PhotoMARVL assessment of branching in 1978 Genetic Gain Trials

J. C. Grace
T. Evanson
R.K. Brownlie

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EXECUTIVE SUMMARY

A total of ninety-one PhotoMARVL images were taken in the 1978 Genetic Gain Trials. There were 5 images from each of the GF7, GF14 and GF22 seedlots in each replicate (Aupouri, Kaingaroa, Mohaka, Golden Downs, Waimate and Longwood); and one extra image from the GF22 seedlot at Longwood.

These data were analysed in two ways. One approach was to compare the PhotoMARVL data for each tree with TreeBLOSSIM predictions for that tree (see SGMC Report No. 120). The second approach, the subject of this report, was to examine:

- the relationship between the diameter of the largest branch in a cluster with respect to cluster height, to determine whether the hypotheses built into TreeBLOSSIM appear realistic;
- the variation in the regression coefficients of the above relationships with respect to site and seedlot, for a set of plots managed under a common silviculture regime.

The essence of the hypotheses built into TreeBLOSSIM was:

- stocking and relative tree size would be major factors affecting branch diameter;
- the diameter of the largest branch in a cluster would not be correlated with cluster height unless there was a change in stocking;
- small trees would not necessarily show a response to thinning;
- if there was a change in stocking, then a sigmoid curve should describe the relationship between the diameter of the largest branch in a cluster with respect to cluster height.

For each tree a regression equation was fitted indicating how the diameter of the largest observed branch in a cluster varied with cluster height. These suggested that the hypotheses built into TreeBLOSSIM were realistic for 82% of the sample trees.

The analysis of the effect of site and seedlot on the regression coefficients was made under the assumption that that the differences in stocking were negligible. At a site level, genotype did not generally have a significant influence on the regression coefficients (which are predicted estimates of the mean value for the diameter of the largest branch for a given tree). However it was considered that some of the larger differences could be attributed to differences in stocking.
At a plot level, the least square mean values of the regression coefficients tended to be higher than would be expected from the relationships built into TreeBLOSSIM.

PhotoMARVL assessment of branching in 1978 Genetic Gain Trials

Introduction

The Stand Growth Modelling Cooperative has supported the development of the integrated tree and branch growth model, TreeBLOSSIM. The trees used to develop the branch growth model (BLOSSIM) were mainly of GF14 (“850”) origin (Table 1).

PhotoMARVL was chosen as a quantitative, non-destructive procedure for determining how well TreeBLOSSIM performs over a wide range of sites, silviculture and genetics. By June 2003, PhotoMARVL data had been collected from the 1975 Final Crop Stocking Trials, and 1978 Genetic Gain Trials. The regional location of these trials is shown in Table 2. While they cover a range of regions and site qualities, more studies will be required to cover the range of site qualities within each region. The noticeable gaps are no data from the Clays growth modelling region, the East Coast of North Island, and the West Coast of South Island.

There are two ways in which PhotoMARVL data may be analysed. One approach is to compare the PhotoMARVL data for each tree with TreeBLOSSIM predictions for that tree. The second approach is to examine:

- the relationship between the diameter of the largest branch in a cluster with respect to cluster height, to determine whether the hypotheses built into TreeBLOSSIM appear realistic;
- the variation in the regression coefficients of the above relationships across New Zealand with respect to site, silviculture and genetics.

The objective of the current study was to analyse the PhotoMARVL data from the 1978 Genetic Gain Trials using the second approach outlined above. The first approach (comparison with TreeBLOSSIM predictions) is discussed in SGMC Report 120.

Table 1. Trees destructively sampled in order to develop the branch growth model (BLOSSIM).

Growth Modelling Region	Seedlot	Trees Sampled	Trial Design
Sands	"850"	8	Diallel trial (no thinning)
Clays	"850"	5	Silviculture trial
Central North Island	"850"	8	Diallel trial (no thinning)
	"850"	3	Final crop stocking trial
	Long internode	8	'Long internode' trial
	Unimproved	12	Stocking trial
	Unimproved	13	Thinning trial
Hawkes Bay	"850"	3	Thinned PSP
Nelson /Marlborough	Unimproved	3	Thinned PSP
	"850"	3	Final crop stocking trial
West Coast (S.I.)	"850"	8	Diallel trial (no thinning)
Canterbury	"850"	3	Final crop stocking trial
Southland	"850"	8	Diallel trial (no thinning)

Table 2. Location of 1975 Final Crop Stocking Trials and 1978 Genetic Gain Trials where PhotoMARVL images have been collected to test TreeBLOSSIM predictions.

