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BRANCH RESPONSE TO THINNING IN EXPERIMENT CY597 RESULTS FROM USING PhotoMARVL

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EXECUTIVE SUMMARY

One of the goals for developing the model TreeBLOSSIM was to be able to predict the final diameter for branches from their size at mid-rotation. The response of branches to thinning is built into the model. Destructive sampling of selected branches provided the necessary data to develop a theory of how branches responded to thinning. However larger sample sizes are needed to determine whether the model correctly predicts the response across the DBH distribution. Non-destructive techniques are the logical alternative for obtaining such data.

In this study PhotoMARVL was used to obtain quantitative data for 35 trees from a thinning experiment in the Canterbury growth modelling region. The relationship between diameter of the largest branch visible in each cluster and cluster height was predicted. It was the larger trees in the most heavily thinned plots that showed a response to thinning confirming previous results. The results will be used as validation data to determine whether TreeBLOSSIM correctly predicts response to thinning across the DBH distribution.

BRANCH RESPONSE TO THINNING IN EXPERIMENT CY597
RESULTS FROM USING PhotoMARVL

J.C. Grace and R.K. Brownlie

INTRODUCTION

TreeBLOSSIM is a linked individual tree and branch growth model that was developed to project mid-rotation inventory data forward in time.

The individual tree growth model was developed using only post-silviculture growth data (SGMC Report No. 77). The branch model was developed using destructive sampling of near-rotation age trees and predicts branch development from age zero.

The branch model is linked to the individual tree growth model in three ways. Firstly the height growth model is used to give the annual height extension. Secondly the ratio of tree DBH to mean DBH is used to give the "tree potential" (SGMC Report No. 98), one component of the equation predicting branch growth. Finally the stocking is used to give the "stocking potential" (SGMC Report No. 98), another component of the equation predicting branch growth. In order to initialise all the branches on a tree, the individual tree growth model needs to be run from age zero.

It has proved difficult to find repeat MARVL data for the same trees, and even then the data is not ideal for model validation as the branch data is only subjective. PhotoMARVL is seen as a suitable tool for testing the branch model as it provides quantitative information on branching without felling trees. PhotoMARVL was used to obtain data on branch response to thinning in the Canterbury Region. The results from analysing the photographic images are summarised in this report. Comparisons of these results with model predictions will be the subject of a second report.

METHODS

Experiment CY597, in Eyrewell Forest was planted in 1975 as the "850" polycross trial with an initial stocking of 625 stems/ha. A final-crop stocking trial was imposed on the trial in 1986. Six different thinning treatments were applied with 3 replicates of each treatment (Table 1). The trial design matches RO2098, which was sampled for the same purpose in 1999 (SGMC Reports 93 and 99).

None of the plots in CY597 were at 625 stems/ha when the final crop stocking trial was established. After thinning, a few trees were lost from some plots. Initially the one plot per treatment was selected – that where the initial stocking and final stocking remained closest to the prescribed treatment. Five plots were selected from replicate 2, and two plots from replicate 1. When the current mean top heights for the plots were examined, it was realised that there was a lot of variation within and between replicates. The mean top height for the original selection covered the complete range in the experiment (23.6 m– 30 m). This was considered undesirable and it was decided to use only 1 replicate. Replicate 2 was chosen as more plots had been selected originally and the other two plots had lost no trees since thinning. The range in mean top height was reduced to 26.6 m to 30 m.

Table 1. Treatments and plots sampled in Experiment CY597.

Treatment No.	Treatment	Plot selected	Mean top height (m) in May 1999
1	Thin to 100 stems/ha at age 11 years	15/21	27.0
2	Thin to 200 stems/ha at age 11 years	9/22	29.3
3	Thin to 400 stems/ha at age 11 years	10/23	27.5
4	Unthinned	13/24	26.6
5	Thin to 100 stems/ha at age 14 years	14/25	26.7
6	Thin to 200 stems/ha at age 14 years	11/26	30.0
7	Thin to 400 stems/ha at age 14 years	12/27	29.0

For each plot, the trees present at the 1999 PSP remeasurement were ranked according to DBH, and their percentage rank calculated. The trees whose rank was closest to 10%, 40%, 70%, and 100% were selected as trees to be PhotoMARVLed. In the PSP system, one of these trees was recorded as having a major defect so the next closest tree was selected. (As the objective is to show the typical response of branches to a thinning it was considered important to avoid trees with major defects.) The selected trees are shown in Table 2. These trees plus those trees whose percentage rank was close to 90% were PhotoMARVLed in the field even if they had major defects.

Table 2. PSP numbers for trees PhotoMARVLed with their DBH in July 1999 in brackets.

Treatment	Plot No.	10%	40%	70%	90%	100%
1	15/21	11/5 (35.7)	15/3 (43.5)	19/1 (45.2)	9/1 (47.4)	16/5 (55.0)
2	9/22	2/26 (27.6)	3/40 (34.7)	1/7 (39.9)	4/46 (43.9)	2/23 (51.2)
3	10/23	0/28 (25.8)	3/20 (30.5)	3/18 (33.7)	2/16 (35.6)	3/22 (39.7)
4	13/24	2/12 (25.2)	1/6 (28.3)	3/14 (31.4)	1/3 (34.5)	1/1 (35.0)
5	14/25	9/2 (36.1)	4/5 (42.4)	9/4 (44.0)	15/6 (50.5)	6/5 (52.0)
6	11/26	0/7 (33.3)	0/31 (37.5)	3/33 (41.5)	1/6 (44.3)	0/38 (54.0)
7	12/27	3/13 (22.5)	1 /4 (31.4)	0/9 (36.3)	0/12 (38.5)	4/18 (42.8)

In the office PhotoMARVL measurements of stem diameter, cluster position, cone position, and diameter of the largest branch in a cluster were recorded using the AP190 analytical stereo plotter (Firth *et al*, 2000) and recorded in a spreadsheet together with notes on obvious malformations.

Data on cluster position and branch diameter were imported into a SAS program and branch diameters linked to the appropriate cluster. The diameter of this largest branch was plotted to determine the variation with cluster height. The correlation between diameter of the largest branch in a cluster and cluster height was calculated for each tree.

When a single thinning occurs, it is suggested that the stem below the actively growing crown could be divided into three zones. In the lowest zone, branch diameters would be determined by the pre-thinning stocking. In the uppermost zone branch diameters would be determined by the post-thinning stocking. Branches in the middle zone would be those formed prior to thinning and that had grown more in response to the thinning. On this basis it is suggested that a sigmoid curve would be appropriate for describing the relationship between diameter of the largest

branch in a cluster and cluster height. The lower and upper asymptotes would give the mean diameter averaged over the largest branch in each cluster before and after thinning respectively; and the sloping part of the curve represents the zone where branches respond to the thinning. If there were no response to the thinning then the asymptotes would be the same. A 4-parameter Gompertz equation, which is asymmetrical about the point of inflection (Eqn. 1), was fitted to each tree individually.

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

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
α, β, γ, δ are model parameters
α gives the mean diameter averaged over the largest branch in each cluster prior to the thinning
β gives the change in the mean diameter as a result of the thinning
$\alpha+\beta$ gives the mean diameter averaged over the largest branch in each cluster after the thinning
the ratio γ/δ gives the point of inflection

When this equation was used previously (SGMC Report No 93), it was necessary to fix one parameter (δ) to obtain realistic estimates and asymptotic standard errors for the other parameters. For the current analyses δ was fixed at 15. With this value, realistic solutions were obtained for most trees where there were obvious changes in branch diameter. Eqn. 1 could not be fitted for trees where there were no major changes in branch diameter. In this case a mean diameter was calculated. There were a few trees where branch diameter tended to increase linearly with increasing cluster height. For these trees a linear regression between the diameter of the largest branch in a cluster and cluster height was calculated. This was merely to show the trend, and does not imply that the diameter of the largest branch in a cluster will continue increasing indefinitely with increasing cluster height.

RESULTS.

The correlation between diameter of the largest branch in a cluster and cluster height is shown in Table 3. For the plots thinned at 11 years (Treatments 1-3), the larger trees generally show a significant correlation between branch diameter and cluster height. With no thinning (Treatment 4) there was generally no significant correlation between branch diameter and cluster height. There was a significant correlation for all the trees thinned to 100 stems/ha at age 14 years (Treatment 5) while few trees thinned to either 200 or 400 stems/ha showed a significant correlation (Treatments 6 and 7).

Table 3. Correlation between diameter of the largest branch measured in a cluster and height to the base of the cluster.

Treatment	Plot No.	10%	40%	70%	90%	100%
1	15/21	0.21 (ns)	0.57 (p=0.0009)	0.47 (p=0.03)	-0.14 (ns)	0.75 ($p \leq 0.0001$)
2	9/22	0.53 (p=0.02)	-0.08 (ns)	0.45 (p=0.03)	0.40 (p=0.04)	0.68 (p=0.005)
3	10/23	0.24 (ns)	-0.07 (ns)	0.53 (p=0.003)	0.41 (p=0.04)	0.49 (p=0.02)
4	13/24	0.21 (ns)	-0.03 (ns)	0.67 ($p \leq 0.0001$)	-0.01 (ns)	0.33 (ns)
5	14/25	0.40 (p=0.05)	0.44 (p=0.02)	0.43 (p=0.03)	0.51 (p=0.003)	0.60 (p=0.004)
6	11/26	0.48 (p=0.01)	0.30 (ns)	0.26 (ns)	0.33 (ns)	0.48 (p=0.02)
7	12/27	0.06 (ns)	0.006 (ns)	0.61 (p=0.002)	-0.21 (ns)	0.27 (ns)

Graphs showing the diameter of the largest branch in a cluster versus cluster height, and the fitted relationship are shown in Appendix 1. The predicted coefficients are shown in Table 4, Table 5 and Table 6.

Nine of the 35 trees had one or more odd large branch. For 7 of these trees, the large branches are definitely attributable to damage to the leader, probably due to wind damage. These branches have had an impact on the mean values for diameter of the largest branch and have been indicated by * in Table 4, Table 5 and Table 6.

Five trees showed a gradual increase in branch diameter, rather than either no response or a sigmoidal response (Appendix 1, and Table 4, Table 5 and Table 6). It was wondered whether this might be due to the trees changing their position in the DBH distribution with time. The DBH rank of each tree was calculated for each PSP measurement and plotted against tree age. The change in rank was assessed visually (Table 4, Table 5 and Table 6). For these 5 trees there was no consistency in the change of rank with time.

Table 4. Predicted coefficients from fitting Eqn. 1 to data obtained from PhotoMARVL images.

Plot and Tree	Position of tree in dbh distribution	Predicted mean diameter, averaged over largest branch in each cluster before thinning (α)	Predicted change in mean diameter averaged over largest branch in each cluster (β)	95% confidence interval for β includes zero (yes/ no, no -β significant)	Predicted height of inflection (γ/δ)	Change in dbh rank over time
Plot 15						
11/5	10%	4.0 *	1.0	yes	13.9	reasonably constant
15/3	40%	2.4	1.4 *	no	10.8	increases but then decreases
19/1	70%	3.2	2.1 *	no	6.4	continual increase
9/1	90%	5.2	-	-		very constant
16/5	100%	3.1	2.8	no	11.8	very constant
Plot 9						
2/26	10%	- gradual increase				continual decrease
3/40	40%	3.4 *	-	-		continual decrease
1/7	70%	2.4	1.1	no	8.8	reasonably constant
4/46	90%	3.1	2.9	no	14.5	generally increasing
2/23	100%	2.9	1.9	no	10.6	reasonably constant
Plot 10						
0/28	10%	2.6	-	-		reasonably constant
3/20	40%	3.8	-	-		gradual decrease
3/18	70%	2.5	0.9	no	11.3	reasonably constant
2/16	90%	- gradual increase				reasonably constant
3/22	100%	2.9	1.6 *	no	9.6	constant

Note: * implies value has been influenced by occurrence of one or more extremely large branches.

Table 5. Predicted coefficients from fitting Eqn. 1 to data obtained from PhotoMARVL images.

Plot and Tree	Position of tree in dbh distribution	Predicted mean diameter, averaged over largest branch in each cluster before thinning (α)	Predicted change in mean diameter averaged over largest branch in each cluster (β)	95% confidence interval for β includes zero (yes/ no, no -β significant)	Predicted height of inflection (γ/δ)	Change in dbh rank over time
Plot 13						
2/12	10%	3.1	-	-		slight decrease
1/6	40%	2.5 *	-	-		gradual decrease
3/14	70%	- gradual increase				gradual increase
1/3	90%	3.3				reasonably constant
1/1	100%	2.7	-	-		gradual increase

Note: * implies value has been influenced by occurrence of one or more extremely large branches.

Table 6. Predicted coefficients from fitting Eqn. 1 to data obtained from PhotoMARVL images.

