Comparison of TreeBLOSSIM predictions with TreeD data:
FR121/2, Kinleith

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EXECUTIVE SUMMARY

TreeD is a ground-based photogrammetric method that allows tree characteristics to be measured from stereo digital images taken of standing trees.

TreeD data were collected from SGMC trial FR121/2, Kinleith in August 2007. The branching characteristics of individual trees were extracted from the images and compared with predictions of branching characteristics from the model TreeBLOSSIM.

The results from this current study were in agreement with results from the previous studies in FR121 series trials, namely:

- 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.
- 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.

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INTRODUCTION

TreeD is a non-destructive technique that allows measurements of tree characteristics to be extracted from stereo digital images of that tree. TreeD data may be utilised in two ways. Firstly it is used to compare TreeD measurements of branch diameter with TreeBLOSSIM predictions to determine how well TreeBLOSSIM predicts branch diameter on independent sites. Secondly the TreeD data can be used to examine the variation in branching due to site, silviculture and seedlot. In this study TreeD has been used to examine the performance of the model TreeBLOSSIM for the SGMC trial FR121/2, in Kinleith Forest.

Within the SGMC, trial FR121/2 is classified as a "medium site index" within the Central North Island Growth Modelling Region (SGMC Report 100). Based on the Land Environments of New Zealand (Leathwick *et al.* 2003), this trial falls into the Level 1 C Land Environment whereas all other SGMC trials in the Central North Island fall into the Level 1 F Land Environment (see SGMC Report No. 144).

The TreeD data from this trial will complement data already collected from five other replicates in this trial series, FR121/4 (Tairua), FR121/7 (Huanui) (see SGMC Report No. 135), FR121/1 (Tungrove), FR121/3 (Gwavas) and FR121/13 (Golden Downs) (see SGMC Report No. 142).

METHODS

<u>Selection of Sample Plots</u>

The treatments considered in previous TreeD studies using the FR121 series trials are shown in Table 1. The treatments sampled have varied slightly between trials for three reasons:

- A long–internode seedlot was not established in some trials.
- The treatment with a final crop stocking of 100 stems/ha was abandoned in some trials.
- The treatment with a final crop stocking of 600 stems/ha was not included in the first study (at Tairua)

The treatments assessed in FR121/2 are shown in Table 2.

Table 1. **Plots for which TreeD images are available in FR121 series trials.**

GF rating	Thinning Treatment	FR121/1 Tungrove	FR121/3 Gwavas	FR121/13 Golden Downs	FR121/4 Tairua	FR121/7 Huanui
14	500⇨200 stem/ha, pruned	4/12	5/12	7/12	6/12	3/12
16	500⇨200 stem/ha, pruned	5/12	6/12	8/12	5/12	5/12
25	500⇨200 stem/ha, pruned	8/12	4/12	4/12	4/12	6/12
13(LI25)	500⇨200 stem/ha, pruned	7/12	11/12	5/12	-	-
25	250⇨100 stems/ha, pruned	-	3/11	1/11	-	1/11
13(LI25)	250⇨100 stems/ha, pruned	-	1/11	3/11	-	-
25	1000⇨400 stem/ha, pruned	9/13	9/13	15/13	8/13	8/13
13(LI25)	1000⇨400 stem/ha, pruned	11/13	8/13	16/13	-	-
25	1000⇨600 stem/ha, unpruned	24/16	16/15	19/16	-	14/16
13(LI25)	1000⇨600 stem/ha, unpruned	23/16	12/15	20/16	-	-

Table 2. **Plots for which images were collected in FR121/2, Kinleith**

GF Rating	Thinning Treatment	Plot Number
14	500⇨200 stem/ha, pruned	4/12
16	500⇨200 stem/ha, pruned	10/12
25	500⇨200 stem/ha, pruned	3/12
13 (LI 25)	500⇨200 stem/ha, pruned	9/12
25	1000⇨400 stem/ha, pruned	15/13
13 (LI 25)	1000⇨400 stem/ha, pruned	14/13
25	1000⇨600 stem/ha, unpruned	23/16
13 (LI 25)	1000⇨600 stem/ha, unpruned	24/16

Selection of Sample Trees

In previous TreeD studies, all the trees in the PSP have been ranked according to DBH at last measurement (in this case 2005 remeasurement, as the 2007 remeasurement had not been carried out at the time the sample trees were selected) 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 $100 \times j/n$, giving values between $100 \times 1/n$ and 100.