Growth Modelling Region	1975 Trials- used to investigate response to silviculture: Forest and Site Quality	1978 Trials-used to investigate response to genetics: Forest and Site Quality
Sands	Woodhill (medium)	Aupouri (low)
Clays	-	-
Central North Island	Kaingaroa (medium)	Kaingaroa (high)
East Coast (N.I.)	-	-
Hawkes Bay	-	Mohaka (high BA)
Nelson /Marlborough	Golden Downs (low)	Golden Downs (medium)
West Coast (S.I.)	-	-
Canterbury	Eyrewell (low)	Waimate (medium)
Southland	-	Longwood (high BA)

Note: Site Quality from SGMC Report No. 24.

Methods

1978 Genetic Gain Trials

The 1978 Genetic Gain Trials were established to compare the growth of GF2, GF7, GF14 and GF22 seedlots when planted in large plots. The trials were planted on six sites:

- Aupouri (AK1058)
- Kaingaroa (RO2103/1)
- Mohaka (WN377)
- Golden Downs (NN530/2)
- Waimate (CY421/1)
- Longwood (SD564/1)

The prescribed silviculture regime was:

- Plant at 1111 stems/ha
- Thin to 600 stems/ha at mean crop height of 6.2 m
- Thin to 300 stems/ha at mean crop height of 12 m
- Three pruning lifts: 2.2m, 4.2m and 6m.

Sample plot selection

At each site one plot from each of the GF7, GF14 and GF22 seedlots was selected (Table 3). These plots were selected based on the following criteria:

- there was minimal mortality,
- the stocking was similar between the three selected plots, and
- the stocking remained close to the prescribed treatment.

The silviculture for the selected plots (Table 4) did not precisely agree with the prescribed treatment. The plots at Waimate did not receive a second thinning. For the plots selected, the stocking after the first thinning varied between 500 and 680 stems; and the stocking after the second thinning (excluding Waimate) varied between 260 and 360 stems/ha. There was some tree mortality at both Waimate and Longwood. At a site level, for the plots selected, the stocking after the first thinning varied by up to 80 stems/ha; and the stocking after the second thinning varied by 20 stems/ha (Waimate and Longwood excluded).

Table 3. Sample plots selected for the PhotoMARVL study.

Site	Plot (GF7)	Plot (GF14)	Plot (GF22)
Aupouri AK1058/0	7/41	8/41	15/61
Kaingaroa RO2103/1	7/31	10/51	15/11
Mohaka WN377/0	1/61	6/41	14/41
Golden Downs NN530/2	7/41	6/31	14/21
Waimate CY421/1	1/61	9/21	6/41
Longwood SD564/1	7/51	5/61	11/31

Notes:
Waimate: In terms of stocking, Plot 12/11 would have been better than Plot 9/21.
Longwood: Plot 8/51 was initially selected for GF22 seedlot, but only one of the five selected trees was undamaged. The plot was therefore replaced with Plot 11/31.

Table 4. Silviculture history of sample plots selected for the PhotoMARVL study.

Site	Plot	Age of 1st thinning	Tree height at 1st thinning	Stems/ha after 1st thinning	Age of 2nd thinning	Stems/ha after 2nd thinning
Aupouri	7/41	5	9.3	600	12.05	360
	8/41	5	8.9	640	12.05	360
	15/61	5	8.6	600	12.05	360
Kaingaroa	7/31	5	8.6	560	10.0	300
	10/51	5	8.4	540	10.0	300
	15/11	5	9.0	600	10.0	300
Mohaka	1/61	5	8.2	620	8.4	320
	6/41	5	9.0	620	8.4	300
	14/41	5	9.5	600	8.4	300
Golden Downs	7/41	8	11.3	680	10.15	300
	6/31	8	11.5	600	10.15	300
	14/21	8	11.8	600	10.15	320
Waimate	1/61	6	7.4	500	-	
	9/21	6	8.4	580	18 (mortality)	560
	6/41	6	8.6	500	16 (mortality) 19 (mortality)	480 460
Longwood	7/51	8	Not Known	600	10 24 (mortality)	260 240
	5/61	8	Not Known	600	10	260
	11/31	8	Not Known	600	10 19 (mortality) 22 (mortality) 24 (mortality)	340 320 280 260

Sample tree selection

For each selected plot, the trees present at the last (winter 2002) PSP re-measurement were ranked according to their diameter at breast height (DBH). Their percentage rank was then calculated. Undamaged trees whose rank was closest to the 10th, 30th, 50th, 70th, and 90th percentile were selected to be PhotoMARVLed (Table 5).

