in FR121/1 (Tungrove) contained understorey shrubs of *Hakea salicifolia* (willow-leaved hakea). The presence of pampas and hardwood shrubs was previously noted in SGMC Report 83, but these plants were not considered to have influenced tree growth.

Tall understory was present in FR121/13 (Golden Downs) in several of the plots, in particular those at 100 stem/ha. The understorey was of such a size that a chainsaw was required to clear "line of sight" to selected sample trees.

Image analysis

The following measurements were extracted from the images using either the PhotoMARVL system (FR121/13) or the TreeD system (FR121/1 and FR121/3):

- 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)*.

TreeBLOSSIM simulations

For each selected sample plot, the latest PSP measurements were imported into Version 3.1 of TreeBLOSSIM.

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 FR121/1, the 2005 (age 15 year) PSP measurement was imported and the data grown forward one year (to age 16 years) as the TreeD data were collected in October 2006.
- For FR121/3, the 2005 (age 15 year) PSP measurement was imported and the data grown forward one year (to age 16 years) as the TreeD data were collected in early November 2006.
- For FR121/13, the 2006 (age15 year) PSP measurement was imported. The age 15 branching data were exported, without growing forward, for comparison with the PhotoMARVL data collected in January 2007. (As January is approx. in the middle of the growing season, it was debatable whether it was more appropriate to compare the PhotoMARVL data with the predicted age 15 or age 16 branch diameters).

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 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.

In this study TreeBLOSSIM was considered to have performed well for predicting branch diameters on an individual tree if the absolute values of $DIFF_{max}$ and $DIFF_{av}$ were 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. Also there should be no trend in the errors with position of the tree in the DBH distribution.

RESULTS

FR121/1, Tungrove (visited in October 2006).

Individual tree values of $DIFF_{max}$, $DIFF_{av}$, and $DIFF_{CL}$ are shown for each plot in Figure 1, Figure 2, and Figure 3. The values of $DIFF_{av}$ were generally less than 20 mm but $DIFF_{max}$ was larger than 20 mm for a number of trees. As expected the long internode seedlot had less branch clusters than the GF seedlots and less branch clusters than predicted by TreeBLOSSIM (large negative values of $DIFF_{CL}$). The least-square mean values of $DIFF_{CL}$ for the GF25 seedlot were quite variable, both positive and negative.

Individual tree values of $DIFF_{max}$, $DIFF_{av}$, and $DIFF_{CL}$ were analysed using the SAS procedure, PROC GLM with plot number as a "class" variable and relative position in the DBH distribution as a continuous variable. The relative position in the DBH distribution was not significant, indicating that TreeBLOSSIM is performing equally well for trees of different DBH within a plot.
Least square mean values for $DIFF_{max}$ (Table 2), $DIFF_{av}$ (Table 3), and $DIFF_{CL}$ (Table 4) were calculated in PROC GLM with plot as a "class variable".

Only 2 of the 28 pairwise comparisons of the least square mean values of $DIFF_{max}$ (Table 2) were significantly different ($p< 0.05$). For a given silvicultural treatment, there were no significant differences between the seedlots.

Table 2. Least-square mean values for $DIFF_{max}$ in mm for FR121/1, Tungrove.

Treatment	GF14	GF16	GF25	LI
500 ⇨ 200	25	19	16	13
1000 ⇨ 400			18	15
1000 ⇨ 600			-3	7

5 of the 28 pairwise comparisons of the least square mean values of $DIFF_{av}$ (Table 3) were significantly different ($p<0.05$). The least square mean values for plots with a final crop stocking of 600 stems per hectare were generally significantly different from the plots with a final crop stocking of 200 stems/ha. For a given silvicultural treatment there were no significant differences between the seedlots.

Table 3. Least-square mean values for $DIFF_{av}$ in mm for FR121/1, Tungrove.

Treatment	GF14	GF16	GF25	LI
500 ⇨ 200	11	5	11	12
1000 ⇨ 400			3	3
1000 ⇨ 600			-3	3

13 of the 18 pairwise comparisons of the least square mean values of $DIFF_{CL}$ (Table 4) were significantly different ($p<0.05$). The most consistent feature was that TreeBLOSSIM consistently overpredicted the number of branch clusters for the long –internode seedlot. This is not unexpected as the long-internode seedlot was selected to have fewer branch clusters.

Table 4. Least-square mean values for $DIFF_{CL}$ for FR121/1, Tungrove.

Treatment	GF14	GF16	GF25	LI
500 ⇨ 200	-0.16	0.27	-0.12	-0.46
1000 ⇨ 400			-0.27	-0.45
1000 ⇨ 600			0.19	-0.56

Figure 1. Graphs showing the difference in branch diameter (maximum =$DIFF_{max}$ and average = $DIFF_{av}$), and difference in the number of branch clusters per metre ($DIFF_{CL}$) between image measurements and TreeBLOSSIM predictions, for individual trees within GF 14 and GF16 PSPs in FR121/1 (Tungrove).

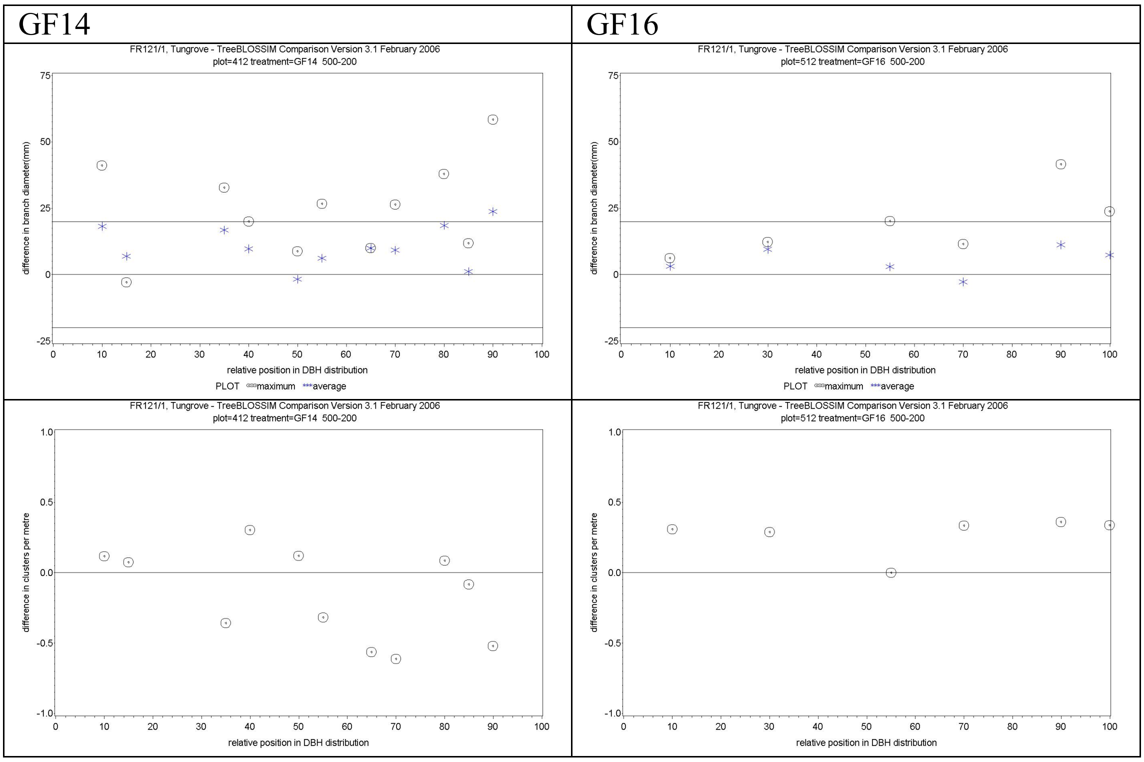


Figure 2. **Graphs showing the difference in branch diameter (maximum =*$DIFF_{max}$* and average = *$DIFF_{av}$*) between image measurements and TreeBLOSSIM predictions, for individual trees within GF 25 and Long Internode PSPs in FR121/1 (Tungrove).**