In previous studies in the FR121 series trials, 6 trees were imaged per treatment. These were trees whose DBH were nearest to the 10, 30, 50, 70, 90, and 100 percentiles, and that had not had descriptive codes assigned in the PSP system that were related to stem damage. The same approach was used to select sample trees for this study. The complete list of trees imaged is shown in Appendix 1. Two columns of particular note are:

- **relpos,** which is the percentage rank of the tree
- **defect,** which is a code assigned to an individual tree based on any previously assigned descriptive codes (DESC_CODE) in the PSP system, and defects observed from examining the image.
  - Defect = 0, no sign of stem damage
  - Defect = 1, probable stem damage
  - Defect = 2, obvious stem damage
  - Defect = 3, tree appeared to be growing towards a gap

Ground-based photogrammetric method (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 FR121/2 was collected using TreeD procedure and the new Canon EOS 5D camera. The camera coped extremely well with the low light conditions prevailing in mid-August.

Site Conditions

The trial was situated on a level site with little undergrowth. There were lots of dead needles hung up on branches, making upper stem measurements difficult in the multinodal plots. Visually the stem form was generally good, which agrees with the low number of trees with stem damage at this site (see SGMC Report 138). Both comments indicate that this is a reasonably sheltered site.

Image analysis

The following measurements were extracted from the images:
- 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 FR121/2, the 2007 (age 17 year) PSP measurement was imported and the branching pattern estimated
- As the images were collected in August 2007, the data was exported as trees and the predicted branching pattern did not need to be grown forward

Comparisons

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 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 were 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 that 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 that stem section (i.e. average diameter *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.

RESULTS

<u>Comparison of TreeD data with TreeBLOSSIM predictions</u>

The individual tree graphs, 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 (Figures 2, 3 and 4), indicated that there were occasional large branches that were not well predicted. When the individual images were examined most of these large branches could be attributed to some form of stem damage (Figure 1).

Figure 1. Bar chart showing the values of $DIFF_{max}$ with respect to assigned defect class.