Table 5. Sample trees selected for PhotoMARVL study.

Site	Plot	GF	PSP Tree Key Number for tree PhotoMARVLed at following nominal percentile positions from DBH distribution:				
			10th	30th	50th	70th	90th
Aupouri	7/41	7	11	1	28	14	26
Aupouri	8/41	14	13	1	11	19	22
Aupouri	15/61	22	16	5	10	4	11
Kaingaroa	7/31	7	5*	26*	19	3	20
Kaingaroa	10/51	14	4	9	13	17	20
Kaingaroa	15/11	22	12	6	7	3	5
Mohaka	1/61	7	14	28	9	4	12
Mohaka	6/41	14	18	19	11	20	8
Mohaka	14/41	22	9	6	4*	10	15
Golden Downs	7/41	7	16	19	22	24	5
Golden Downs	6/31	14	22	19	29	23	9
Golden Downs	14/21	22	4	11	9	1	8
Waimate	1/61	7	2*	3*	25	14	20
Waimate	9/21	14	10*	25	17	2*	23
Waimate	6/41	22	1	12	16	2	23
Longwood	7/51	7	6	9	12	1	2
Longwood	5/61	14	6	8	10	12	3
Longwood	11/31**	22	11	2	7	10	6

Notes:
Tree-Key is a unique code used to identify trees in the PSP system
* Indicates that sample tree chosen initially was replaced in the field with listed tree. Trees were only replaced if the tree was damaged or very difficult to view.
** Indicates plot originally selected was replaced in field by the one shown.
These ninety PhotoMARVL images, plus an extra image from the undamaged tree in Plot 8/51, Longwood, were collected between July and December 2002.

<u>Analysis of PhotoMARVL data</u>

In the office, the following measurements were extracted from the photograph for each branch cluster using the AP190 analytical stereo plotter (Firth *et al*, 2000):

- 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 photograph.

The data were stored in an EXCEL spreadsheet and then imported into SAS for analysis.

The essence of the hypotheses built into TreeBLOSSIM is:

- the diameter of the largest branch in a cluster will not be correlated with cluster height unless there is a change in stocking;
- small trees will not necessarily show a response to thinning;
- if there is a change in stocking, then a sigmoid curve should describe the relationship between the diameter of the largest branch in a cluster with respect to cluster height.

To determine whether there was a significant change in the diameter of the largest branch in a cluster with cluster height, the correlation between these two variables was calculated. A significant correlation indicates that the branches have responded to the thinning treatment, but does not indicate the form of the response.

Apart from the Waimate plots, all plots received two thinnings, however the PhotoMARVL data only showed signs of one response to thinning. This is considered to be due to the pruning removing branches that grew and died at 1111 stems/ha. The first thinning was scheduled for a mean crop height of 6.2 m, and the scheduled prune height was 6 m.

Three different regression equations (predicting diameter of the largest branch in a cluster as a function of cluster height) were fitted to the PhotoMARVL data from each tree. These were:

- a sigmoid curve, simulating response to a single thinning (see SGMC Report No. 93 for logic)
- a horizontal line indicating no response to thinning
- a linear regression that allows branch diameter to increase/decrease with height to base of cluster.

The sigmoid curve fitted, was a 4-parameter Gompertz equation, which is asymmetrical about the point of inflection (Eqn. 1).

$$D = \alpha + \beta \exp(-\exp(\gamma - \delta \times H)) \qquad (1)$$

where:

D is the diameter of the largest measured branch in a cluster

H is the height of the cluster above the base of the crown

$\alpha, \beta, \gamma, \delta$ are model coefficients:

- α is assumed to represent the mean diameter averaged over the largest branch in each cluster prior the thinning
- β is assumed to represent the change in the mean diameter as a result of the thinning
- $\alpha + \beta$ is assumed to represent the mean diameter averaged over the largest branch in each cluster after the thinning
- (γ/δ + height to base of crown) gives the point of inflection.

When this equation was used initially (SGMC Report No 93), it was necessary to fix δ to obtain realistic estimates and asymptotic standard errors for the other coefficients. For this, and all previous analyses, a value of 15 has been used for δ. Realistic solutions were obtained for most trees where there were obvious changes in branch diameter.

Assuming the differences in stocking between plots had minimal impact on branch diameters within a plot, the SAS procedure PROC GLM was used to predict α, β, and $\alpha+\beta$ as functions of dbh rank and GF for each site.