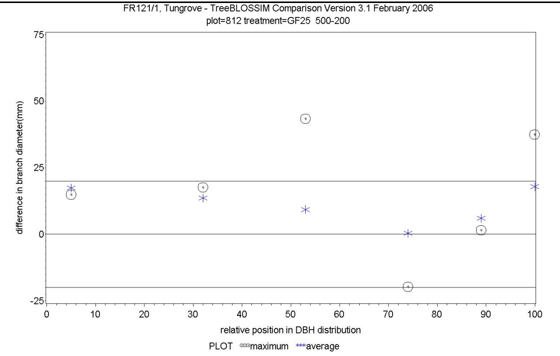
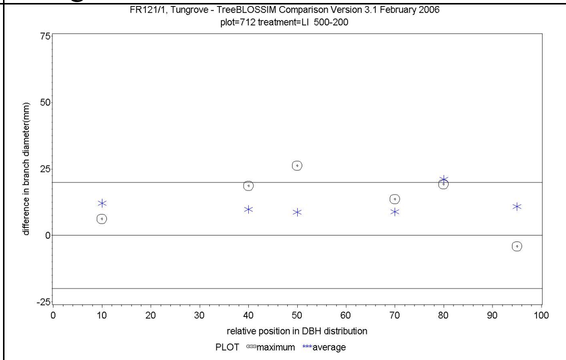
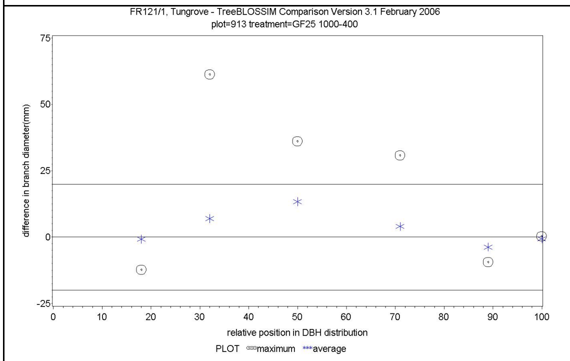
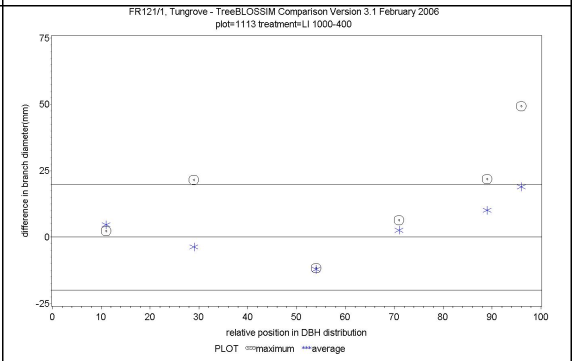
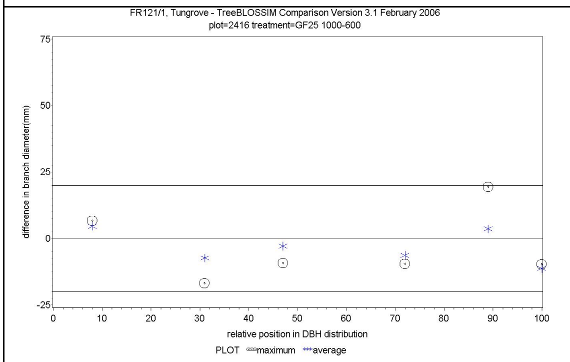
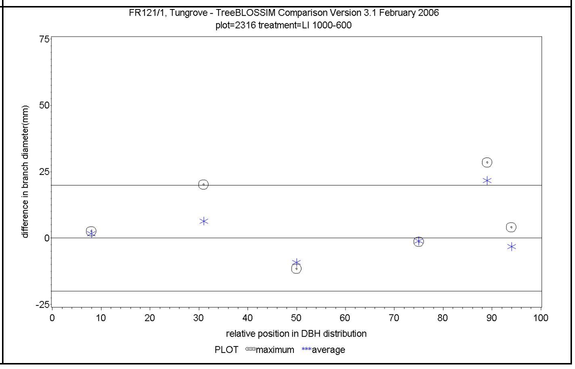
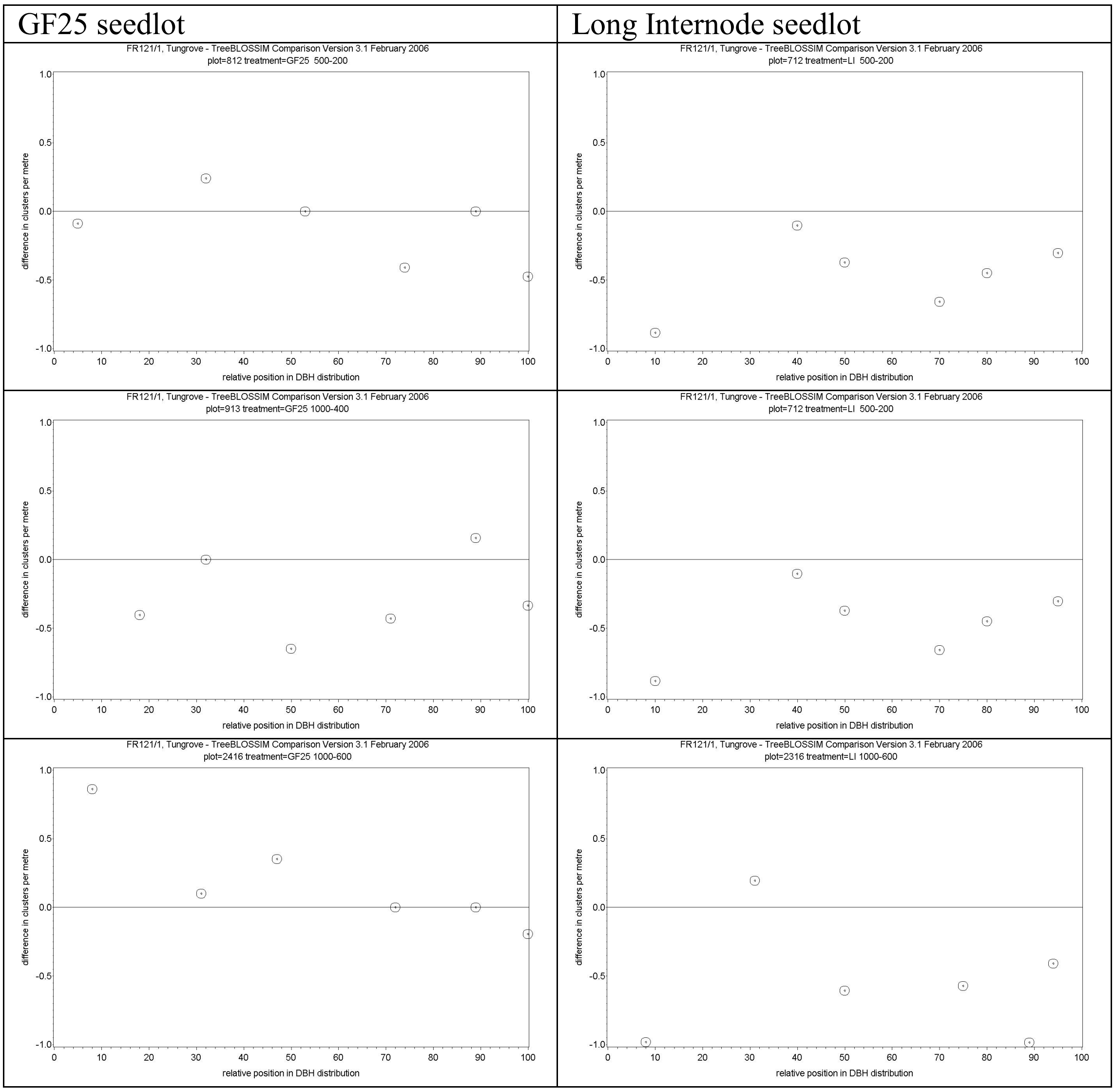
GF25 seedlot	Long Internode seedlot
	
	
	

Figure 3. **Graphs showing the difference in the number of branch clusters per metre (*$DIFF_{CL}$*) between image measurements and TreeBLOSSIM predictions, for individual trees within GF25 and Long Internode PSPs in FR121/1 (Tungrove).**



FR121/3 Gwavas (visited in November 2006).