Plot and Tree	Position of tree in dbh distribution	Predicted mean diameter, averaged over largest branch in each cluster before thinning (α)	Predicted change in mean diameter averaged over largest branch in each cluster (β)	95% confidence interval for β includes zero (yes/ no, no -β significant)	Predicted height of inflection (γ/δ)	Change in dbh rank over time
Plot 14						
9/2	10%	3.3	1.0	yes	10.9	slight decrease
4/5	40%	2.5	0.8	no	11.3	reasonably constant
9/4	70%	3.4	2.5 *	no	10.4	gradual increase
15/6	90%	3.7	2.7	no	16.2	slight decrease
6/5	100%	3.6	1.6	no	12.5	slight increase
Plot 11						
0/7	10%	- gradual increase				reasonably constant
0/31	40%	2.8	-	-		reasonably constant
3/33	70%	3.4 *	-	-		reasonably constant
1/6	90%	3.3	1.1	no	10.5	reasonably constant
0/38	100%	- gradual increase				constant
Plot 12						
3/13	10%	2.3	-	-		decrease before thinning
1 /4	40%	2.5	-	-		reasonably constant
0/9	70%	2.4	1.0	no	8.8	decrease after thinning
0/12	90%	3.6 *	-	-		decrease before thinning
4/18	100%	5.0	-	-		slight increase after thinning

Note: * implies value has been influenced by occurrence of one or more extremely large branches.

DISCUSSION.

The results from these analyses are similar in many respects to those from Experiment RO2098 (SGMC Reports No. 93 and 99). It was the larger trees in the most heavily thinned plots that tended to show a response to thinning. A sigmoid curve (Eqn. 1) appeared appropriate for describing this response for most trees. Fewer trees showed a response to thinning when thinned to 200 or 400 stems/ha at 14 years compared with those thinned at 11 years.

This study raised two points that were not apparent from analysing the PhotoMARVL images from Experiment RO2098.

Firstly, large branches, caused by damage to the stem, have a large impact on mean values. From examining the PSP data, there was a lot of wind damage in the third replicate in 1988. The damage observed in the PhotoMARVL trees probably originated from this event. In 1988 the mean top height of sample plots in the replicate examined varied between 13.5 and 14.8 m while the height of damage varied between 8.0 and 14.8 m.

Secondly several trees showed a gradual increase in branch diameter with cluster height, rather than an abrupt change. The reason for this gradual change is not known. One obvious difference between the two sites is the environment with Canterbury having a much lower rainfall.

FUTURE RESEARCH

The next step is to compare the data from the PhotoMARVL images with predictions from TreeBLOSSIM.

Since there are differences in the response to thinning between Experiments RO2098 and CY597, it is important to repeat this study in the other two replicates of the experiment in Woodhill and Golden Downs. This will provide further data to determine whether branch growth in response to thinning is model realistically in TreeBLOSSIM.

Currently TreeBLOSSIM does not consider the effects of stem damage on branch development. This should be considered in future improvements of TreeBLOSSIM.

REFERENCES

Stand Growth Modelling Cooperative Reports.

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

98: Grace, J.C. 2001: Influence of site and genetics on branch diameter at time of pruning.

99: Grace, J.C.; Brownlie, R.K. 2001: Use of PhotoMARVL to determine response to thinning: Further results from Experiment RO2098.

Other reports/ papers.

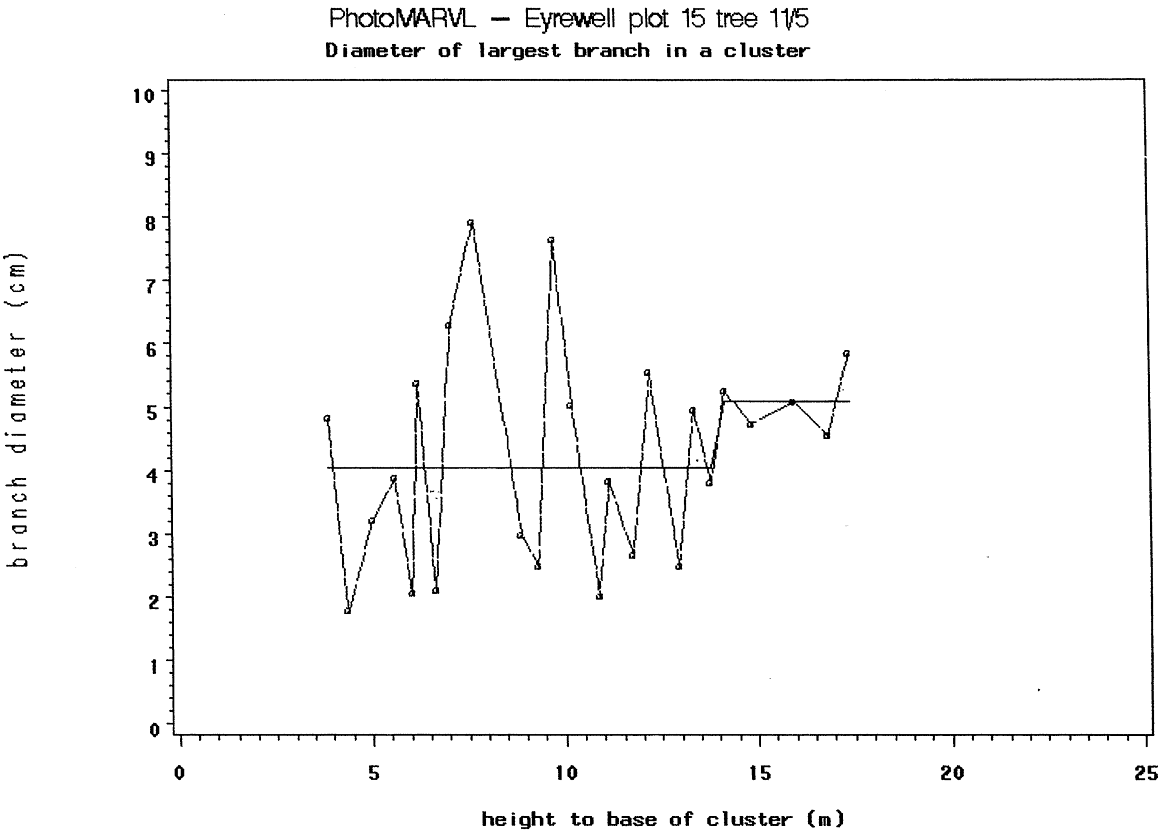
Firth, J.G.; Brownlie, R.K.; Carson, W.W. 2000: Accurate stem measurements, key to new image-based system. New Zealand Journal of Forestry 45 (2): 25-29.

APPENDIX 1.

Diagrams showing largest branch in a cluster versus cluster height for each tree.

The branches measured by PhotoMARVL are marked with a circle and have been joined together for clarity. The curve predicted by Eqn. 1 is the continuous line with no circles.

Figure 1.



The image showed a large nodal swelling at 8 m. The cluster has a number of large steep branches.

Figure 2

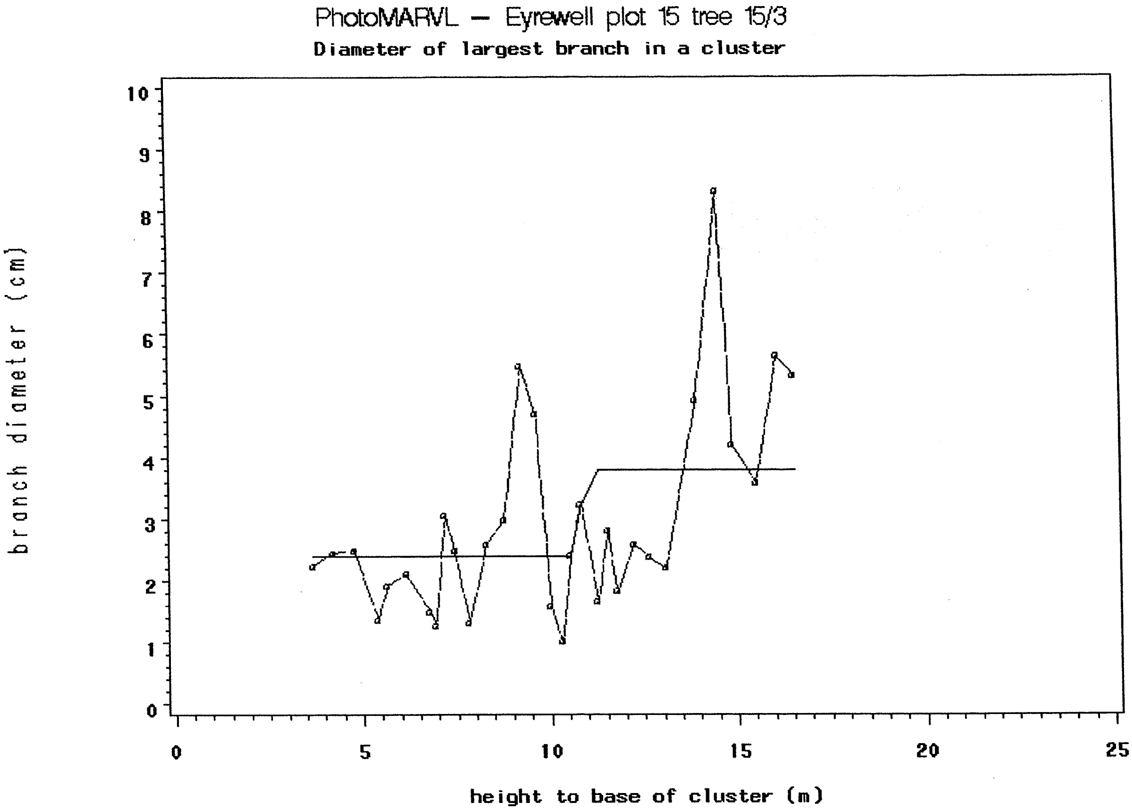
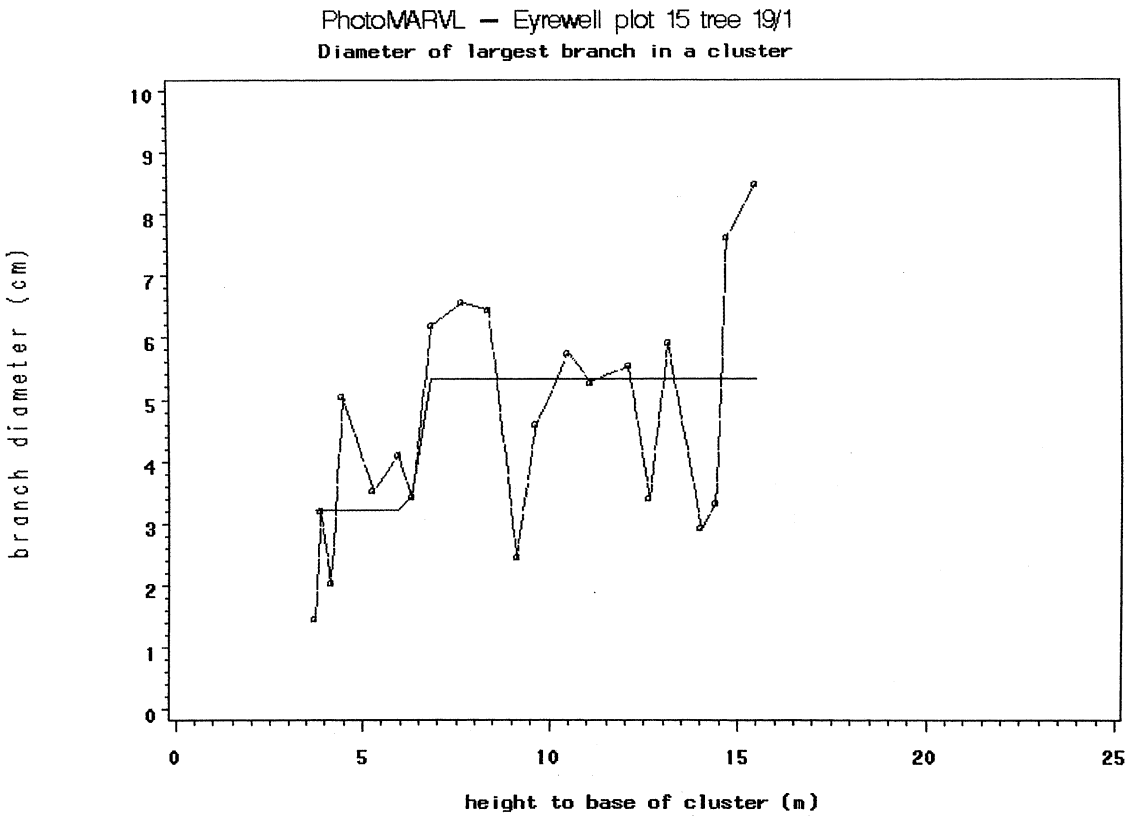


Figure 3



From examining the images, there appeared to be a fork at 14.8 m.