TreeBLOSSIM Potentials

Site and stocking potentials are incorporated into TreeBLOSSIM (see SGMC Report No. 108 for derivation). The value obtained by multiplying these potentials can be considered as the mean value for the diameter of the largest branch in a cluster for the mean tree for that stocking and site. This value can therefore be compared with the least square means obtained above.

Results

Relationship between diameter of the largest branch in a cluster and cluster height

Details of the predicted regression equation between diameter of the largest branch in a cluster and cluster height are given in Appendix 1 (Tables 10-15).

The number of trees that showed a response to thinning varied between sites (Table 6). The extremes were Waimate and Kaingaroa. The trees at Waimate did not receive a 2nd thinning, and for most trees, branch diameter did not increase with height in the tree. At Kaingaroa, most trees showed a response to thinning. For Waimate only a “no response” is considered realistic. For the other sites, both “a no response” and “a sigmoid response” are considered realistic based on the hypotheses built into TreeBLOSSIM. Hence the hypotheses, built into TreeBLOSSIM, are appropriate for 82% of the trees. The reason why a “gradual change” is appropriate for some trees needs to be considered, as a logical explanation could lead to improvements to TreeBLOSSIM.

Table 6. Number of trees for which different curves were considered appropriate.

	No response	**Sigmoid Response**	**Gradual Change**
Aupouri	4	9	2
Kaingaroa	2	12	1
Mohaka	6	6	3
Golden Downs	8	6	1
Waimate	9	4	2
Longwood	7	6	3
Total over 6 sites	36	43	12

Trees with a gradual change in branch diameter were excluded from the analysis of the values of α, β, and $\alpha+\beta$ (see Figures A-C), leading to an unbalanced design. When the data were examined by site, GF did not generally have a significant influence on the values of α, β, and $\alpha+\beta$. The least square mean values (values that take into account unbalanced designs) are shown in Tables 7 – 9.

<u>Predicted values of α (represents mean diameter averaged over the largest branch in cluster before thinning)</u>

The predicted value of α tended to increase with increasing rank (Figure A). There were also differences between sites. The least square mean values of α for each plot (Table 7) indicate the branch diameter (averaged over the largest branch in a cluster) that would be expected for the mean tree at each GF rating on each site at a stocking of around 600 stems/ha. The variations in stocking (Table 4) also need to be considered when interpreting these values. Branch diameter is known to vary with spacing, it is considered that 3 of the 4 larger differences in α are due to variations in stocking between the plots on a given site:

- Aupouri, GF14: 40 stems/ha more than other two seedlots, α lower.
- Kaingaroa, GF22: 40-60 stem/ha more than other two seedlots, α lower.
- Golden Downs, GF7: 80 stems/ha higher than other two seedlots, α higher. One tree in this plot (Tree-key 24, Figure 49) had unusually large branches.
- Waimate, GF14: 80 stems/ha higher than other two seedlots, (in cm) α lower.

The values from TreeBLOSSIM (estimated using the site and stocking potentials (see SGMC Report No. 108)) are lower, but within 2 cm of the least square mean values of α.

Figure A. Predicted values of α, the predicted branch diameter before thinning for individual trees.

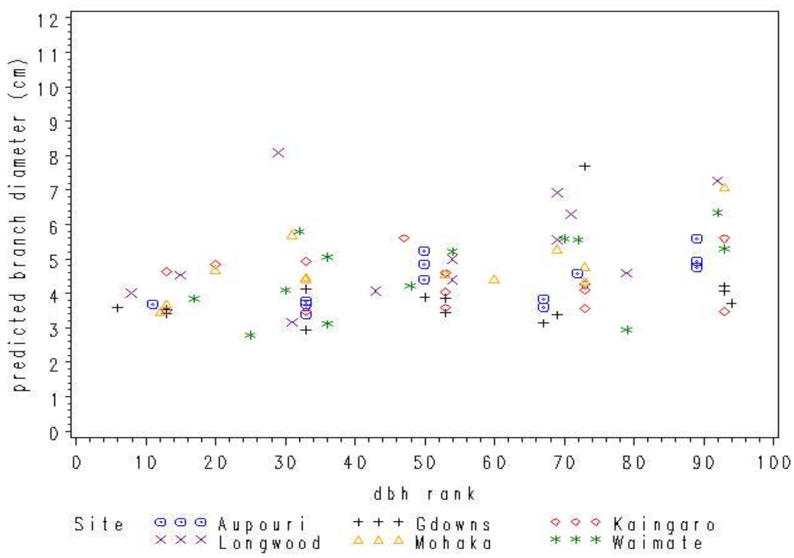

Table 7. Least Square Mean values of α for individual plots and value for 600 stem/ha built into TreeBLOSSIM (values in cm)