Many trees had obvious stem damage around 8 m. In the field an attempt was made to replace any trees with obvious stem damage with "undamaged" trees. Trees with obvious stem damage around 8 m were not imaged, whereas trees with obvious stem damage around 15 m were imaged. The reason being that on the trees where the damage was higher, there should be a section of stem where branching has not been affected by stem damage.
The amount of damage also appeared to be related to position of the plot in the trial. The plots at 100 stems/ha were in an exposed area and had suffered more damage. Plot 12/15 (at 600 stems/ha) was an isolated plot and had also suffered from damage.

Individual tree values of $DIFF_{max}$, $DIFF_{av}$, and $DIFF_{CL}$ are shown for each plot in Figures 4, 5 and 6. The values of $DIFF_{av}$ and $DIFF_{max}$ were generally larger than 20 mm for trees in plots thinned to a final crop stockings of 100 and 200 stems/ha. The differences were smaller for the plots thinned to a final crop stocking of 400 or 600 stems/ha. As expected the long internode seedlot had less branch clusters than predicted by TreeBLOSSIM (large negative values of $DIFF_{CL}$).

Individual tree values of $DIFF_{max}$, $DIFF_{av}$, and $DIFF_{CL}$ were analysed using the SAS procedure, PROC GLM with plot number as a "class" variable and relative position in the DBH distribution as a continuous variable. The relative position in the DBH distribution was not significant, indicating that TreeBLOSSIM is performing equally well for trees of different DBH within a plot.
Least square mean values for $DIFF_{max}$ (Table 5), $DIFF_{av}$ (Table 6), and $DIFF_{CL}$ (Table 7) were calculated in PROC GLM with plot as a "class variable".

16 of the 45 pairwise comparisons of the least square mean values of $DIFF_{max}$ (Table 5) were significantly different ($p< 0.05$). For plots with a final crop stocking of 100, 400 and 600 stems/ha, there were no significant differences between the seedlots. The differences tended to be larger for the lower final crop stockings.

Table 5. Least-square mean values for $DIFF_{max}$ in mm for FR121/3, Gwavas.

Treatment	GF14	GF16	GF25	LI
250 ⇨ 100			75	75
500 ⇨ 200	51	25	88	35
1000 ⇨ 400			13	32
1000 ⇨ 600			19	36

19 of the 45 pairwise comparisons of the least square mean values of $DIFF_{av}$ (Table 6) were significantly different ($p< 0.05$). For plots with a final crop stocking of 100, 400 and 600 stems/ha, there were no significant differences between the seedlots. The differences tended to be larger for the lower final crop stockings.

Table 6. Least-square mean values for $DIFF_{av}$ in mm for FR121/3, Gwavas.

Treatment	GF14	GF16	GF25	LI
250 ⇨ 100			31	30
500 ⇨ 200	20	12	34	20
1000 ⇨ 400			7	17
1000 ⇨ 600			6	17

The least square mean values of $DIFF_{CL}$ (Table 7) were significant from zero for 4 of the 10 plots, including the GF14 plot. The most consistent feature was that TreeBLOSSIM consistently overpredicted the number of branch clusters for the long –internode seedlot. This is not unexpected as the long-internode seedlot was selected to have fewer branch clusters. 15 of the 45 pairwise comparisons of the least square mean values of $DIFF_{CL}$ (Table 7) were significantly different ($p< 0.05$).

Table 7. Least-square mean values for $DIFF_{CL}$ for FR121/3, Gwavas.

Treatment	GF14	GF16	GF25	LI
250 ⇨ 100			0.14	-0.29
500 ⇨ 200	-0.34	-0.10	-0.25	-0.37
1000 ⇨ 400			-0.03	-0.62
1000 ⇨ 600			0.24	-0.55

Figure 4. Graphs showing the difference in branch diameter (maximum =$DIFF_{max}$ and average = $DIFF_{av}$), and difference in the number of branch clusters per metre ($DIFF_{CL}$) between image measurements and TreeBLOSSIM predictions, for individual trees within GF 14 and GF16 PSPs in FR121/3 (Gwavas).

GF14 seedlot	GF16 seedlot

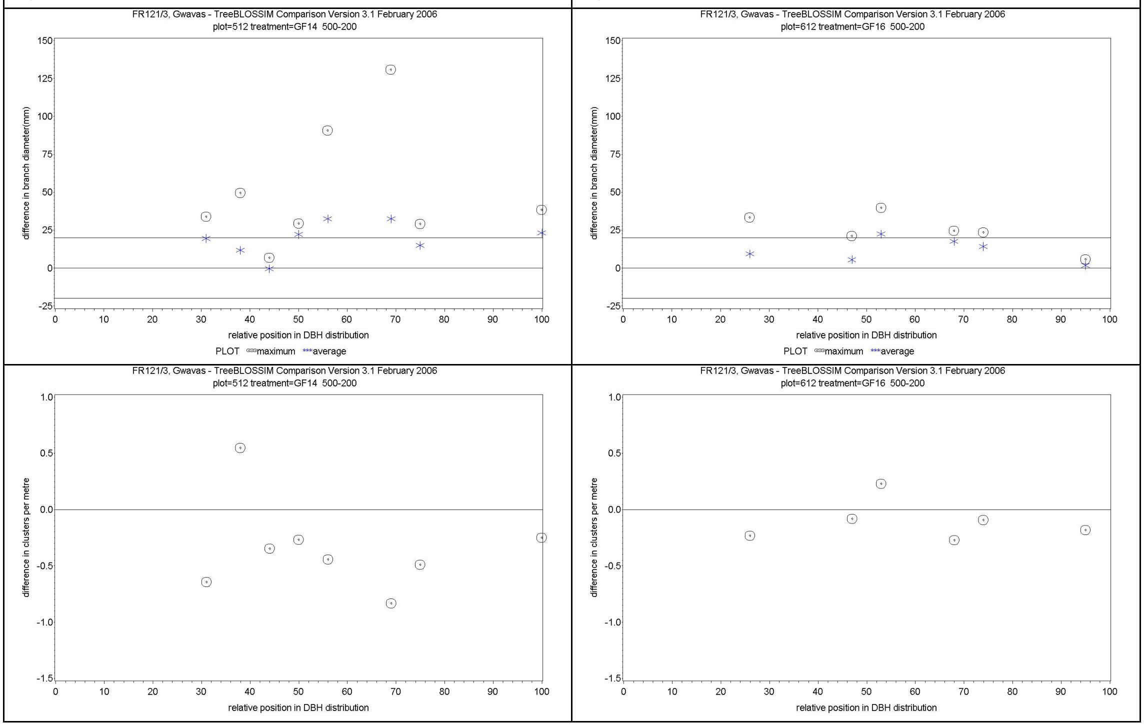
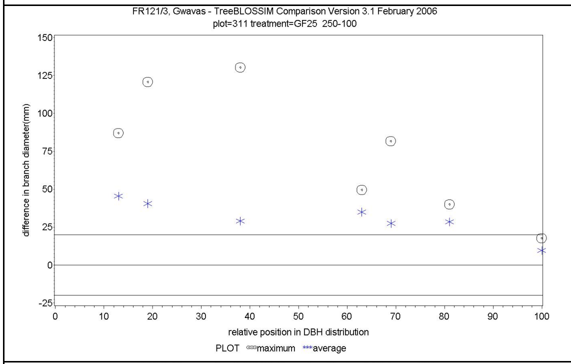
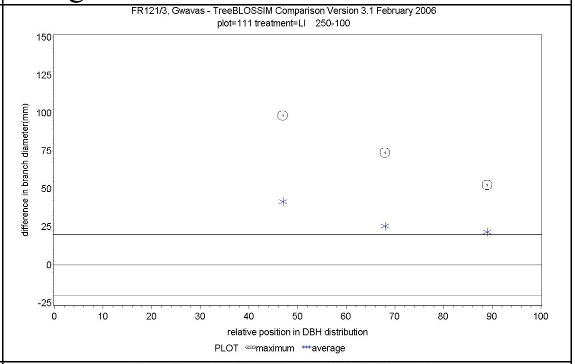
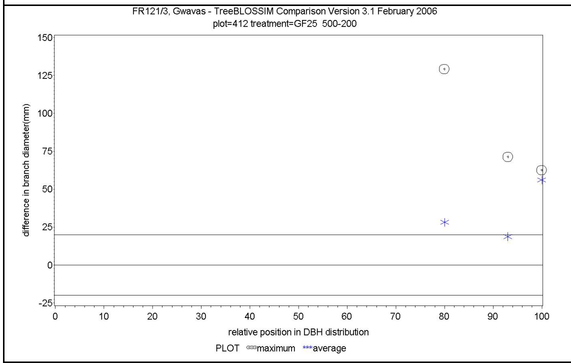