Figure 4

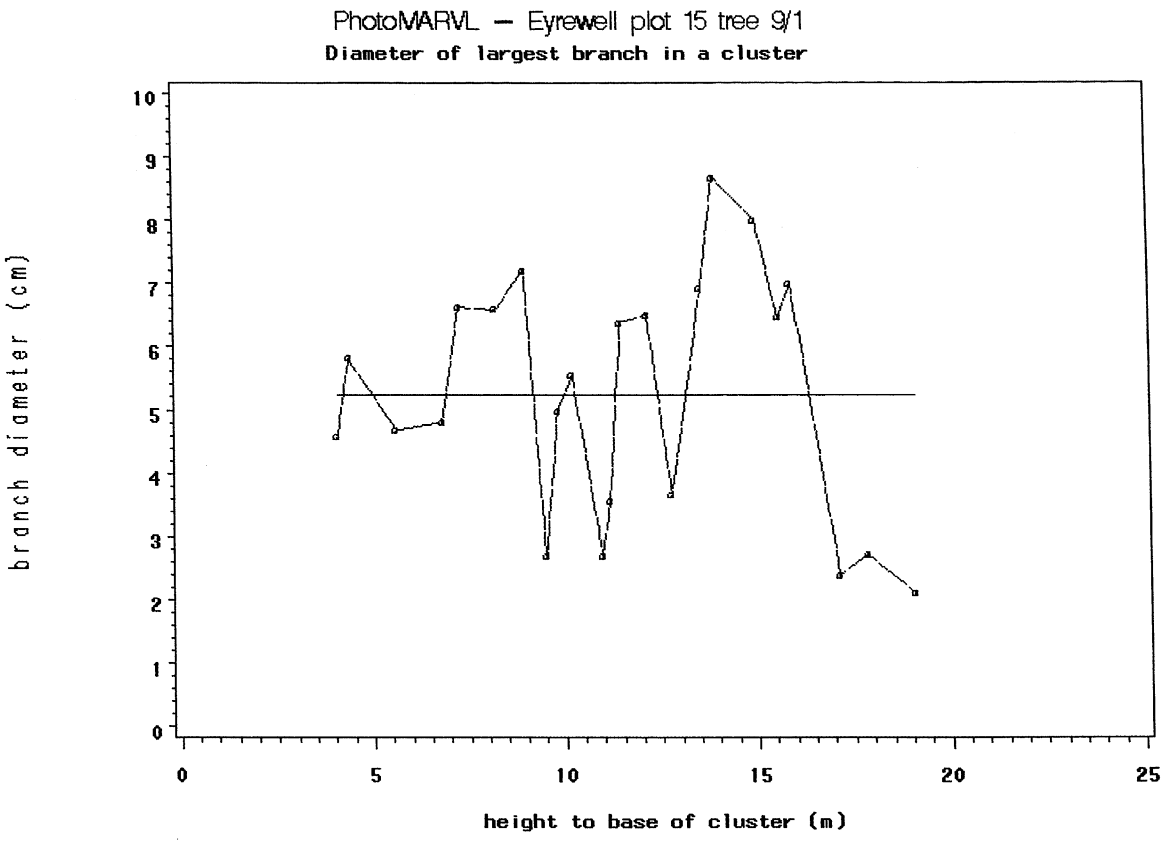


Figure 5

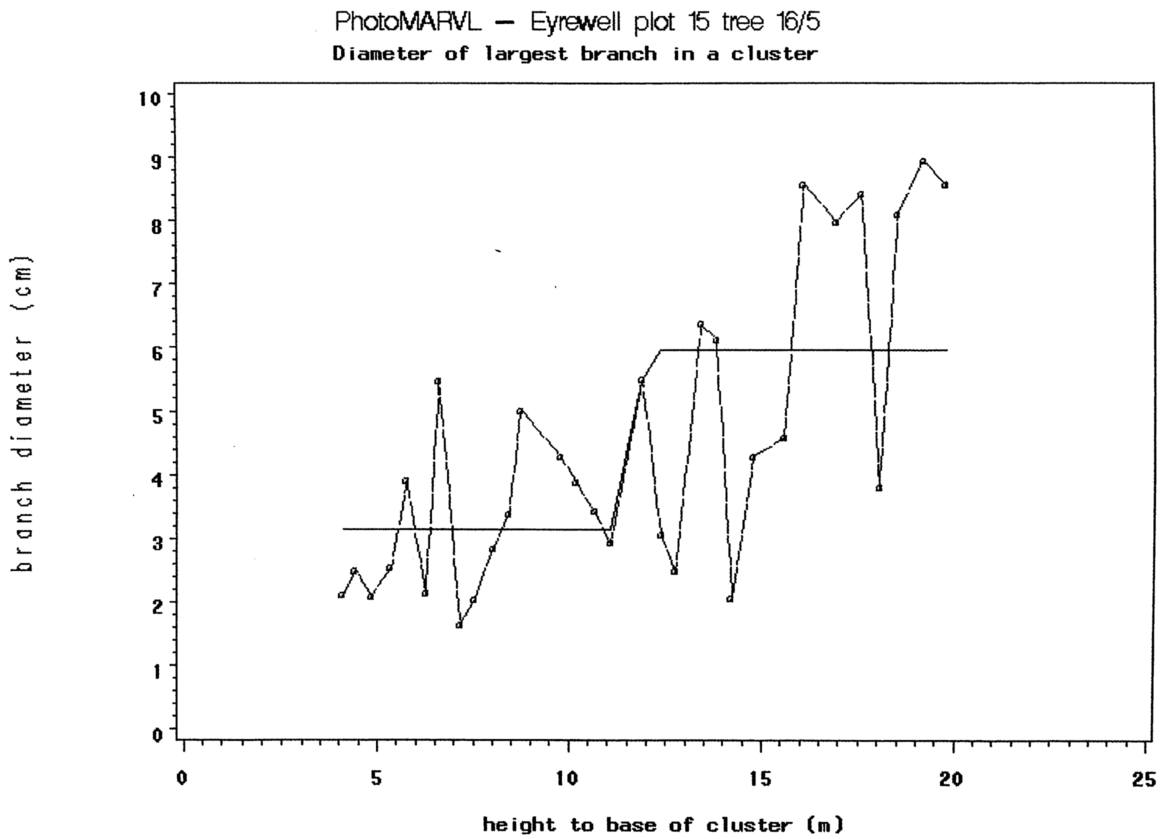
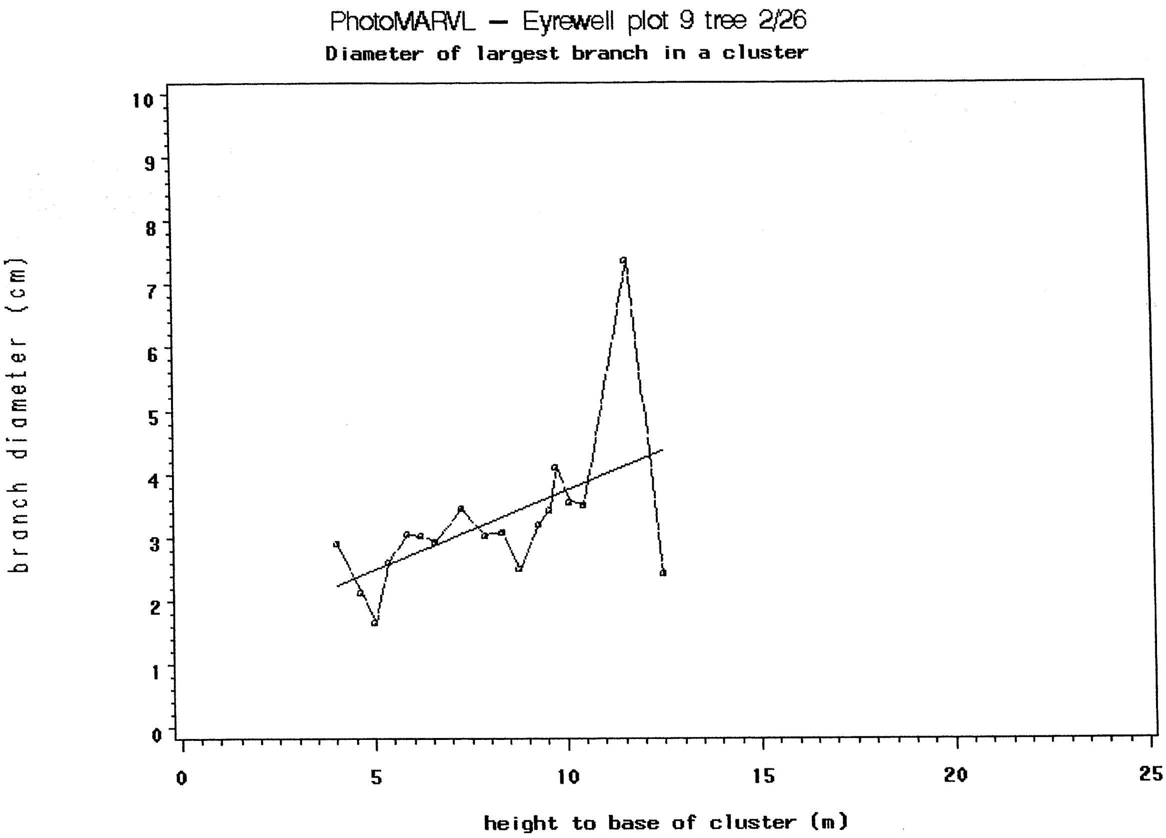


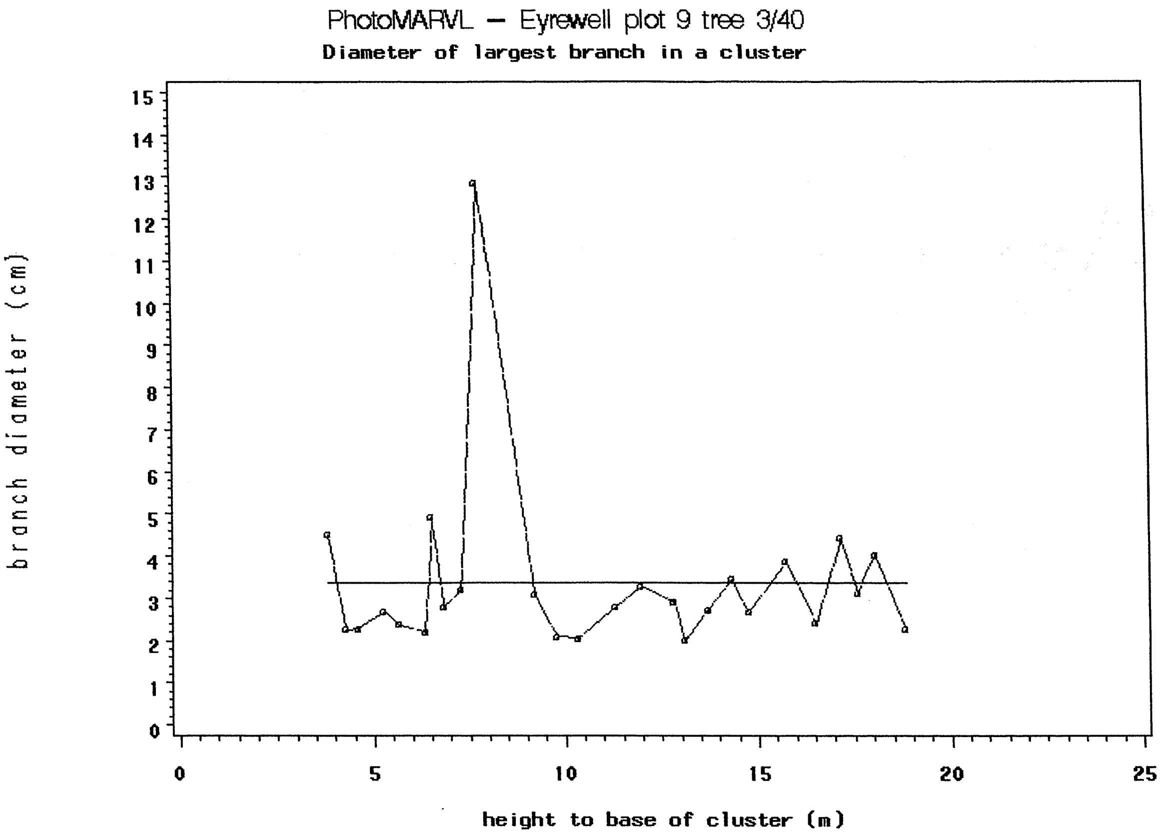
Figure 6



The image showed a large cluster (basket whorl) at 13 m. The large branch on the graph was just below this cluster.

The diameter rank of this tree gradually decreased with time, but as
Figure 6 shows branch diameter tends to increase with height. These two facts seem somewhat contradictory. One explanation might be that the top had blown out and the branches below the damage increased in diameter due increased light. This has been observed in both Esk Forest and Otago Coast Forest. At the same time the loss of the leader reduced the ability of the tree to compete.

Figure 7



The image showed that the leader had been damaged at 8.1 m. The shape of the stem indicates that another branch has taken over as the leader. The large branch measured was probably competing to be the leader at some stage.