	GF7	GF14	GF22	TreeBLOSSIM
Aupouri	4.4	4.0	4.5	4.0
Kaingaroa	4.8	4.6	3.6	3.1
Mohaka	5.0	4.6	4.7	3.8
Golden Downs	4.6	3.5	3.6	2.7
Waimate	5.3	3.8	4.8	3.4
Longwood	5.3	5.0	5.7	4.4

Predicted values of β (represents the change in mean branch diameter averaged over the largest branch in a cluster as a result of thinning)

There was no obvious relationship between the predicted value of β and rank (Figure B). The least square mean values of β (Table 8) indicate the change in predicted branch diameter (for the largest branch in a cluster) for the mean tree as a result of thinning from approximately 600 stems/ha to 300 stems/ha. Again the variations in stocking from the prescribed treatment need to be considered.

The most noticeable features are:

- β is around 2 cm for Aupouri and Kaingaroa
- β is around 0.5 cm for Mohaka and Golden Downs

The values built into TreeBLOSSIM (estimated using the site and stocking potentials (see SGMC Report No. 108)) indicate changes in branch diameter as a result of thinning will be larger at Aupouri and Kaingaroa compared to the other sites. However the observed response is larger than that built into TreeBLOSSIM.

Figure B. Predicted values of β, the predicted change in branch diameter as a result of thinning from 600 to 300 stems/ha for individual trees.

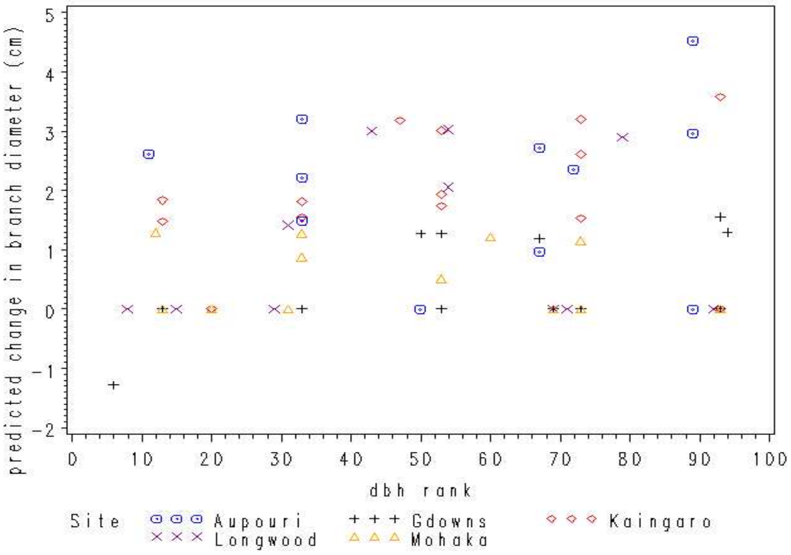

Table 8. Least Square Mean values of β for individual plots and values built into TreeBLOSSIM for a change in stocking from 600 to 300 stems/ha (values in cm)

	GF7	GF14	GF22	TreeBLOSSIM
Aupouri	2.1	0.6	2.6	0.8
Kaingaroa	1.6	1.7	2.4	0.7
Mohaka	0.4	0.6	0.5	0.2
Golden Downs	0.6	0.3	0.3	0.4
Longwood	0.5	1.2	1.4	0.5

<u>Predicted values of $\alpha+\beta$ (represents the mean branch diameter averaged over the largest branch in each cluster after thinning)</u>

The predicted values of $\alpha+\beta$ for individual trees tended to increase with increasing rank (Figure C). There also appeared to be differences between sites. The least square mean values of $\alpha+\beta$ (Table 9) indicate the branch diameter (averaged over the largest branch in a cluster) that might be expected for the mean tree in a plot of known GF on each site for stockings around 300 stems/ha. The actual plot stockings (Table 4) need to be considered when interpreting these values. The changes in stocking were small at Aupouri, Kaingaroa, Mohaka and Golden Downs. At Longwood, the stocking varied and there was a lot of mortality in the GF22 plot. The values built into TreeBLOSSIM (estimated using the site and stocking potentials (see SGMC Report No. 108)) are lower, but tend to be within 2 cm of the observed values of $\alpha+\beta$.

Figure C. Predicted values of $\alpha+\beta$, the predicted branch diameter after thinning for individual trees.