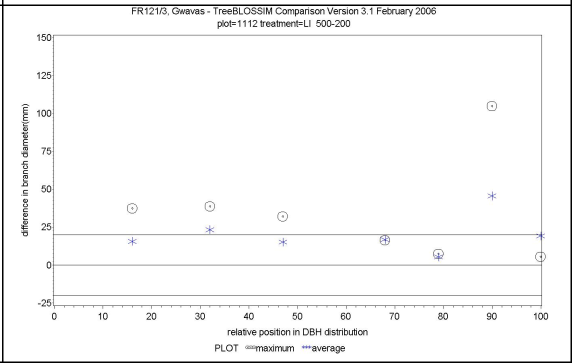
Figure 5. **Graphs showing the difference in branch diameter (maximum =$DIFF_{max}$ and average = $DIFF_{av}$) between image measurements and TreeBLOSSIM predictions, for individual trees within GF25 and Long Internode PSPs in FR121/3 (Gwavas).**

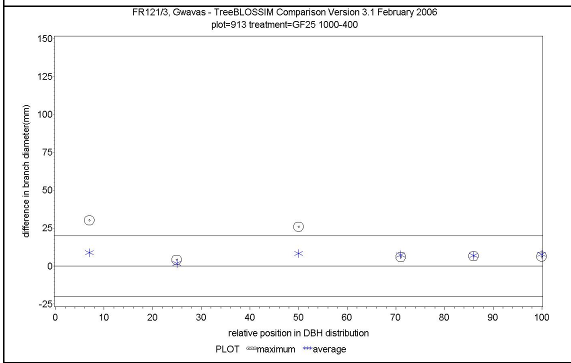
GF25 seedlot	Long Internode seedlot

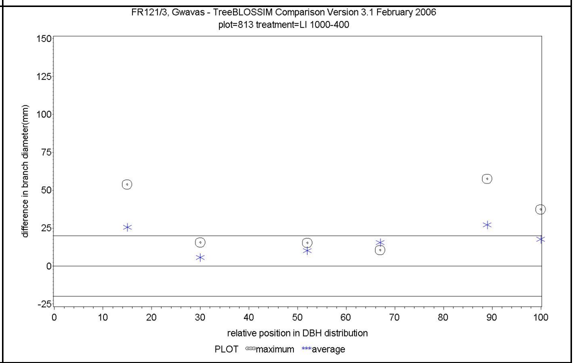


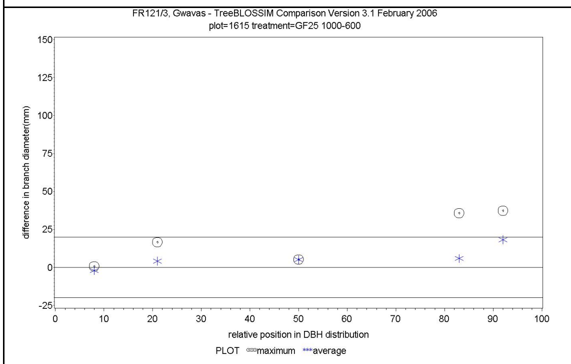












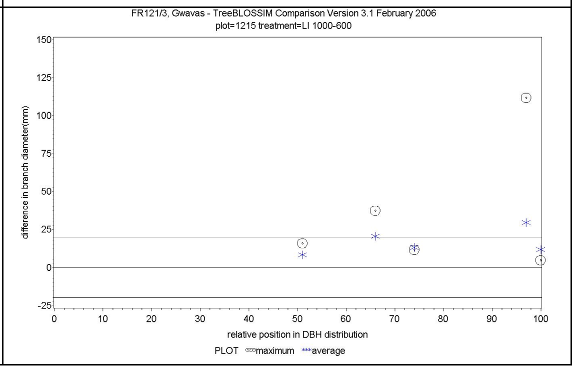
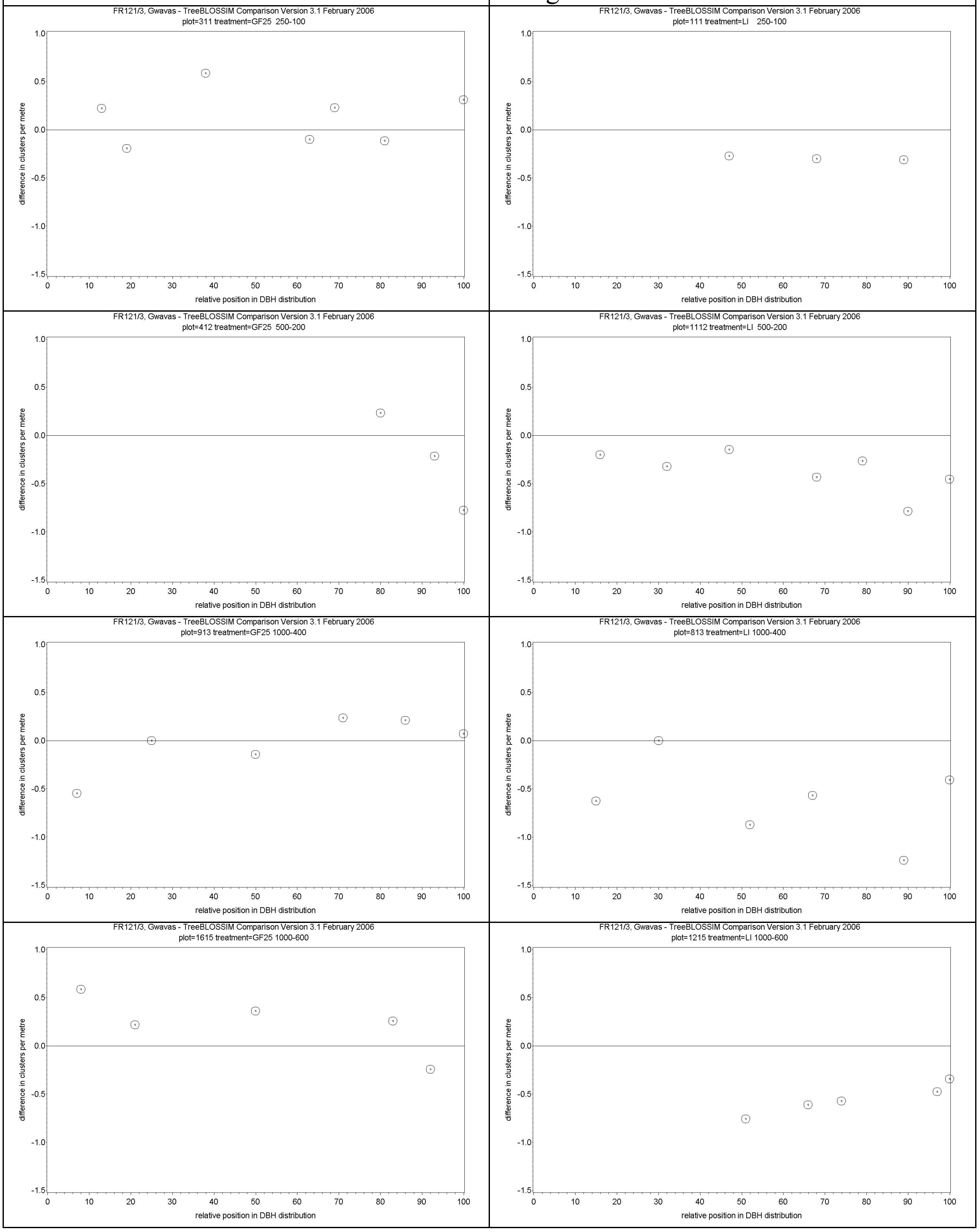


Figure 6. Graphs showing the difference in the number of branch clusters per metre ($DIFF_{CL}$) between image measurements and TreeBLOSSIM predictions, for individual trees within GF25 and Long Internode PSPs in FR121/3 (Gwavas).