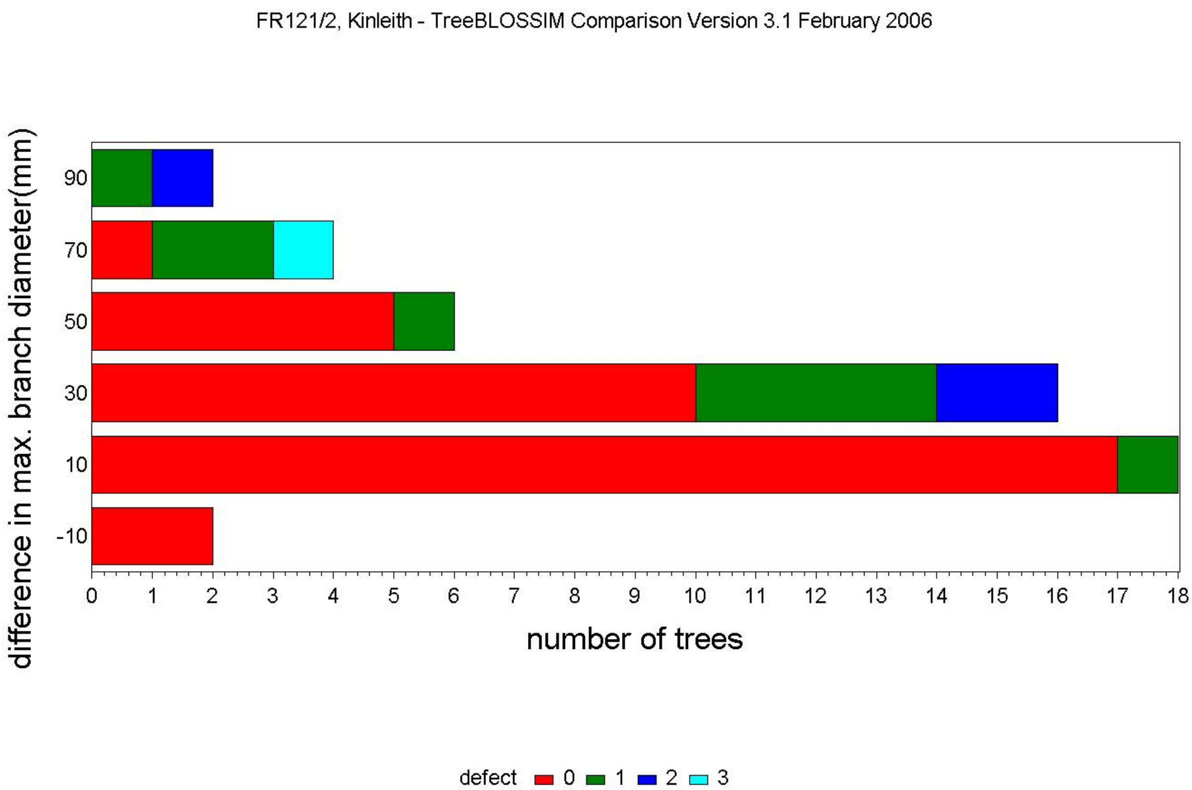


Figure 2. **Graphs showing the difference in branch diameter (maximum =$DIFF_{max}$ and average = $DIFF_{av}$), and difference in the number of branch clusters per metre ($DIFF_{CL}$) between image measurements and TreeBLOSSIM predictions, for individual trees within GF 14 and GF16 PSPs in FR121/2 (Kinleith).**