Figure 8

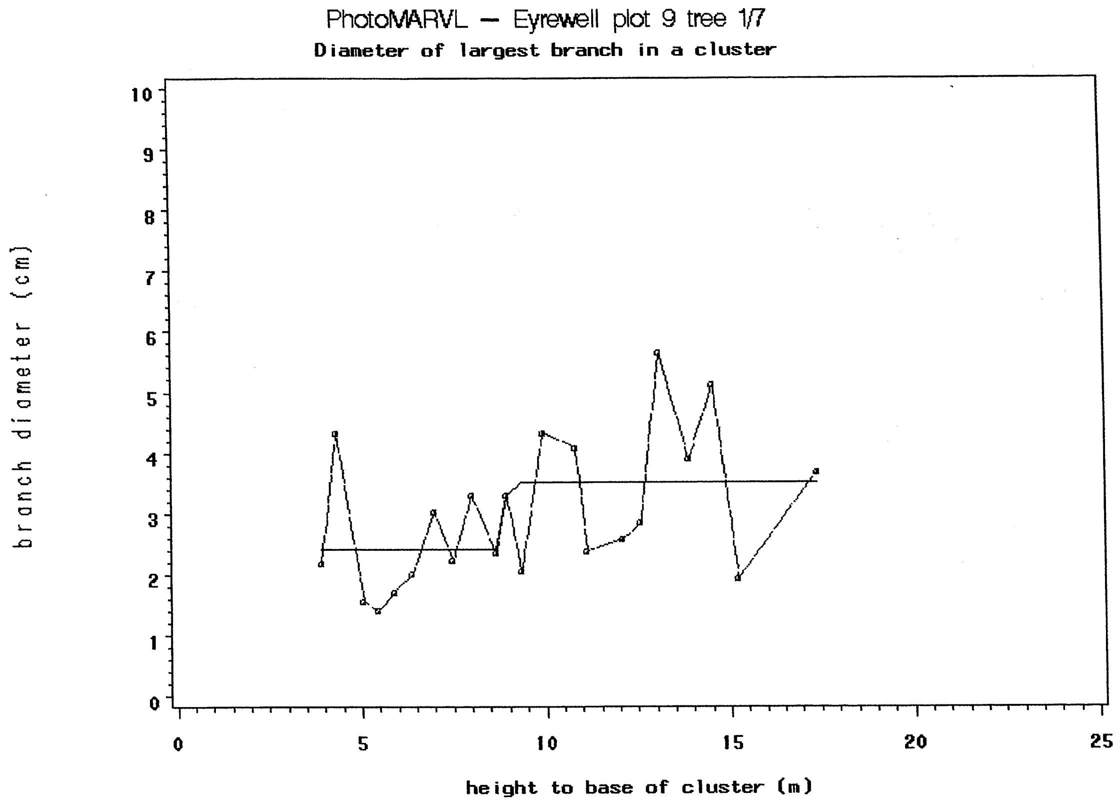


Figure 9

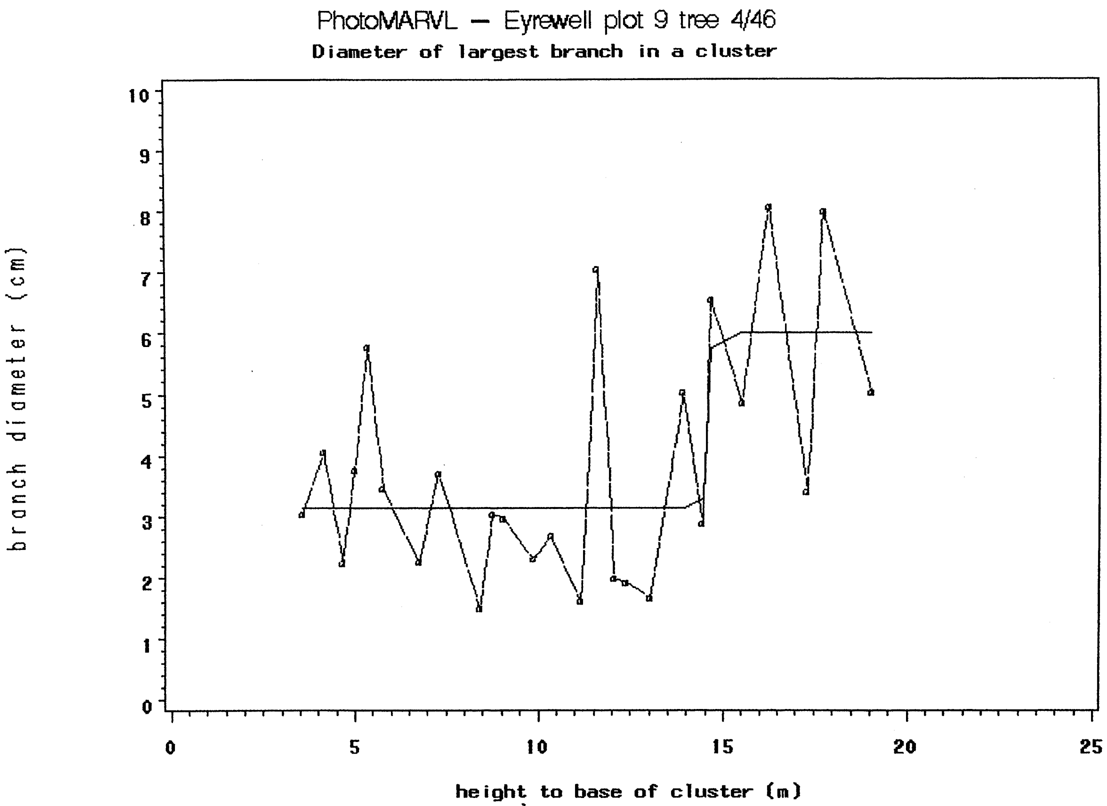


Figure 10

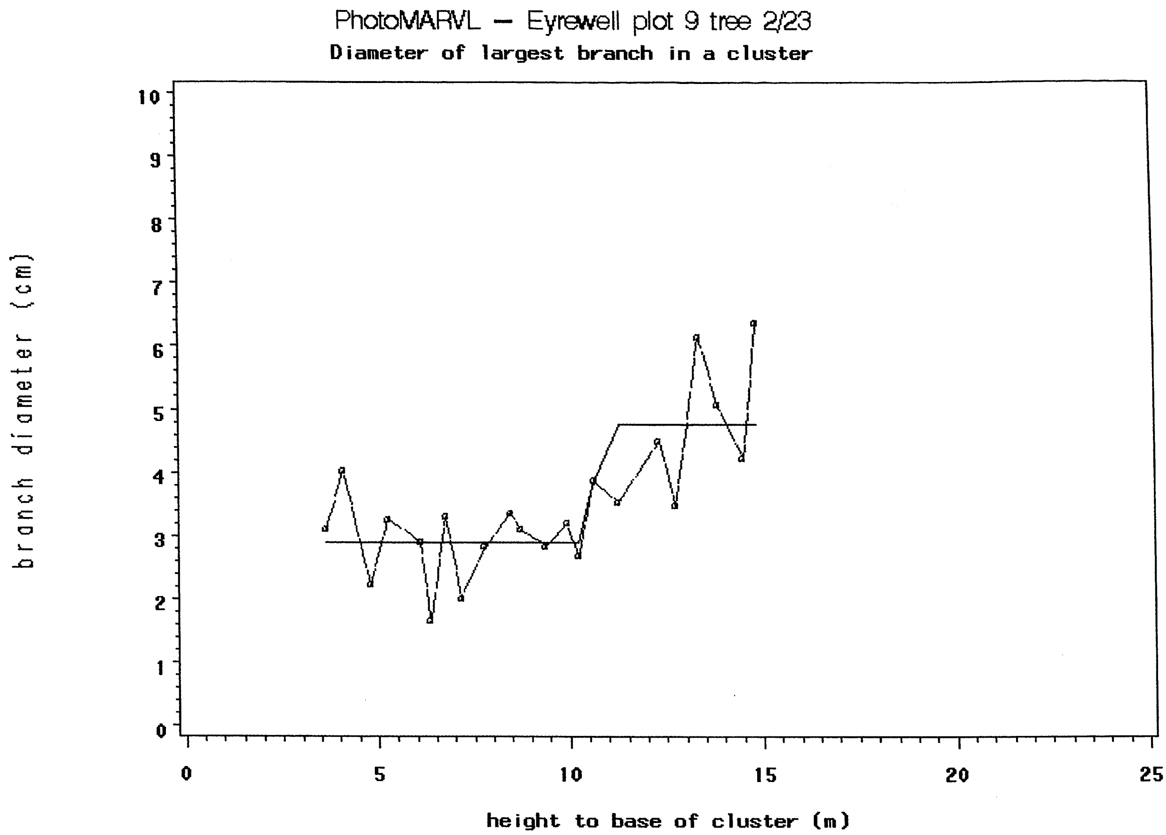


Figure 11

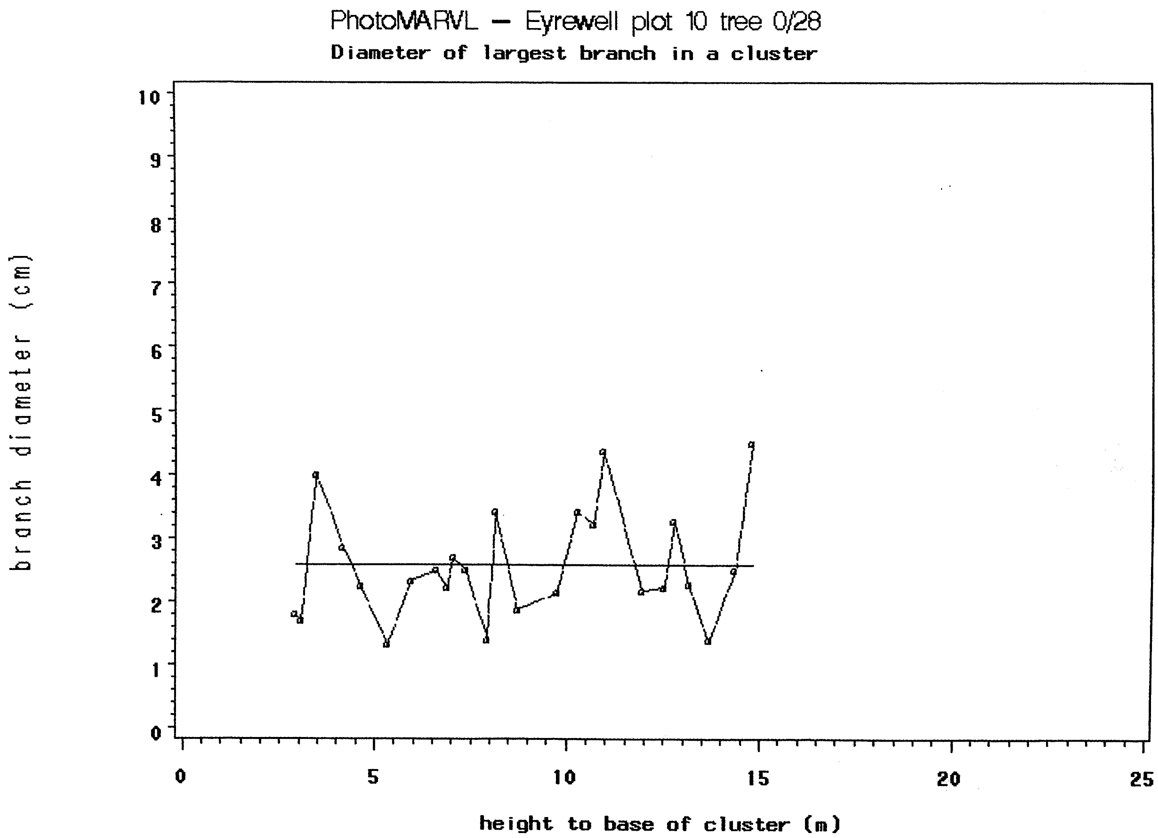
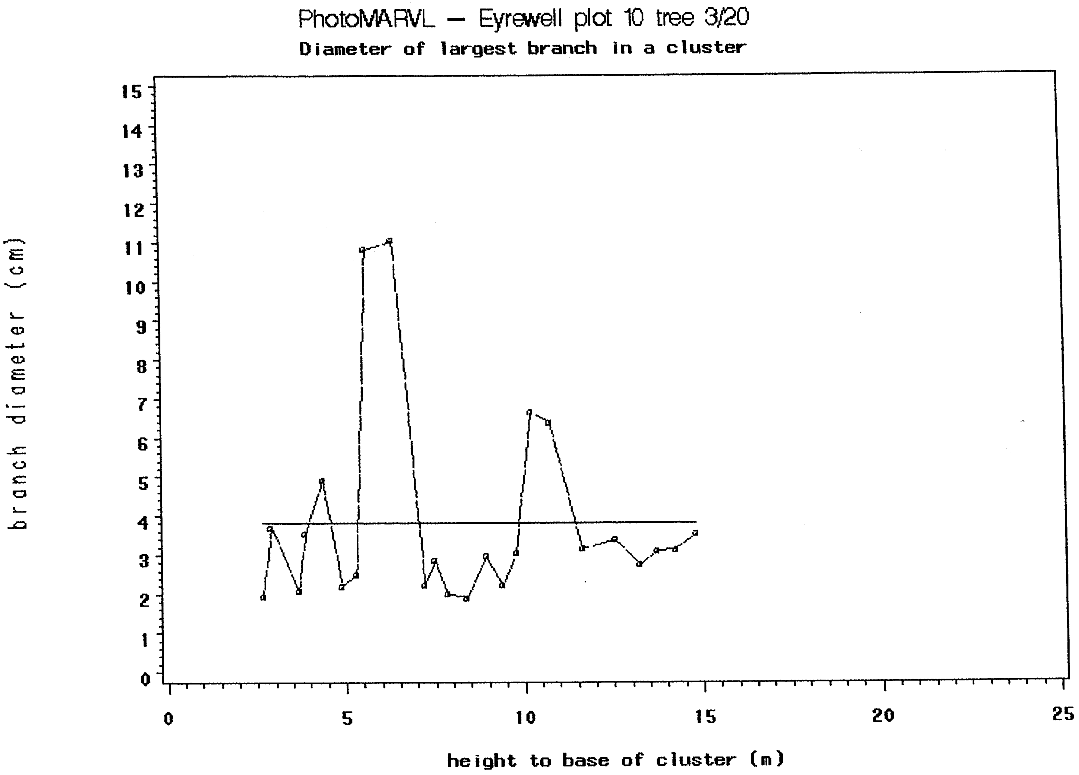


Figure 12



The image showed that the leader had been damaged at 11.1 m. The large branch at this point was a steep branch.