GF25 seedlot	Long Internode Seedlot



FR121/13 Golden Downs (visited in January 2007).

Individual tree values of $DIFF_{max}$, $DIFF_{av}$, and $DIFF_{CL}$ are shown for each plot in Figures 7, 8 and 9. The values of $DIFF_{av}$ and $DIFF_{max}$ tended to be larger for plots with final crop stockings of 100 and 200 stems/ha.

Individual tree values of $DIFF_{max}$, $DIFF_{av}$, and $DIFF_{CL}$ were analysed using the SAS procedure, PROC GLM with plot number as a "class" variable and relative position in the DBH distribution as a continuous variable. The relative position in the DBH distribution was not significant, indicating that TreeBLOSSIM is performing equally well for trees of different DBH within a plot.

Least square mean values for $DIFF_{max}$ (Table 8), $DIFF_{av}$ (Table 9), and $DIFF_{CL}$ (Table 10) were calculated in PROC GLM with plot as a "class variable".

22 of the 45 pairwise comparisons of the least square mean values of $DIFF_{max}$ (Table 8) were significantly different ($p < 0.05$). For 3 of the 4 silvicultural treatments, there were no significant differences between the seedlots. The exception was the treatment with a final crop stocking of 400 stems/ha. There was also a trend for TreeBLOSSIM to perform better at higher final crop stockings.

Table 8. Least-square mean values for $DIFF_{max}$ in mm for FR121/13, Golden Downs

Treatment	GF14	GF16	GF25	LI
250 ⇨ 100			44	53
500 ⇨ 200	19	26	29	30
1000 ⇨ 400			14	25
1000 ⇨ 600			7	15

19 of the 45 pairwise comparisons of the least square mean values of $DIFF_{av}$ (Table 9) were significantly different ($p < 0.05$). For a given silvicultural treatment, there were no significant differences between the seedlots, but there was a clear trend for TreeBLOSSIM to perform better at higher final crop stockings.

Table 9. Least-square mean values for $DIFF_{av}$ in mm for FR121/13, Golden Downs

Treatment	GF14	GF16	GF25	LI
250 ⇨ 100			27	32
500 ⇨ 200	13	15	15	18
1000 ⇨ 400			12	22
1000 ⇨ 600			3	11

The least square mean values of $DIFF_{CL}$ (Table 10) were significant for 5 of the 10 plots. The values for the long–internode seedlot were negative whereas the values for the other seedlots were positive. 20 of the 45 pairwise comparisons of the least square mean values of $DIFF_{CL}$ were significantly different ($p < 0.05$).

Table 10. Least-square mean values for $DIFF_{CL}$ for FR121/13, Golden Downs

Treatment	GF14	GF16	GF25	LI
250 ⇨ 100			0.6	-0.1
500 ⇨ 200	0.2	0.2	0.5	-0.2
1000 ⇨ 400			0.4	-0.5
1000 ⇨ 600			0.6	-0.0

Figure 7. **Graphs showing the difference in branch diameter (maximum =$DIFF_{max}$ and average = $DIFF_{av}$), and difference in the number of branch clusters per metre ($DIFF_{CL}$) between image measurements and TreeBLOSSIM predictions, for individual trees within GF14 and GF16 PSPs in FR121/13 (Golden Downs).**

GF 14 seedlot	GF16 seedlot

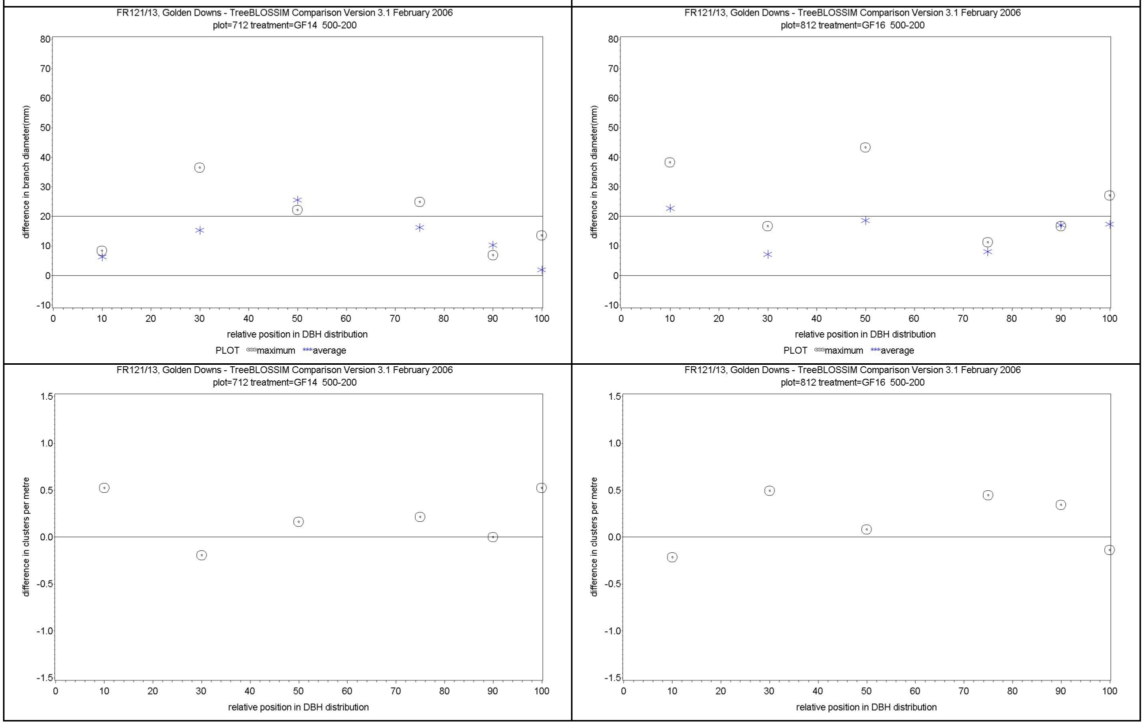


Figure 8. **Graphs showing the difference in branch diameter (maximum =$DIFF_{max}$ and average = $DIFF_{av}$) between image measurements and TreeBLOSSIM predictions, for individual trees within GF25 and Long Internode PSPs in FR121/13 (Golden Downs).**