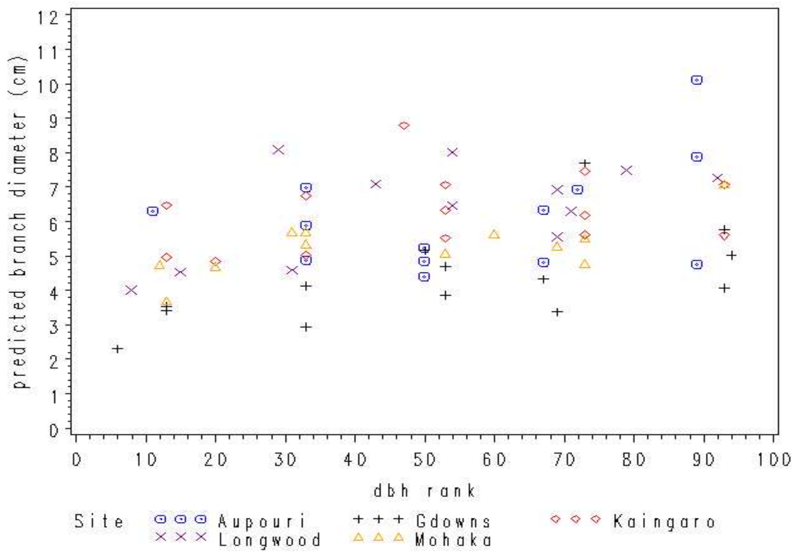

Table 9. Least Square Mean values for $\alpha+\beta$ for individual plots and values for 300 stems/ha built into TreeBLOSSIM (values in cm).

	GF7	GF14	GF22	TreeBLOSSIM
Aupouri	6.5	4.6	7.1	4.8
Kaingaroa	6.4	6.3	6.0	3.8
Mohaka	5.4	5.2	5.2	4.0
Golden Downs	5.2	3.8	3.9	3.1
Longwood	5.8	6.2	7.1	5.0

Discussion

Ninety-one PhotoMARVL images were collected from the 1978 Genetic Gain Trials. Regression equations were fitted to predict the diameter of the largest branch in a cluster as a function of cluster height. Based on the appropriate regression equation for each tree, it is considered that the hypotheses built into TreeBLOSSIM with regards to thinning are reasonable.

For some trees, a gradual change in branch diameter was appropriate. A possible explanation is that the competitive status of such trees changes more than the "norm". For example, a mildly suppressed tree could become a dominant tree if a local gap opened up. Such changes, whilst feasible, are not built into TreeBLOSSIM, and would be difficult to implement in a "distant-independent" model such as TreeBLOSSIM.

The least square mean values of the regression coefficients give an indication of branch diameter (averaged over the largest branch in a cluster) for the mean tree in a plot. Due to the slight differences in stocking between plots, care needs to be taken when interpreting these values, particularly between plots on a given site and between sites. The data do, however, indicate that the predictions of branch diameter from TreeBLOSSIM are likely to be smaller than observed.

There were generally no significant effect of GF on the values of α, β, and $\alpha+\beta$ when analysed by site. The differences between genotype were generally less than 1 cm. Thus the seedlot only has a minor effect on branch diameter in the 1978 Genetic Gain Trials.

Future Research

Another use of the images is to investigate whether stem taper differs with seedlots.

References

Stand Growth Modelling Cooperative Reports Numbers:

93: Grace, J.C.; Brownlie, R.K. 2000: Suitability of PhotoMARVL for measuring crown structure.

108: Grace, J.C.; Pont, D. 2001: Branch functions within TreeBLOSSIM – Version 1.1.

120: Grace, J.C.; Brownlie, R.K.; Evanson, T. 2003: Comparison of PhotoMARVL data with TreeBLOSSIM predictions: 1978 Genetic Gain Trials.

Other reports/ papers.

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.

APPENDIX 1. Correlations, and predicted coefficients from fitting equations to data obtained from PhotoMARVL images.

Definitions:

B:CH Correlation:

Correlation between diameter of the largest branch measured in a cluster and height to the base of the cluster.

Coefficients:

(α) = Predicted mean diameter, averaged over largest branch in each cluster before thinning (cm)

(β) = Predicted change in mean diameter averaged over largest branch in each cluster (cm)

(ϕ) = Predicted height of inflection (γ/δ)+H (m)

Table 10. Results from Aupouri PhotoMARVL images.