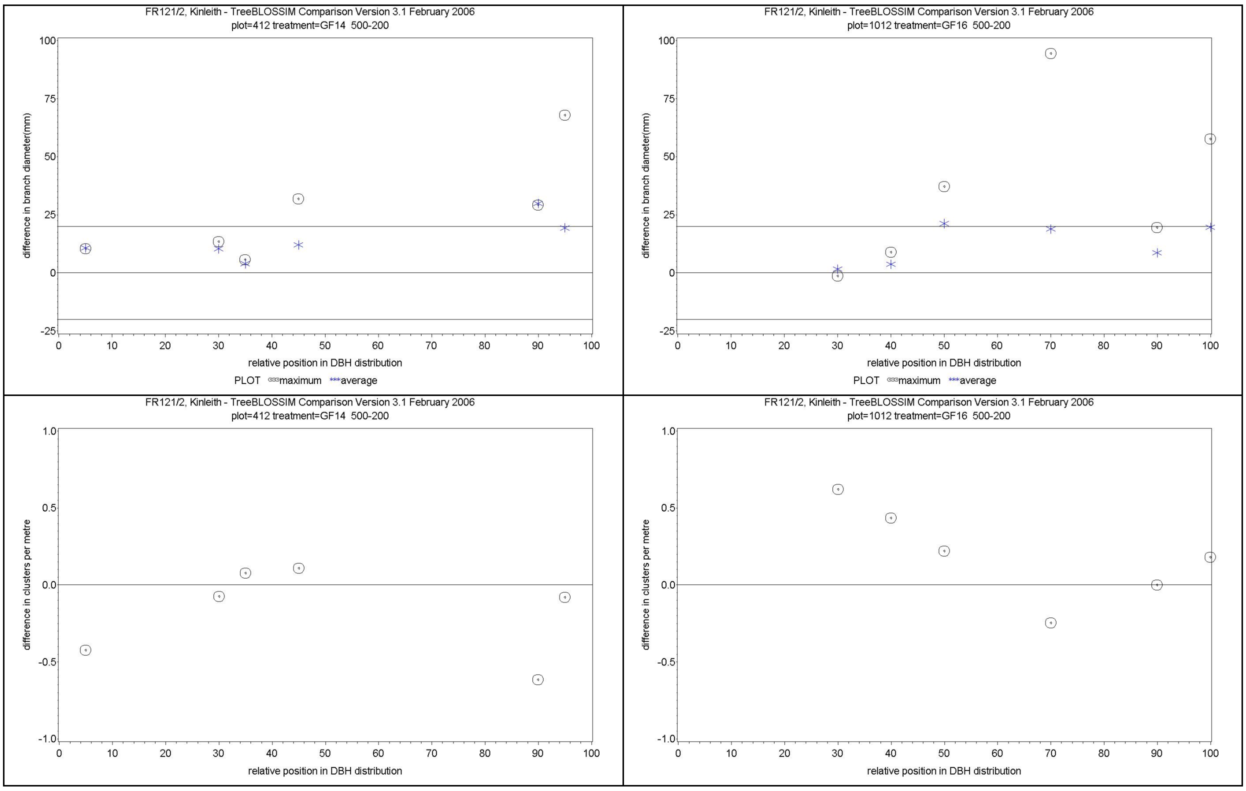


Figure 3. **Graphs showing the difference in branch diameter (maximum =*$DIFF_{max}$* and average = *$DIFF_{av}$*) between image measurements and TreeBLOSSIM predictions, for individual trees within GF 25 and Long Internode PSPs in FR121/2 (Kinleith).**