GF25 seedlot	Long Internode seedlot

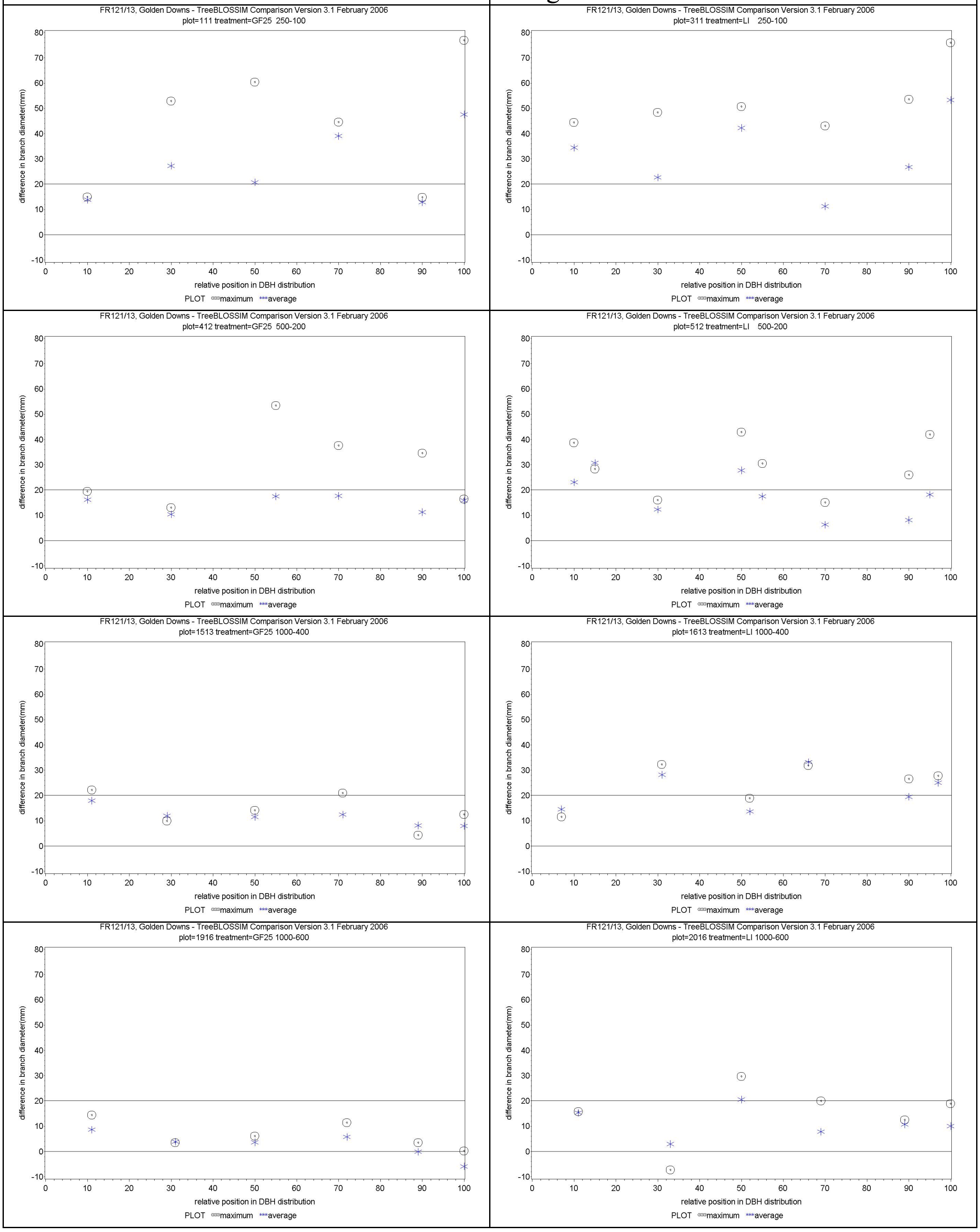
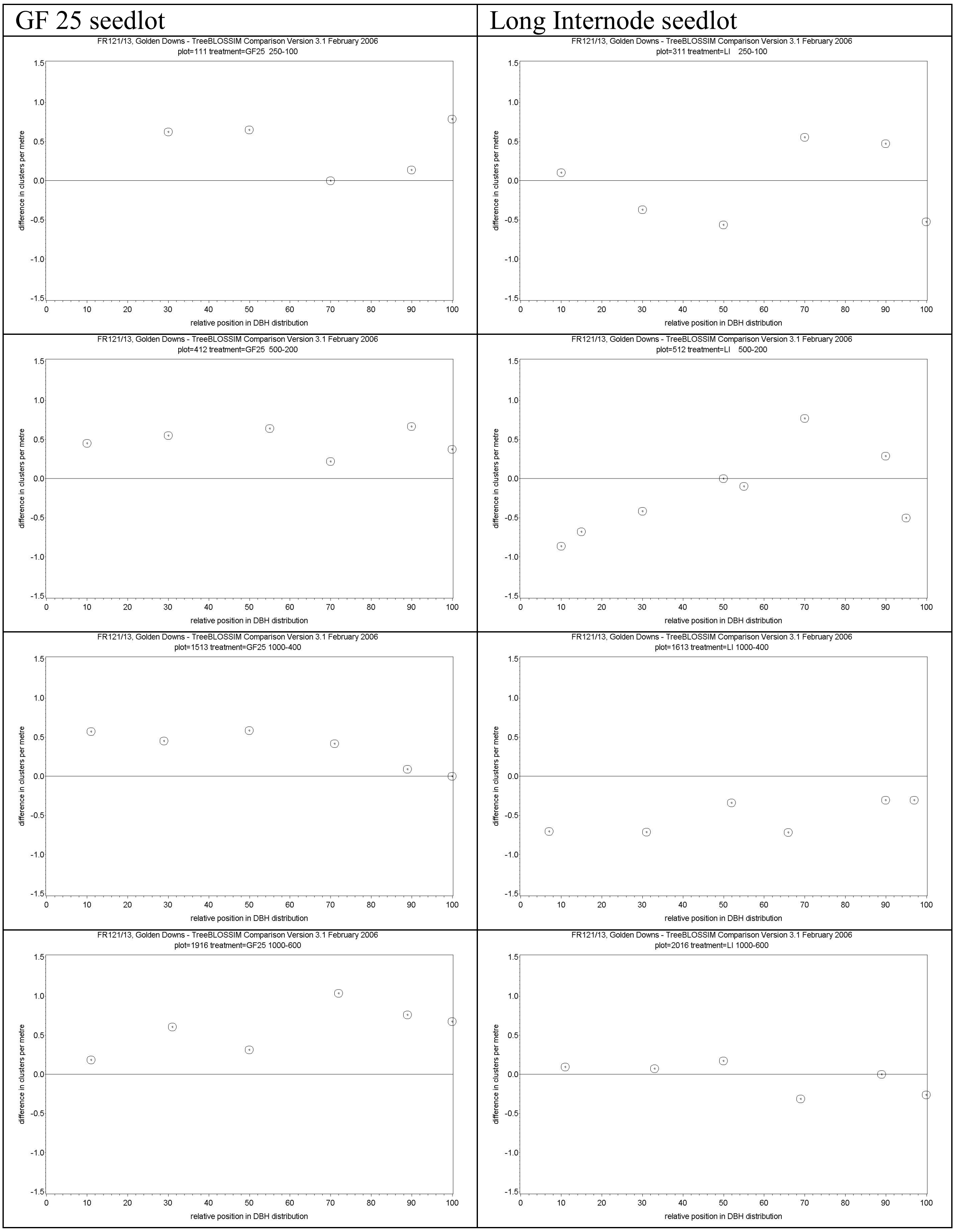


Figure 9. Graphs showing the difference in the number of branch clusters per metre ($DIFF_{CL}$) between image measurements and TreeBLOSSIM predictions, for individual trees within GF25 and Long Internode PSPs in FR121/13 (Golden Downs).



Assessment of stem damage

Previous SGMC studies (see SGMC Reports Nos. 134, 136, and 137) identified that TreeBLOSSIM was poor at predicting branch diameter for trees where there had been previous stem damage. Such trees had larger branch diameters than expected. Some criteria were developed by which trees with stem damage could possibly be identified in GF14 seedlots.

One particular criteria that was considered to be particularly useful was:

- BDI_{max} - BDI_{av}

Stems were more likely to be damaged if the difference was above 60 mm (SGMC Report No. 136) or above 80 mm (SGMC Report Nos. 134 and 137).