			Fit:	**Curve**			**Slope**		**Horizontal line**
Rating	**Plot/tree**	**Position of tree in DBH distribution**	**B:CH Correlation (Significance level)**	**α_1 (cm)**	**β_1 (cm)**	**ϕ_1 (m)**	**α_2 (cm)**	**β_2 (cm)**	**α_3 (cm)**
GF7	7_41_11	11	0.62 (p=0.019)	3.69	2.61	17.52			
GF7	7_41_1	33	0.34 (ns)	3.69	2.21	17.14			
GF7	7_41_28	50	0.06 (ns)						4.86
GF7	7_41_14	72	0.47 (p=0.020)	4.57	2.35	15.32			
GF7	7_41_26	89	0.49 (p=0.029)	4.94	2.96	15.93			
GF14	8_41_13	11	0.54 (p=0.016)				2.20	0.20	
GF14	8_41_1	33	0.59 (p=0.004)	3.40	1.48	15.08			
GF14	8_41_11	50	0.30 (ns)						4.41
GF14	8_41_19	67	0.07 (ns)	3.85	0.97	16.64			
GF14	8_41_22	89	-0.09 (ns)						4.76
GF22	15_61_16	6	0.49 (p=0.006)				3.28	0.28	
GF22	15_61_5	33	0.39 (ns)	3.78	3.21	15.29			
GF22	15_61_10	50	0.07 (ns)						5.23
GF22	15_61_4	67	0.40 (p=0.042)	3.61	2.73	16.46			
GF22	15_61_11	89	0.55 (p=0.002)	5.60	4.53	19.24			

Table 11. Results from Kaingaroa PhotoMARVL images.

			Fit:	Curve			Slope		Horizontal line
Rating	Plot/tree	Position of Tree in DBH Distribution	B/CH Correlation (Significance level)	α_1 (cm)	β_1 (cm)	ϕ_1 (m)	α_2 (cm)	β_2 (cm)	α_3 (cm)
GF7	7_31_3	20	0.22 (ns)						4.84
GF7	7_31_26	47	0.44 (0.033)	5.61	3.18	12.82			
GF7	7_31_19	53	0.47 (0.032)	4.59	1.74	15.56			
GF7	7_31_1	73	0.37 (ns)	4.09	1.53	15.28			
GF7	7_31_20	93	0.71 (p=001)				3.82	0.42	
GF14	10_51_1	13	0.49 (p=0.015)	4.63	1.84	14.97			
GF14	10_51_7	33	0.35 (ns)	4.93	1.82	17.12			
GF14	10_51_11	53	0.44 (p=0.028)	3.58	1.94	13.79			
GF14	10_51_15	73	0.83 (p=0.0001)	4.26	3.21	12.03			
GF14	10_51_18	93	0.24 (ns)						5.60
GF22	15_11_12	13	0.68 (p=0.0001)	3.49	1.48	15.03			
GF22	15_11_6	33	0.89 (p=0.0001)	3.48	1.55	12.81			
GF22	15_11_7	53	0.83 (p=0.0001)	4.04	3.02	13.66			
GF22	15_11_3	73	0.84 (p=0.0001)	3.57	2.62	13.43			
GF22	15_11_5	93	0.69 (p=0.0007)	3.48	3.58	9.25			

Table 12. Results from Mohaka PhotoMARVL images

			Fit:	Curve			Slope		Horizontal line
Rating	**Plot/tree**	**Position of Tree in DBH Distribution**	**B/CH Correlation (Significance level)**	α_1 **(cm)**	β_1 **(cm)**	ϕ_1 **(m)**	α_2 **(cm)**	β_2 **(cm)**	α_3 **(cm)**
GF7	1_61_14	12	0.39 (ns)	3.46	1.3	12.57			
GF7	1_61_28	31	0.11 (ns)						5.72
GF7	1_61_9	50	0.37 (p=0.048)				4.79	0.10	
GF7	1_61_4	69	0.14 (ns)						5.30
GF7	1_61_12	94	0.69 (p=0.0008)				3.71	0.39	
GF14	6_41_18	20	0.29 (ns)						4.70
GF14	6_41_19	33	0.50 (p=0.004)	4.47	0.88	14.91			
GF14	6_41_11	53	0.55 (p=0.005)	4.58	0.51	15.69			
GF14	6_41_20	73	0.37 (p=0.032)	4.36	1.16	17.14			
GF14	6_41_8	93	0.65 (p=0.004)				4.34	0.20	
GF22	14_41_9	13	0.14 (ns)						3.70
GF22	14_41_6	33	0.44 (p=0.02)	4.44	1.28	13.4			
GF22	14_41_4	60	0.43 (p=0.022)	4.44	1.22	13.57			
GF22	14_41_10	73	0.06 (ns)						4.79
GF22	14_41_15	93	0.25 (ns)						7.09

Table 13. Results from Golden Downs PhotoMARVL images.