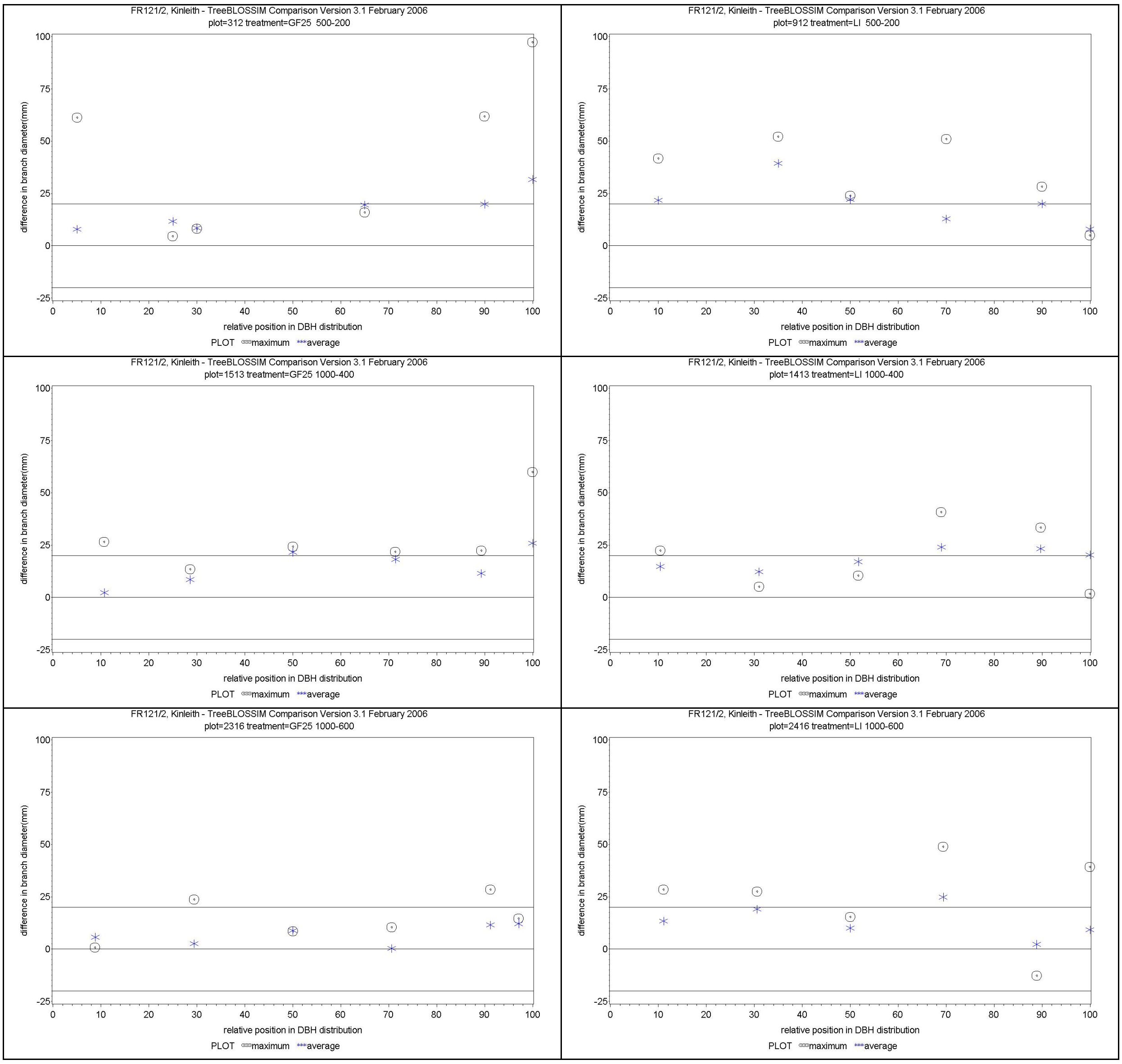
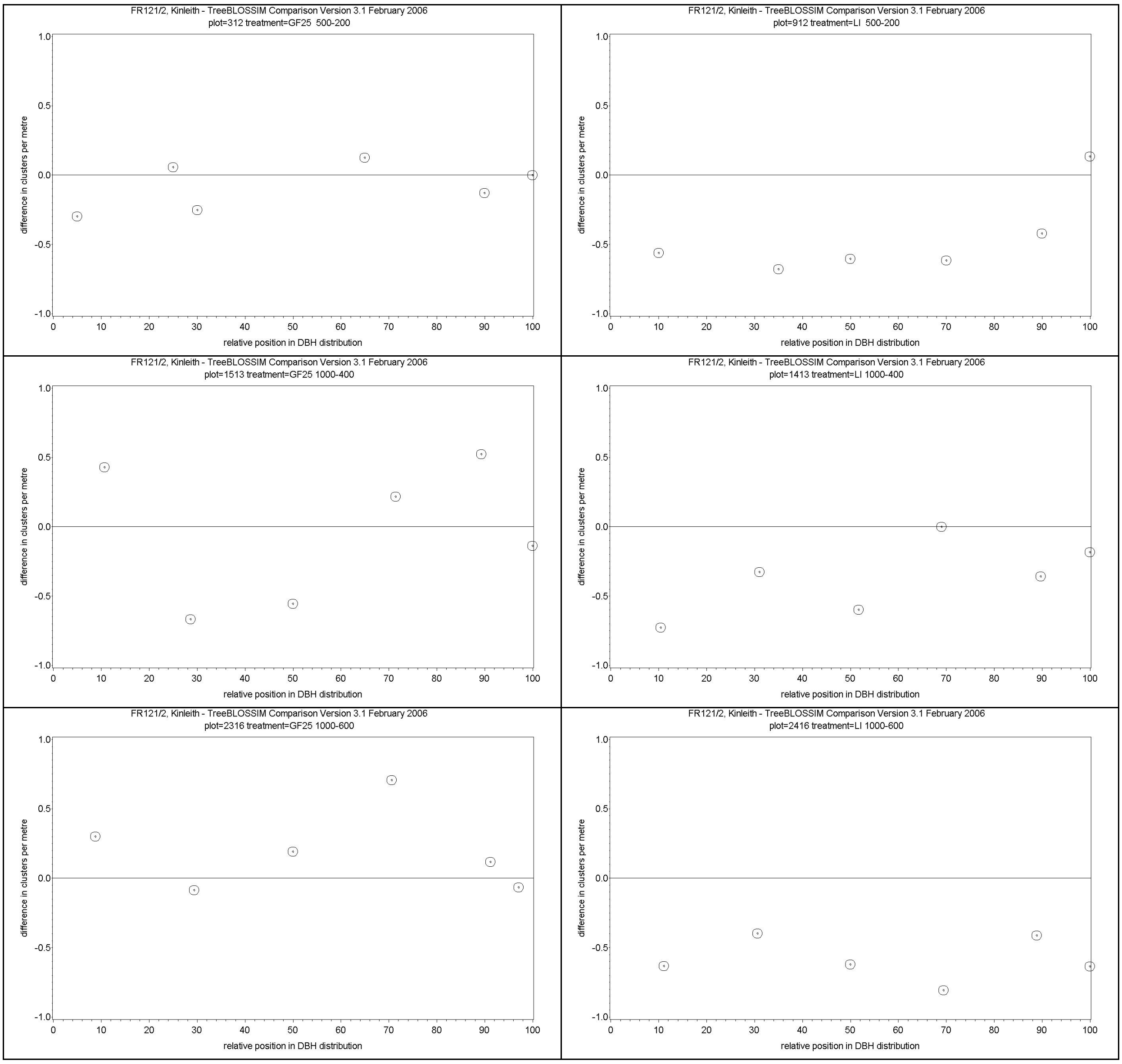