The above difference was calculated for trees in FR121/1, FR121/3 and FR121/13. There were no trees for which BDI_{max} - BDI_{av} > 60 mm in FR121/13, Golden Downs There were 5 trees that satisfied this condition in FR121/1 at Tungrove (Table 11). These trees all showed signs of stem damage, obvious leader changes or steeply angled branches, which are a sign of leader damage. There were more (total of 15) trees, that satisfied the above condition in FR121/3 at Gwavas, a windier site than FR121/1 (Table 12). Most of the trees that satisfied this condition contained stem damage.

These results again indicate that stem damage is one reason for poor performance of TreeBLOSSIM, but this is only an issue if one is trying to predict the branching characteristics of the tree with no prior information. If inventory data were available, then the large branches would already be noted, and these should be able to be grown forward in time with acceptable accuracy.

Table 11. Trees for which BDI_{max} - BDI_{av} is greater than 60 mm at FR121/1, Tungrove

Plot	Treekey	Relative position	BDI_{max} - DBI_{av} (mm) (>60 mm)	Comment
4_12	3	90	66	Tree with possible leader change
5_12	3	90	61	Steeply angled branches and possible stem deviation
8_12	34	53	67	Steeply angled branches
9_13	10	71	60	Steeply angled branches
9_13	40	32	79	Contained a double leader that was measured.

Table 12. Trees for which *BDI_{max}* - *BDI_{av}* is greater than 60 mm at FR121/3, Gwavas

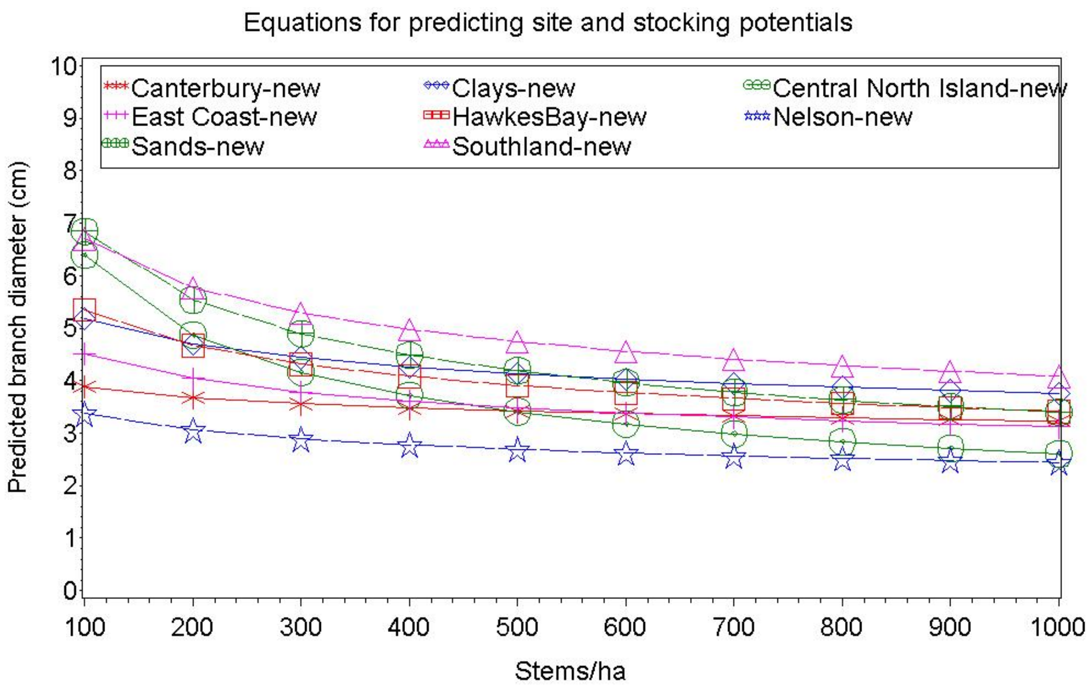
Plot	Treekey	Relative position	BDI_{max} - DBI_{av} (mm) (>60 mm)	Comment
1_11	2	68	87	Some large steep branches but in an open area
1_11	12	47	89	Large branches including one steep branch. Tree also in an open area
3_11	12	69	91	Large branches to one side of tree but no obvious signs of stem damage
3_11	14	13	64	Tree contains a lot of large branches. No obvious signs of old damage but appears to have lost its top recently.
3_11	37	19	116	Tree in gap with large steeply angled branches.
3_11	48	38	125	Several probable leader changes – Swept stem and steep branches.
4_12	21	93	76	Large branches but no obvious sign of stem damage
4_12	40	80	137	Contains a large spike knot
5_12	8	38	66	Contains a steeply angled branch
5_12	37	69	127	Contains a steeply angled branch
5_12	43	56	81	Steeply angled branches and swept stem
8_13	37	89	66	Analysis indicated a large branch near the top of the image but it is difficult to see and determine whether it is related to damage.
11_12	23	90	88	Large branches, at least one very steep branch
12_15	27	97	115	Some steep angled branches

Comments on errors with respect to stocking

The site and stocking potential will influence the branch diameters attained at different stockings. The relationship varies with growth modelling region (Figure 10). A rapid rise in branch diameter is predicted for some regions, but not for others. The regions considered in these analyses were:
FR121/1 – Clays
FR121/3 – Hawkes Bay
FR121/13 – Nelson

None of these regions show a particularly strong response to the change in stocking. The least square mean errors for $DIFF_{max}$ and $DIFF_{av}$ indicate that TreeBLOSSIM has not performed that well at low stockings particularly in Golden Downs (Tables 8 and 9) and Gwavas (Tables 5 and 6), though here the results are also influenced by stem damage. These results suggest that there should be a greater increase in branch diameter with decreasing stocking in these regions, and that the functions need modification.

Figure 10. Graph showing site and stocking potentials in TreeBLOSSIM V3 implemented in 2006.



DISCUSSION

PhotoMARVL / TreeD studies were carried out for a range of silvicultural treatments and seedlots in the 1990/91 silviculture breed trials FR121/1 (Tungrove), FR121/3 (Gwavas), and FR121/13 (Golden Downs) between October 2006 and February 2007.

The main points to emerge from the analysis of these data were:

- TreeBLOSSIM performance was similar for the seedlots considered (GF14,GF16, GF25 and Long Internode) suggesting that branch diameters vary little between seedlots.
- TreeBLOSSIM performance tended to be poorer for the plots at lower final crop stocking indicating that the site and stocking potentials still need further modification.
- Stem damage has a major influence on branching with branch diameter being larger than predicted by TreeBLOSSIM.
- Further research is needed to determine how trees respond to stem damage, in particular the reasons for the larger than expected branch diameters and the consequent effects of stem damage on wood property distributions within the stem.

ACKNOWLEDGMENTS

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APPENDIX 1. List of trees for which images were taken.