			Fit:	Curve			Slope		Horizontal line
Rating	**Plot/tree**	**Position of Tree in DBH Distribution**	**B/CH Correlation (Significance level)**	**α_1 (cm)**	**β_1 (cm)**	**ϕ_1 (m)**	**α_2 (cm)**	**β_2 (cm)**	**α_3 (cm)**
GF7	7_41_16	13	0.13 (ns)						3.53
GF7	7_41_19	33	0.26 (ns)						4.14
GF7	7_41_22	53	0.52 (p=0.003)	3.43	1.27	12.43			
GF7	7_41_25	73	0.40 (ns)						7.69
GF7	7_41_5	93	0.48 (p=0.01)	4.21	1.56	12.48			
GF14	6_31_22	13	0.07 (ns)						3.42
GF14	6_31_19	33	0.02 (ns)						2.94
GF14	6_31_29	53	-0.01 (ns)						3.87
GF14	6_31_23	67	0.51 (p=0.009)	3.14	1.19	14.27			
GF14	6_31_9	93	-0.15 (ns)						4.07
GF22	14_21_4	6	-0.71 (p=0.003)	3.58	-1.28	15.22			
GF22	14_21_11	31	0.57 (p=0.004)				3.34	0.14	
GF22	14_21_9	50	0.57 (p=0.003)	3.89	1.27	13.05			
GF22	14_21_1	69	0.39 (ns)						3.37
GF22	14_21_8	94	0.39 (p=0.05)	3.72	1.30	12.43			

Table 14. Results from Waimate PhotoMARVL images.

			Fit:	Curve			Slope		Horizontal line
Rating	**Plot/tree**	**Position of tree in DBH distribution**	**B/CH Correlation (Significance level)**	α_1 (cm)	β_1 (cm)	ϕ_1 (m)	α_2 (cm)	β_2 (cm)	α_3 (cm)
GF7	1_61_2	32	0.42 (ns)						5.81
GF7	1_61_3	36	0.45 (ns)						5.05
GF7	1_61_25	48	0.42 (ns)	4.23	1.41	10.12			
GF7	1_61_14	72	0.36 (ns)						5.57
GF7	1_61_20	92	0.40 (ns)	6.35	4.04	11.11			
GF14	9_21_10	25	0.16 (ns)						2.79
GF14	9_21_25	36	0.78 (p=000.1)	3.11	1.95	10.26			
GF14	9_21_17	54	0.42 (ns)						5.22
GF14	9_21_2	79	0.74 (p=0.0001)	2.95	1.61	10.89			
GF14	9_21_23	93	0.03 (ns)						5.29
GF22	6_41_1	17	0.32 (ns)						3.85
GF22	6_41_12	30	-0.23 (ns)						4.09
GF22	6_41_16	52	0.82 (p=0.0001)				2.94	0.28	
GF22	6_41_2	70	0.40 (ns)						5.59
GF22	6_41_23	87	0.47 (p=0.04)				4.02	0.48	

Table 15. Results from Longwood PhotoMARVL images.

			Fit:	Curve			Slope		Horizontal line
Rating	**Plot/tree**	**Position of Tree in DBH Distribution**	**B/CH Correlation (Significance level)**	α_1 (cm)	β_1 (cm)	ϕ_1 (m)	α_2 (cm)	β_2 (cm)	α_3 (cm)
GF7	7_51_7	15	0.19 (ns)						4.53
GF7	7_51_10	31	0.39 (ns)				3.73	0.20	
GF7	7_51_13	54	0.59 (p=0.002)	4.41	2.06	9.66			
GF7	7_51_1	69	0.35 (ns)						5.56
GF7	7_51_2	92	0.20 (ns)						7.27
GF14	5_61_6	8	0.32 (ns)						4.02
GF14	5_61_8	31	0.49 (p=0.001)	3.17	1.42	11.58			
GF14	5_61_10	54	0.48 (p=0.02)	4.99	3.03	12.49			
GF14	5_61_12	69	0.13 (ns)						6.94
GF14	5_61_3	92	0.64 (p=0.02)				4.11	0.55	
GF22	11_31_11	29	0.31 (ns)						8.1
GF22	11_31_2	43	0.45 (p=0.02)	4.08	3.01	9.63			
GF22	11_31_7	50	0.48 (p=0.01)				3.85	0.25	
GF22	11_31_10	71	0.29 (ns)						6.3
GF22	11_31_6	79	0.56 (p=0.002)	4.59	2.90	14.04			
GF22	8_51_13	100	0.63 (p=0.001)	5.57	2.87	10.2			