Figure 4. Graphs showing the difference in the number of branch clusters per metre ($DIFF_{CL}$) between image measurements and TreeBLOSSIM predictions, for individual trees within GF25 and Long Internode PSPs in FR121/2 (Kinleith).



At a plot level there was no significant correlation ($p<0.05$) between any of $DIFF_{max}$, $DIFF_{av}$, and $DIFF_{CL}$ and relative position of the tree in the DBH distribution (apart from one case). Least square mean values for $DIFF_{max}$ (Table 3), $DIFF_{av}$ (Table 4), and $DIFF_{CL}$ (Table 5) were calculated using the SAS procedure PROC GLM with plot as a "class variable". Trees with stem damage were not excluded, and this will have an influence on the least square means.

For a given stocking, there were no significant differences between the least mean values of $DIFF_{max}$ (Table 3), and $DIFF_{av}$ (Table 4), indicating that branch diameters are similar across seedlots.

Points that stand out from examining these tables:

- The long internode seedlot has noticeably fewer branch clusters than the other seedlots considered. The negative values of $DIFF_{CL}$ are evidence that there were less branch clusters than expected from model predictions.
- Visually the GF16 trees had lots of branch clusters. The positive value of $DIFF_{CL}$ is evidence that there were more branch clusters than expected from model predictions.
- There is a slight trend in the prediction of branch diameter with respect to final crop stocking. The predictions were slightly better at higher final crop stockings. This can be seen by examining the values $DIFF_{max}$ and $DIFF_{av}$.

Table 3. Least-square mean values for $DIFF_{max}$ in mm, FR121/2, Kinleith.

Treatment	GF14	GF16	GF25	LI25, GF13
500 ⇨ 200	26	36	42	34
1000 ⇨ 400			28	19
1000 ⇨ 600			14	25

Table 4. Least-square mean values for $DIFF_{av}$ in mm, FR121/2, Kinleith.

Treatment	GF14	GF16	GF25	LI25, GF13
500 ⇨ 200	14	12	16	21
1000 ⇨ 400			15	19
1000 ⇨ 600			7	13

Table 5. Least-square mean values for $DIFF_{CL}$, FR121/2, Kinleith.

Treatment	GF14	GF16	GF25	LI25, GF13
500 ⇨ 200	-0.17	0.20	-0.08	-0.46
1000 ⇨ 400			-0.03	-0.36
1000 ⇨ 600			0.20	-0.58

Comparison of results from FR121/2, Kinleith with previous results from FR8, Tahorakuri

SGMC trial, FR8 is also classified as a medium site index within the Central North Island Growth Modelling Region, but has a Land Environment classification of “F” at level 1. The percentage of trees with stem damage was similar in both FR8 and FR121/2 (see SGMC Report No. 138). There is however only 1 treatment that is common to both experiments, namely the GF14 seedlot planted at 500 stems/ha and thinned to 200 stems/ha. While both trials have a long internode seedlot, they do not have the same LI rating. This is insufficient information to justify a detailed comparison; however the least square mean values for $DIFF_{max}$, $DIFF_{av}$, and $DIFF_{CL}$ for the common treatment (Table 6) indicate that the differences between measured branching characteristics and TreeBLOSSIM predictions are similar.