Tungrove FR121/1

phim_no	Plotno	seedlot	Final stems / ha	Treeno	Treekey	rel_pos	DBH (cm)
9295	2416	GF25	600	1	1	31	27.3
9297	2416	GF25	600	6	6	47	27.7
9299	2416	GF25	600	14	14	72	32.2
9301	2416	GF25	600	26	26	8	19.7
9303	2416	GF25	600	35	35	100	43.8
9305	2416	GF25	600	54	54	89	37.4
9307	2316	LI	600	6	6	89	40.5
9309	2316	LI	600	7	7	94	38.1
9311	2316	LI	600	14	14	75	36.2
9313	2316	LI	600	30	30	31	23.5
9315	2316	LI	600	32	32	50	30.3
9317	2316	LI	600	37	37	8	51.4
9319	913	GF25	400	1	1	18	28.4
9321	913	GF25	400	3	3	50	33.8
9323	913	GF25	400	6	6	89	37.3
9325	913	GF25	400	10	10	71	36
9327	913	GF25	400	38	40	32	30.6
9329	913	GF25	400	60	62	100	42.3
9331	812	GF25	200	7	7	89	48.9
9333	812	GF25	200	19	19	5	34.2
9335	812	GF25	200	23	23	74	46.9
9337	812	GF25	200	34	34	53	44.8
9339	812	GF25	200	37	37	100	52.7
9341	812	GF25	200	42	42	32	44.3
9343	1113	LI	400	15	15	29	31.9
9345	1113	LI	400	29	29	71	35.3
9347	1113	LI	400	39	39	89	40.3
9349	1113	LI	400	58	58	11	27.2
9351	1113	LI	400	61	61	54	35.2
9354	1113	LI	400	69	69	96	40.3
9358	712	LI	200	6	6	95	47.2
9360	712	LI	200	8	8	10	33
9362	712	LI	200	9	9	70	39.2
9364	712	LI	200	19	19	50	38.3
9366	712	LI	200	27	27	40	37
9368	712	LI	200	45	45	80	40.3
9370	512	GF16	200	3	3	90	44.6
9374	512	GF16	200	18	19	70	42.1
9376	512	GF16	200	20	21	55	40.5
9378	512	GF16	200	31	32	100	49.2
9385	512	GF16	200	38	39	30	37.8
9388	512	GF16	200	41	42	10	31.4
9390	512	GF16	200	46	47	35	38.1
9392	412	GF14	200	3	3	90	48
9396	412	GF14	200	5	5	40	41.8
9398	412	GF14	200	10	10	70	43.8
9400	412	GF14	200	17	17	10	34.9
9402	412	GF14	200	26	26	35	41
9404	412	GF14	200	28	28	50	42.1
9406	412	GF14	200	30	30	65	42.8
9408	412	GF14	200	32	32	85	47.9
9410	412	GF14	200	44	44	55	42.9
9412	412	GF14	200	48	49	15	35.4
9414	412	GF14	200	21	21	80	47.1

Gwavas, FR121/3

phim_no	plotno	seedlot	Final stems / ha	treeno	treekey	rel_pos	DBH (cm)
9423	111	GF13/LI	100	9	9	89	62.4
9425	111	GF13/LI	100	2	2	68	60.5
9427	111	GF13/LI	100	12	12	47	57.8
9429	311	GF25	100	12	12	69	56.2
9431	311	GF25	100	27	27	63	58.7
9433	311	GF25	100	25	25	100	60.9
9435	311	GF25	100	49	49	81	58.3
9437	311	GF25	100	48	48	38	55.9
9439	311	GF25	100	37	37	19	53.3
9441	311	GF25	100	14	14	13	51.8
9443	512	GF14	200	31	31	100	56.8
9445	512	GF14	200	37	37	69	53.6
9447	512	GF14	200	48	48	31	49.1
9449	512	GF14	200	43	43	56	49.5
9451	512	GF14	200	15	15	75	51.6
9453	512	GF14	200	19	19	50	51.9
9455	512	GF14	200	8	8	38	52.6
9457	512	GF14	200	7	7	44	52.8
9459	612	GF16	200	11	11	74	50.7
9461	612	GF16	200	18	18	68	49.3
9463	612	GF16	200	1	1	47	47.1
9466	612	GF16	200	36	36	26	42.3
9470	612	GF16	200	45	47	95	54.6
9472	612	GF16	200	33	33	53	46.6
9474	1112	GF13/LI	200	23	23	90	53
9476	1112	GF13/LI	200	26	26	16	42.2
9478	1112	GF13/LI	200	1	1	68	50.9
9480	1112	GF13/LI	200	17	17	79	51.8
9482	1112	GF13/LI	200	27	27	100	57
9484	1112	GF13/LI	200	37	37	32	45.7
9486	1112	GF13/LI	200	41	41	47	47.8
9488	913	GF25	400	60	60	71	46.5
9490	913	GF25	400	6	6	25	38.3
9492	913	GF25	400	9	9	50	39.7
9494	913	GF25	400	21	21	100	54.2
9496	913	GF25	400	32	32	86	49.7
9498	913	GF25	400	63	63	7	34.6
9500	813	GF13/LI	400	29	29	15	35.5
9502	813	GF13/LI	400	35	35	52	44.2
9504	813	GF13/LI	400	37	37	89	49.3
9506	813	GF13/LI	400	49	50	100	52
9508	813	GF13/LI	400	56	57	67	49.6
9510	813	GF13/LI	400	57	58	30	39.7
9512	412	GF25	200	11	11	100	61.8
9514	412	GF25	200	21	21	93	59.1
9517	412	GF25	200	40	40	80	59.5
9520	1215	GF13/LI	600	9	9	100	49.8
9522	1215	GF13/LI	600	29	29	51	39.4
9524	1215	GF13/LI	600	40	40	66	41.9
9526	1215	GF13/LI	600	22	22	74	41.3
9528	1215	GF13/LI	600	27	27	97	49.1
9530	1615	GF25	600	4	4	50	42
9533	1615	GF25	600	17	17	92	55.5
9535	1615	GF25	600	56	56	21	40.5
9537	1615	GF25	600	57	57	83	52.2
9539	1615	GF25	600	60	60	8	27.5

Golden Downs, FR121/13

phim_no	plotno	seedlot	Final stems/ha	treeno	treekey	rel_pos	DBH (cm)
9637	512	LI	200	31	31	90	41.1
9639	512	LI	200	23	23	15	33
9641	512	LI	200	20	20	70	37.6
209	512	LI	200	8	8	95	40.8
211	512	LI	200	7	7	30	33.9
213	512	LI	200	4	4	10	32.8
215	512	LI	200	2	2	55	36.6
217	512	LI	200	49	49	50	35.5
219	712	GF14	200	46	46	50	36.6
221	712	GF14	200	36	36	10	33.1
223	712	GF14	200	32	32	100	40.7
225	712	GF14	200	24	24	30	34.2
227	712	GF14	200	6	6	90	39.5
229	712	GF14	200	3	3	75	37.6
231	812	GF16	200	39	16	10	34.5
233	812	GF16	200	34	14	50	36.7
235	812	GF16	200	23	10	90	38.7
237	812	GF16	200	18	8	30	36.1
239	812	GF16	200	13	6	75	38.2
241	812	GF16	200	5	2	100	43.3
243	412	GF25	200	33	34	70	37.5
245	412	GF25	200	28	29	90	41.6
247	412	GF25	200	18	19	100	42.1
249	412	GF25	200	13	14	55	37
251	412	GF25	200	3	3	10	31.2
253	412	GF25	200	40	41	30	35.2
255	111	GF25	100	14	13	50	45.4
257	111	GF25	100	12	11	10	38.2
259	111	GF25	100	9	8	70	46.7
261	111	GF25	100	21	20	100	52.5
263	111	GF25	100	37	36	90	47
265	111	GF25	100	39	38	30	41.7
267	311	LI	100	31	31	10	33.5
269	311	LI	100	38	39	50	38.8
271	311	LI	100	46	48	30	37.7
273	311	LI	100	13	13	70	41
275	311	LI	100	11	11	90	44.7
277	311	LI	100	8	8	100	46.5
279	1513	GF25	400	62	62	89	37.4
281	1513	GF25	400	60	60	50	34.4
283	1513	GF25	400	44	44	100	41.5
285	1513	GF25	400	21	21	11	27.6
287	1513	GF25	400	29	29	29	31.4
289	1513	GF25	400	67	67	71	36.5
291	1916	GF25	600	43	43	31	26.3
293	1916	GF25	600	44	44	11	23.8
295	1916	GF25	600	27	27	50	28.9
297	1916	GF25	600	16	16	89	33.2
299	1916	GF25	600	10	10	100	38.3
301	1916	GF25	600	14	14	72	31.7
303	2016	LI	600	32	32	33	27.1
305	2016	LI	600	30	30	69	29.8
307	2016	LI	600	6	6	11	25.8
309	2016	LI	600	23	23	100	35.6
311	2016	LI	600	50	50	50	28.8
313	2016	LI	600	40	40	89	31.7
315	1613	LI	400	23	23	31	29.5
317	1613	LI	400	8	8	97	36.8
319	1613	LI	400	9	9	7	24.3
321	1613	LI	400	60	60	90	36
323	1613	LI	400	52	52	66	33.5
325	1613	LI	400	45	45	52	32.2