Figure 13

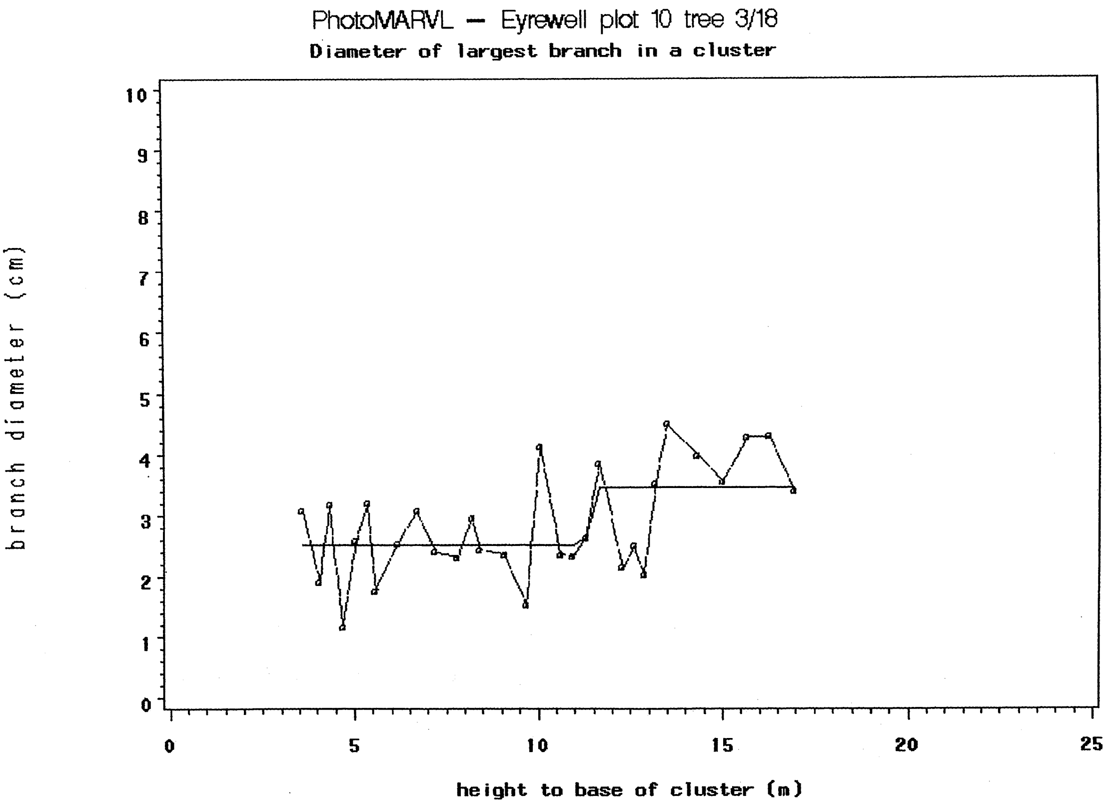
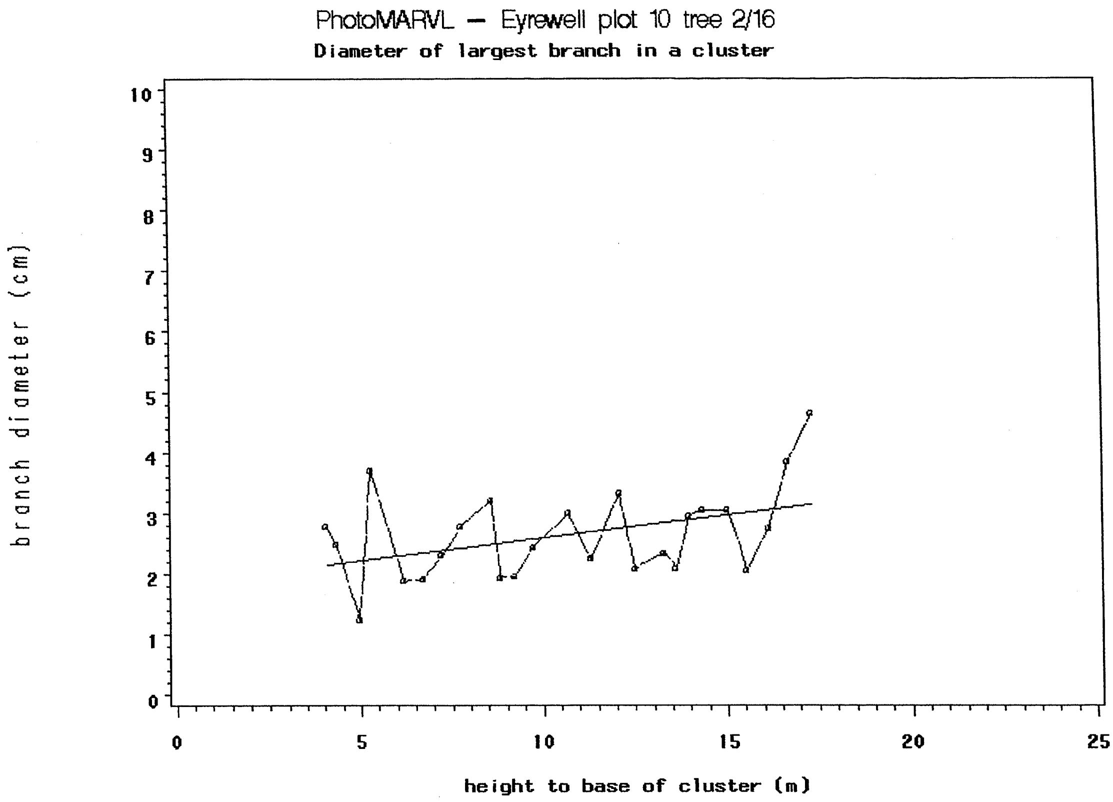


Figure 14



Plot was only thinned to 400 stems/ha. Tree 2/16 has always been a reasonably large tree in the plot.