Table 6. Least square mean values of differences between branching characteristics and TreeBLOSSIM predictions for FR121/2 (this report) and FR8 (SGMC Report No. 133)

Branching Characteristic	FR121/2	FR8
$DIFF_{max}$ (mm)	26	12
$DIFF_{av}$ (mm)	14	10
$DIFF_{CL}$	-0.17	-0.04

DISCUSSION

TreeD data was collected from FR121/2, Kinleith to determine how well the branching component of TreeBLOSSIM performed for this site. The study complemented previous TreeD studies in the FR121 series (see SGMC Report Nos. 135 and 142).

The results from this study were in agreement with results from the previous studies, namely:

- 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.
- 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.

REFERENCES

Brownlie, R.K.; Carson, W.W.; Firth, J.G.; Goulding, C.J. 2007. An image-based dendrometry tool for Standing Trees. *New Zealand Journal of Forestry Science* 37 (2): 153-168.

Firth, J.G.; Brownlie, R.K.; Carson, W.W. 2000. Accurate stem measurements, key to new image-based system. *New Zealand Journal of Forestry* 45 (2): 25-29.

Leathwick, J.; Wilson, G.; Rutledge, D.; Wardle, P.; Morgan, F.; Johnston, K.; McLeod, M.; Kirkpatrick, R. 2003. "Land Environments of New Zealand (LENZ) - Nga Taiao o Aotearoa". Ministry for the Environment, Wellington.

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Appendix 1. Sample trees from FR121/2, Kinleith.

phim_no	Plotno	seedlot	finalstems	Treeno	Treekey	rel_pos	DBH (cm)	defect
66	312	GF25	200	43	43	5	39.5	1
68	312	GF25	200	28	28	25	44.9	1
70	312	GF25	200	29	29	30	46.2	0
72	312	GF25	200	18	18	65	51.1	0
74	312	GF25	200	23	23	100	55.9	2
78	312	GF25	200	5	5	90	55.7	3
80	412	GF14	200	29	29	90	59.2	1
82	412	GF14	200	34	34	30	48.3	0
84	412	GF14	200	46	46	95	61.7	1
86	412	GF14	200	33	33	45	51.2	2
88	412	GF14	200	19	19	5	41.2	0
90	412	GF14	200	18	18	35	47.1	0
92	1012	GF16	200	41	42	100	59.3	0
94	1012	GF16	200	49	50	30	44.0	0
96	1012	GF16	200	18	19	50	47.9	0
98	1012	GF16	200	15	16	70	52.0	1
100	1012	GF16	200	12	13	40	46.1	0
102	1012	GF16	200	2	2	90	55.2	0
104	912	GF13	200	8	8	10	41.8	0
106	912	GF13	200	15	15	35	44.0	0
108	912	GF13	200	31	31	100	56.1	0
110	912	GF13	200	32	32	50	48.0	1
112	912	GF13	200	33	33	90	52.0	1
114	912	GF13	200	46	47	70	50.4	1
116	1513	GF25	400	7	7	100	60.0	0
118	1513	GF25	400	22	22	71.4	42.5	0
120	1513	GF25	400	35	35	28.6	37.5	0
122	1513	GF25	400	38	38	50	40.5	0
126	1513	GF25	400	44	44	89.3	45.3	1
124	1513	GF25	400	48	48	10.7	32.4	0
128	1413	GF13	400	16	17	69	40.0	0
130	1413	GF13	400	17	18	51.7	36.2	0
132	1413	GF13	400	22	23	31	34.7	0
134	1413	GF13	400	37	38	10.4	24.2	0
136	1413	GF13	400	42	43	89.7	44.9	0
138	1413	GF13	400	50	52	100	52.8	0
140	2316	GF25	600	8	8	50	34.9	0
142	2316	GF25	600	17	18	8.8	22.6	0
144	2316	GF25	600	25	26	29.4	31.2	0
146	2316	GF25	600	48	49	91.2	41.7	0
148	2316	GF25	600	53	54	70.6	38.3	0
150	2316	GF25	600	56	57	97.1	46.5	0
152	2416	GF13	600	8	8	88.9	43.5	0
154	2416	GF13	600	22	22	50	33.2	0
156	2416	GF13	600	27	27	100	49.4	0
158	2416	GF13	600	30	30	11.1	22.7	2
160	2416	GF13	600	43	44	69.4	35.6	0
162	2416	GF13	600	52	53	30.6	29.1	0