Figure 15

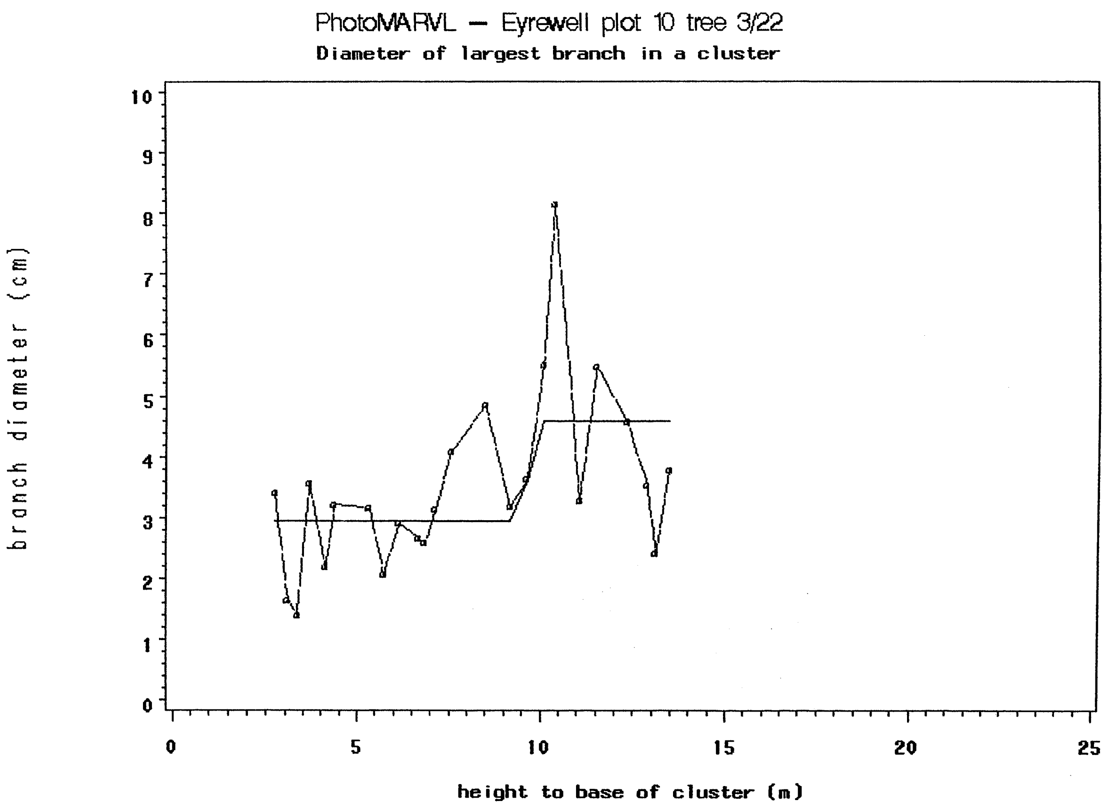


Figure 16

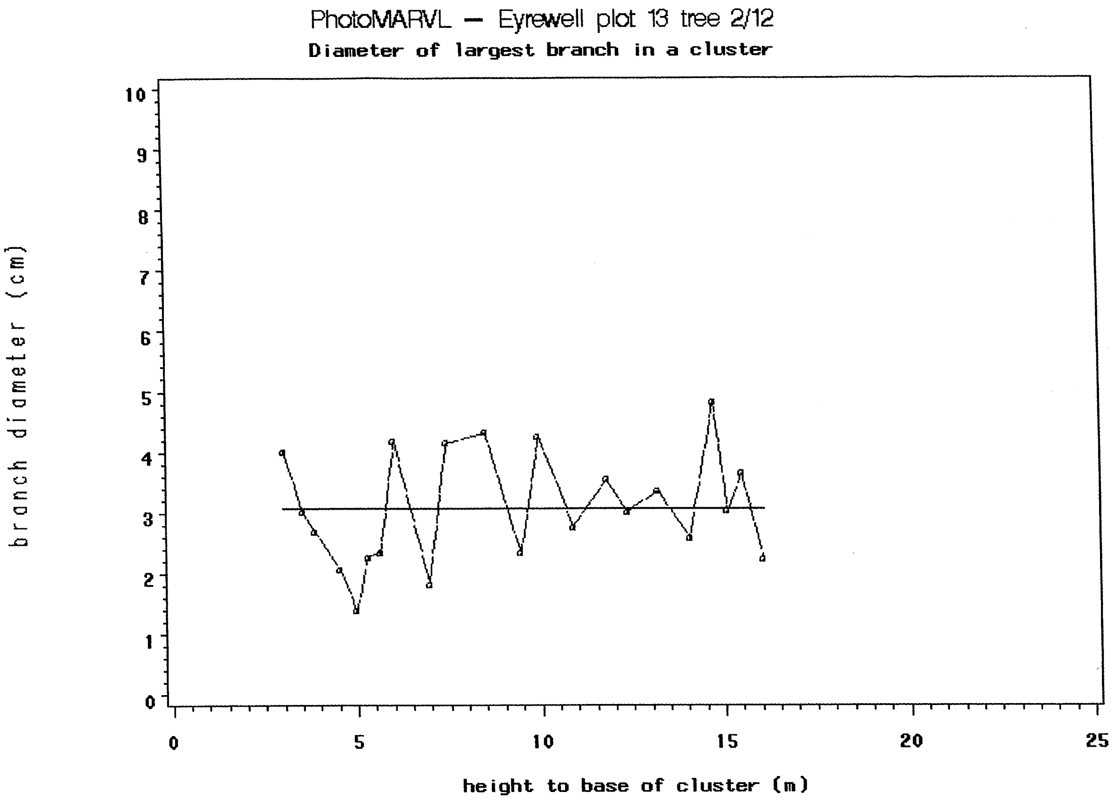
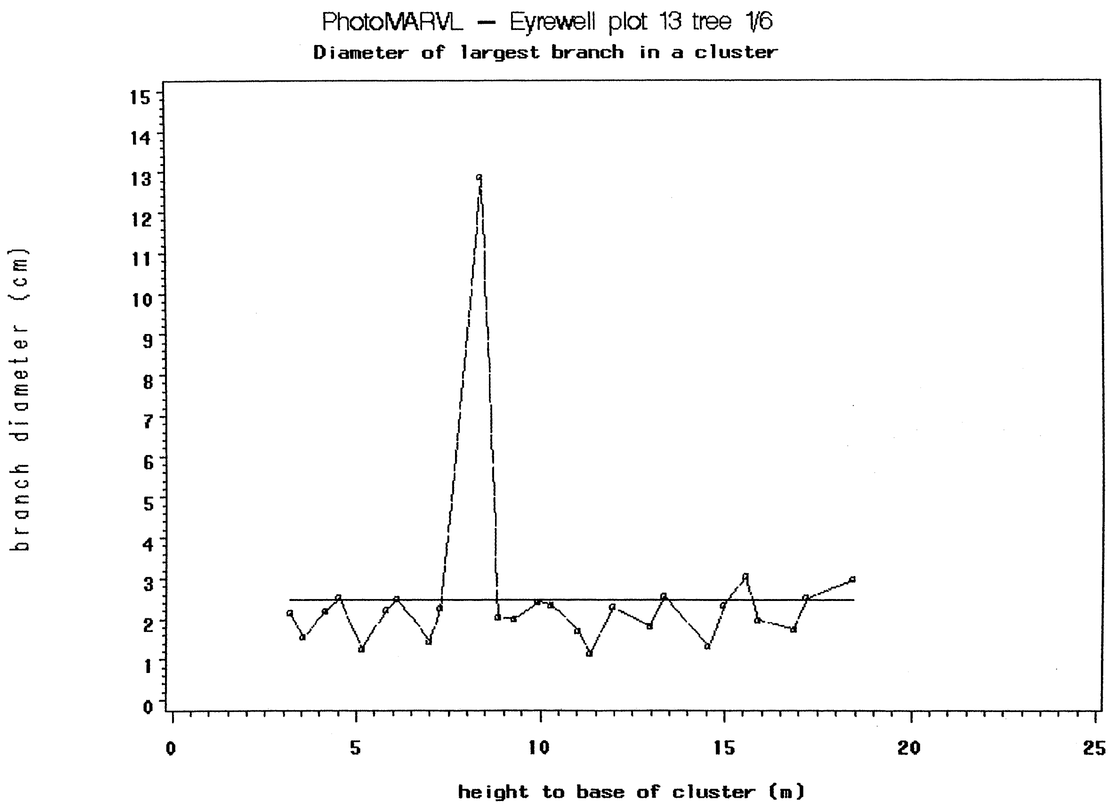
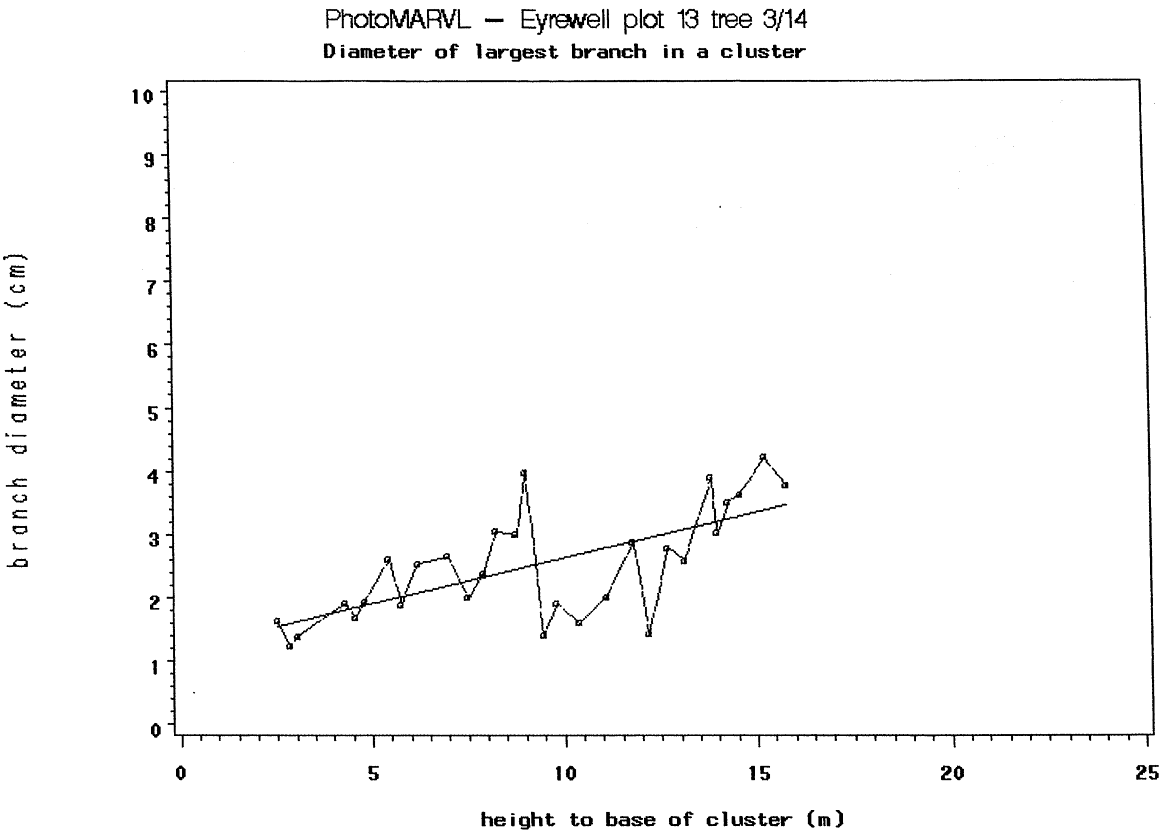


Figure 17



The image showed a fork at 8.7 m. The larger of the forks was measured above this point. The large branch diameter is the diameter of the other fork.

Figure 18



The image showed that the tree forked at 9.6 m. The left-hand fork (on the image) was measured above that point. The diameter of the right-hand fork (not shown on this graph) was 163 mm. The two forks appear to be a similar size. Initially they are very close together but move apart with increasing height above 9.6 m. This may explain the gradual increase in branch diameter above the fork. The gradual increase in branch diameter below the fork may also be a result of the fork. Larger than expected branches have been observed immediately below leader damage at both Esk and Otago Coast Forests.

Figure 19

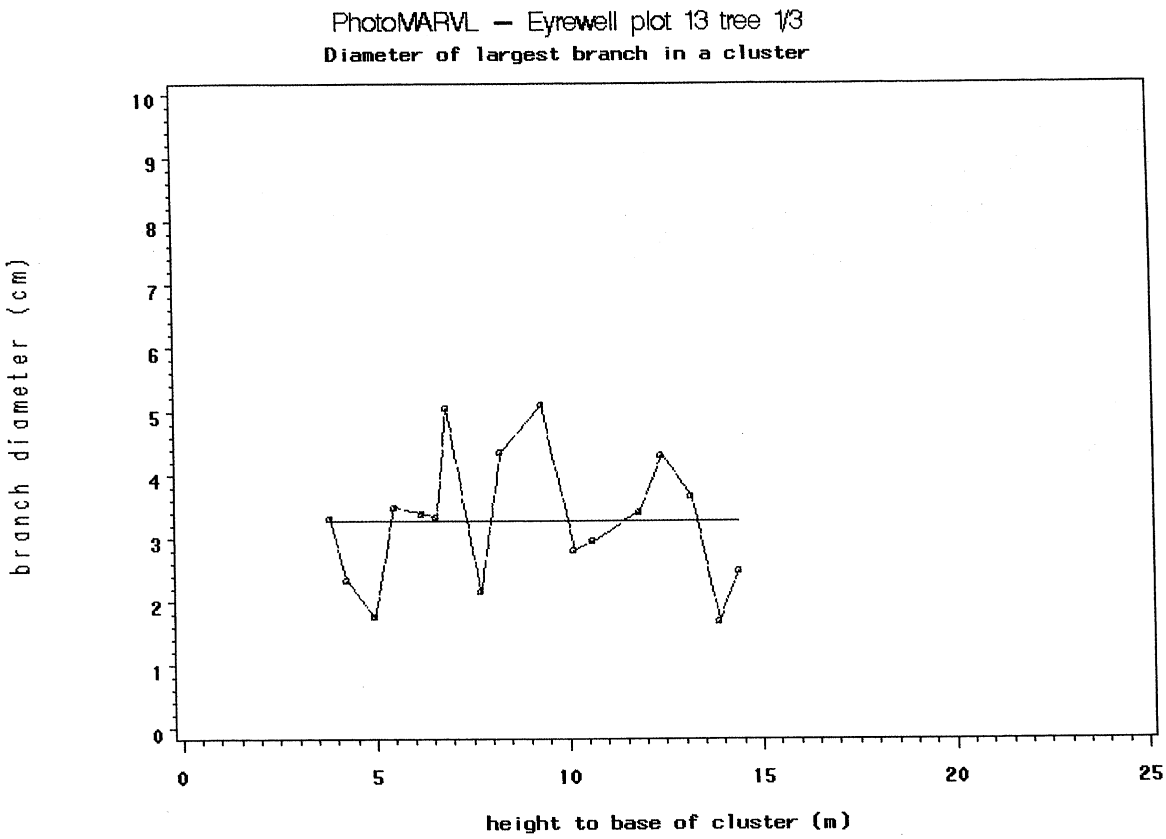


Figure 20

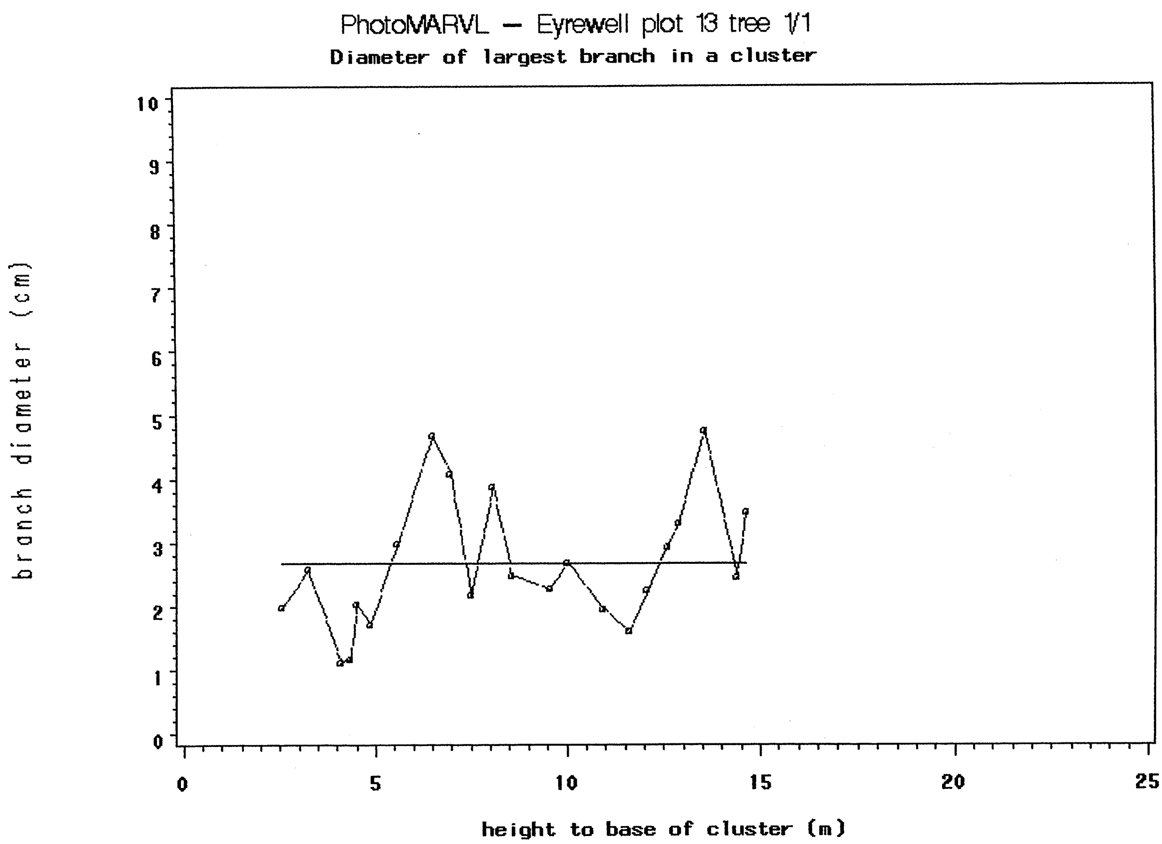


Figure 21

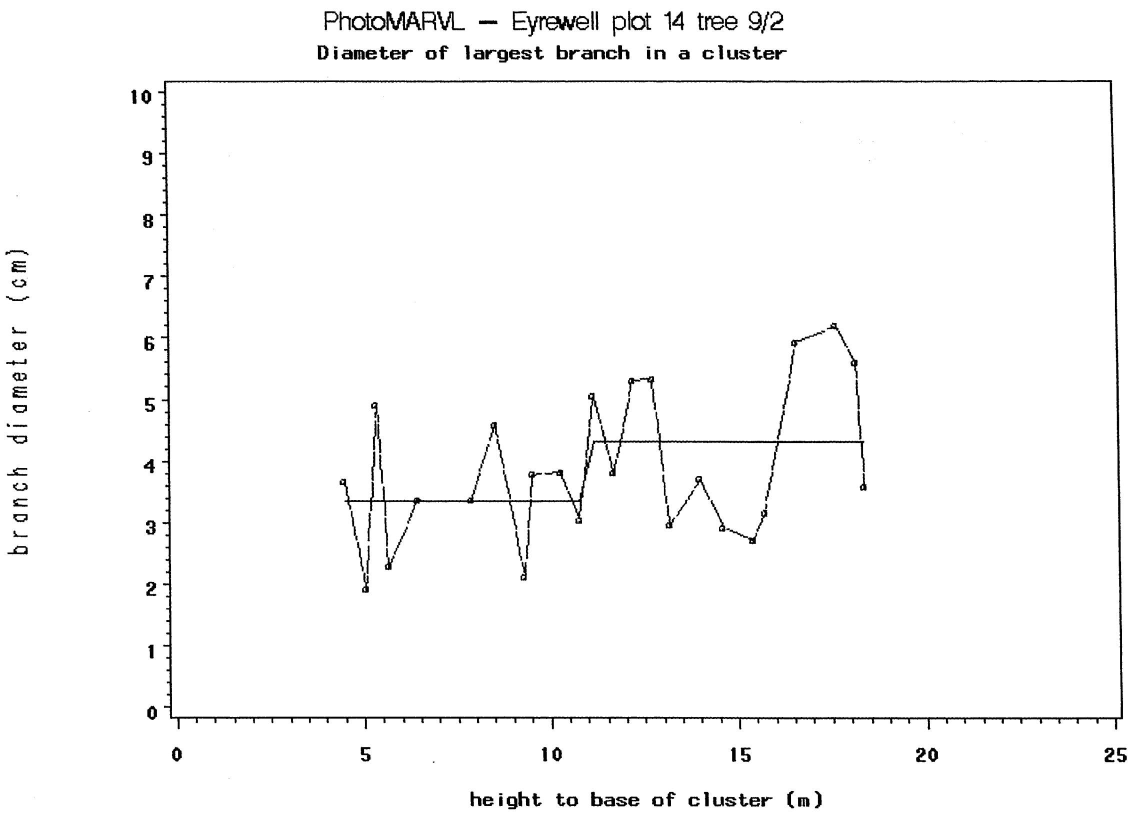


Figure 22

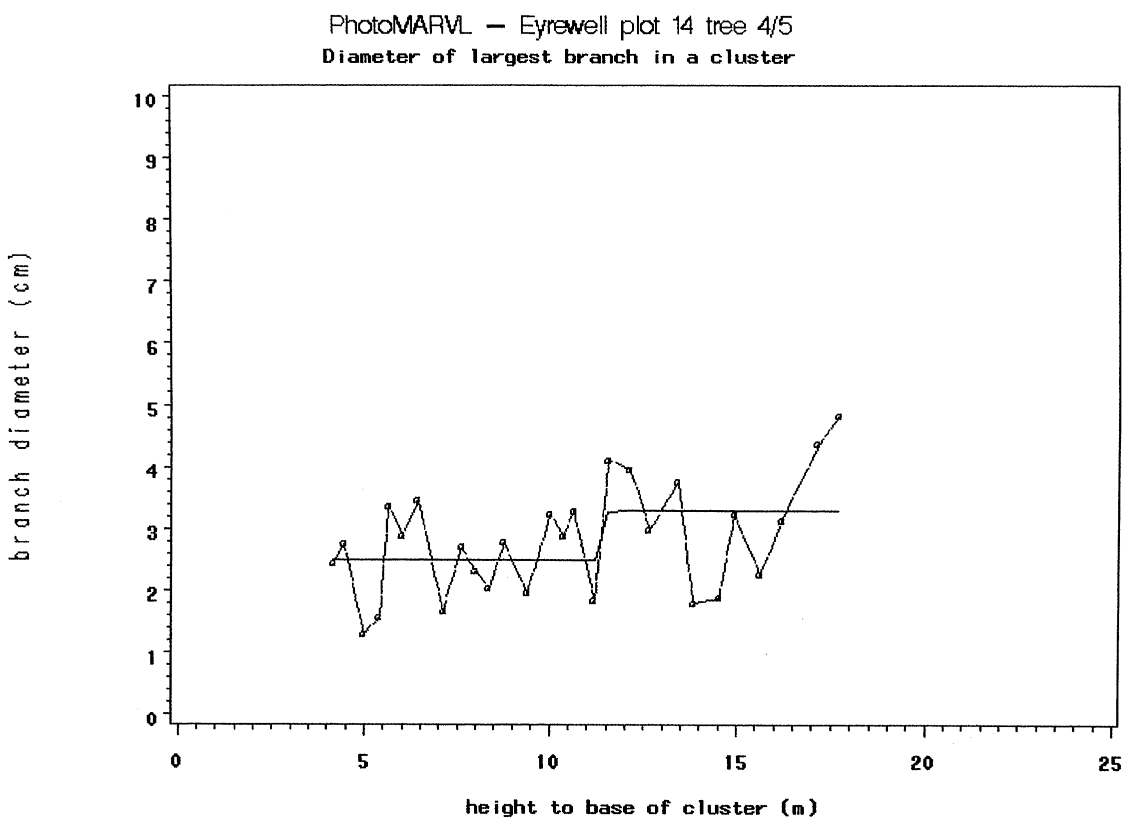


Figure 23

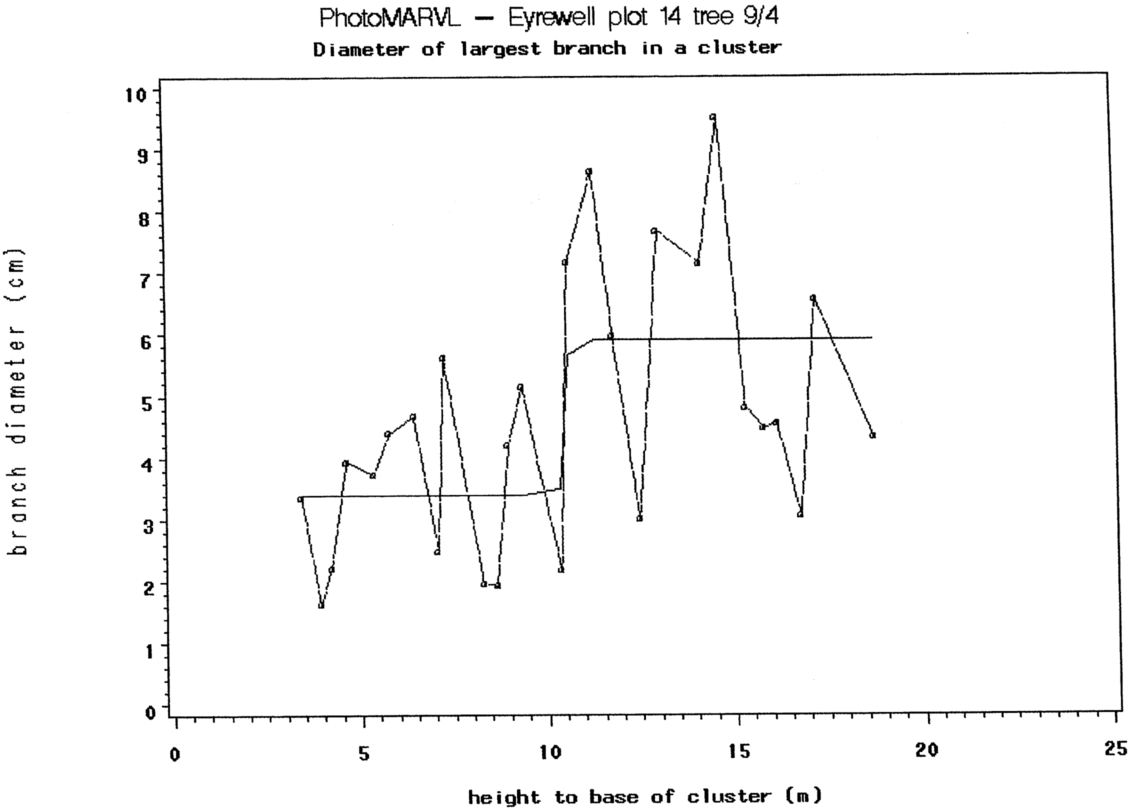


Figure 24

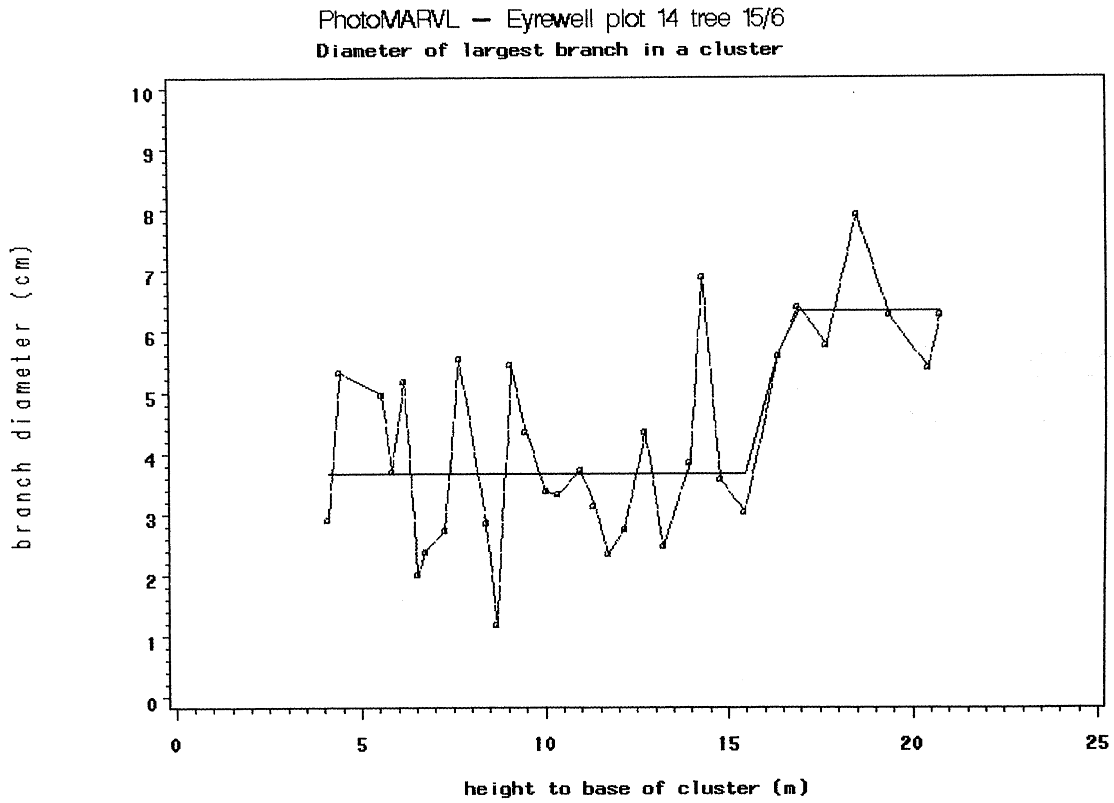


Figure 25

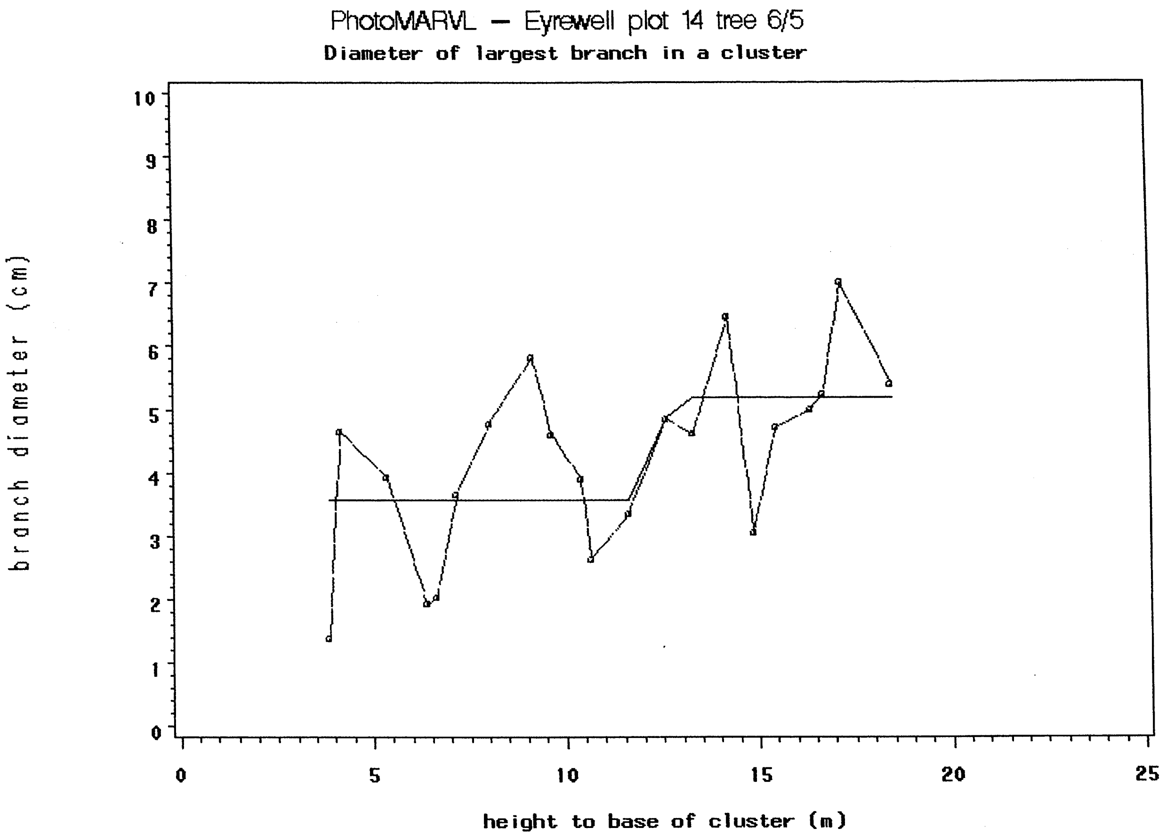


Figure 26

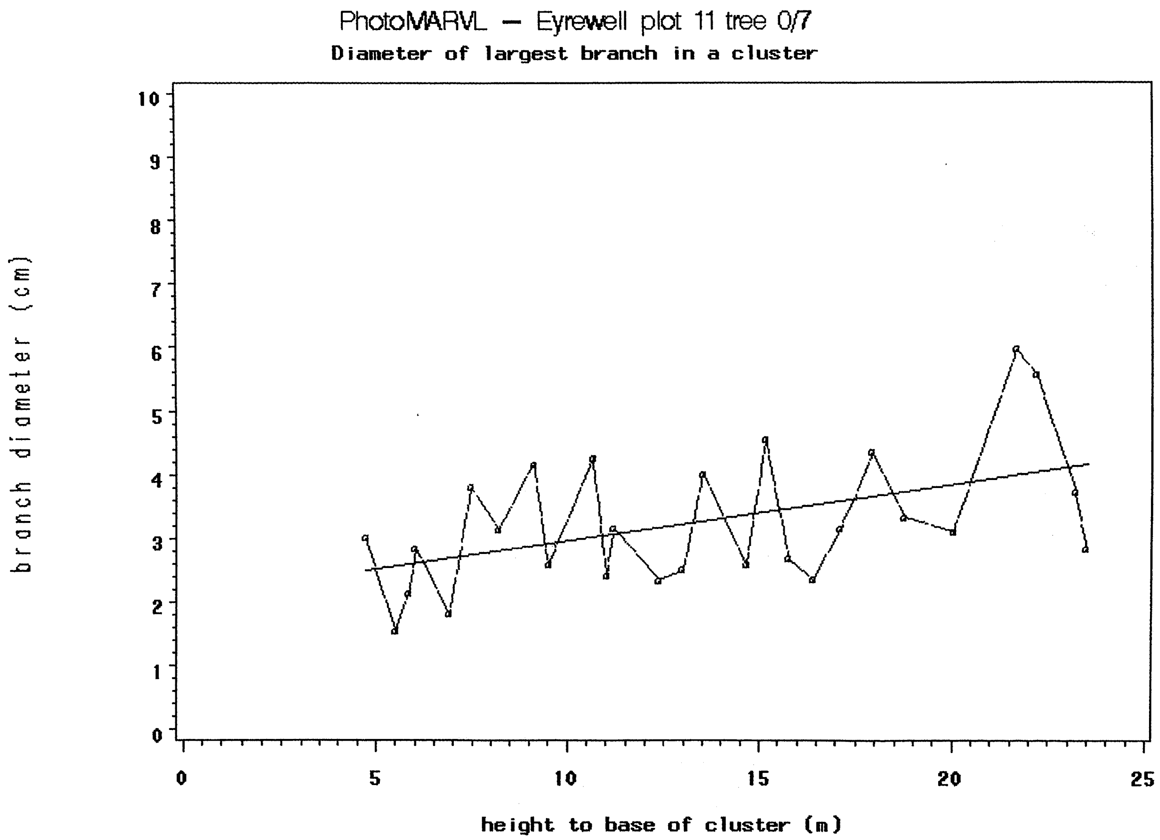


Figure 27

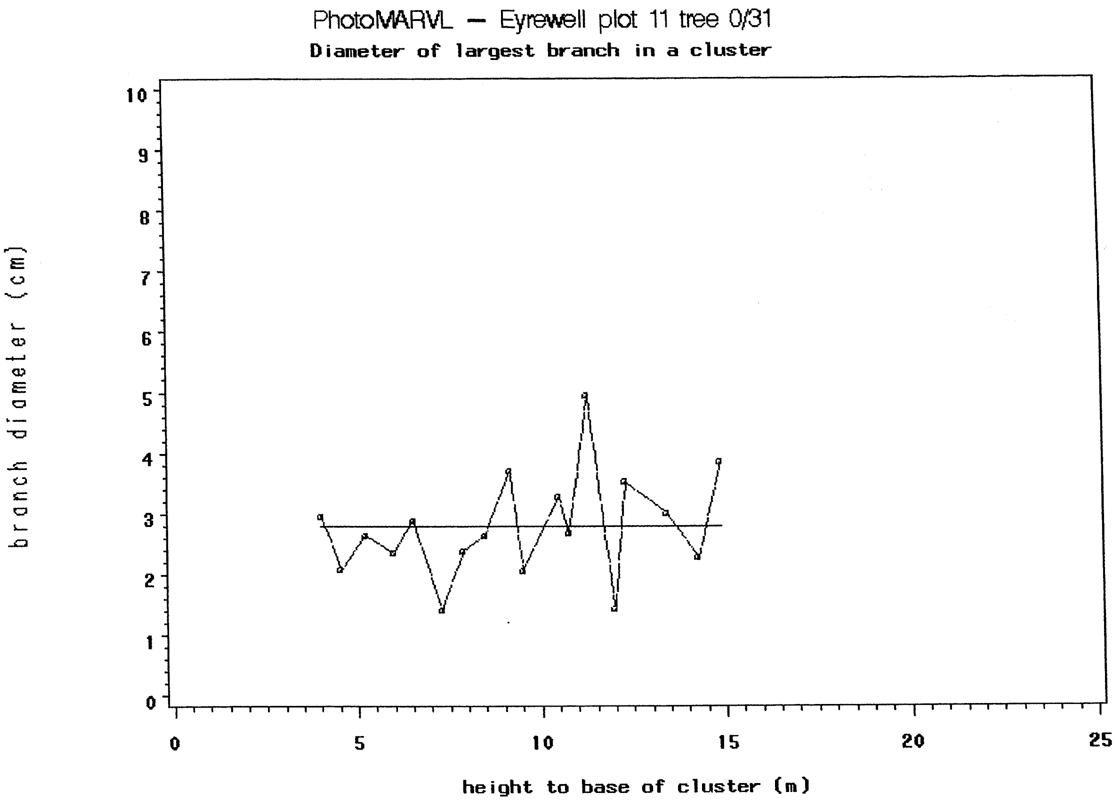
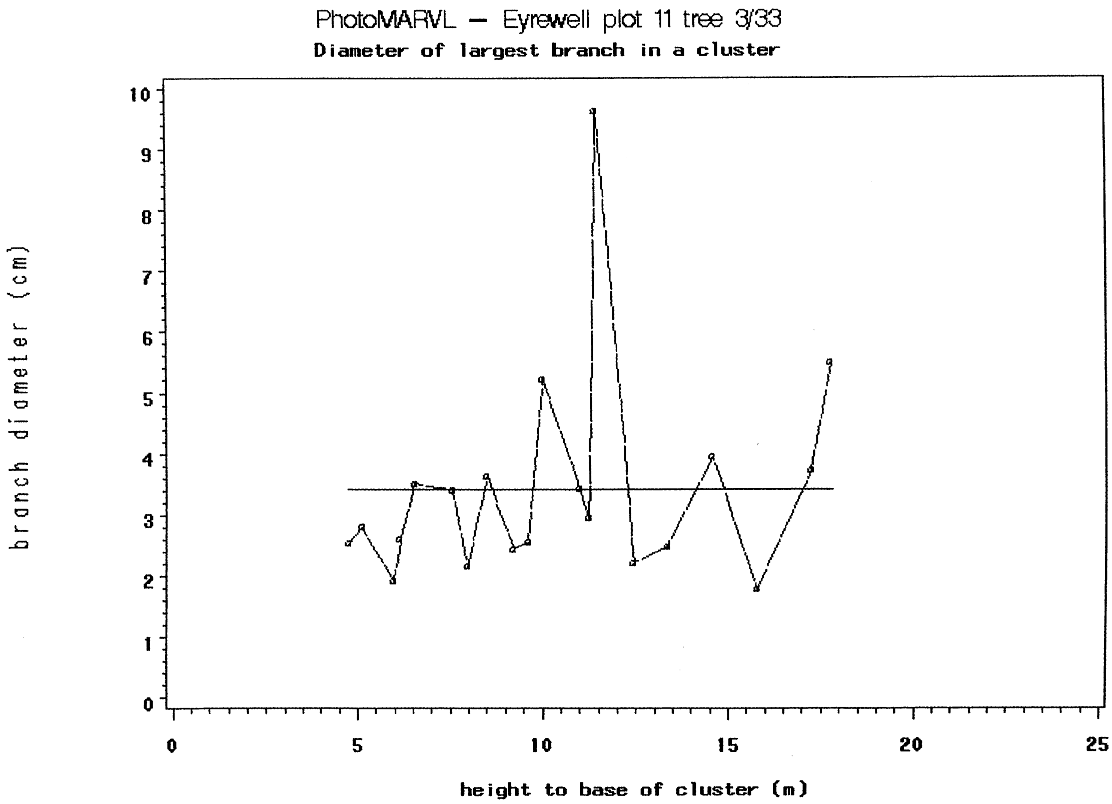


Figure 28



The image showed that the leader had been damaged at 11.7m. The large branch is obviously a result of this damage.

Figure 29

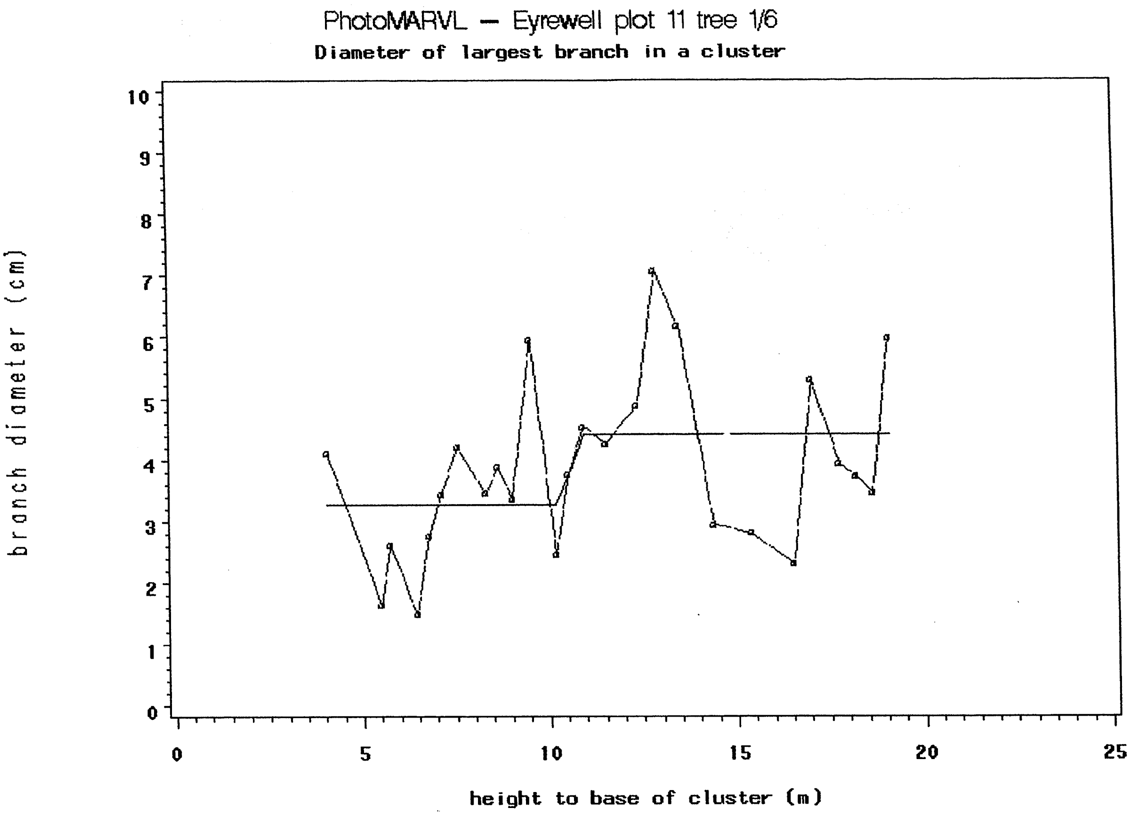


Figure 30

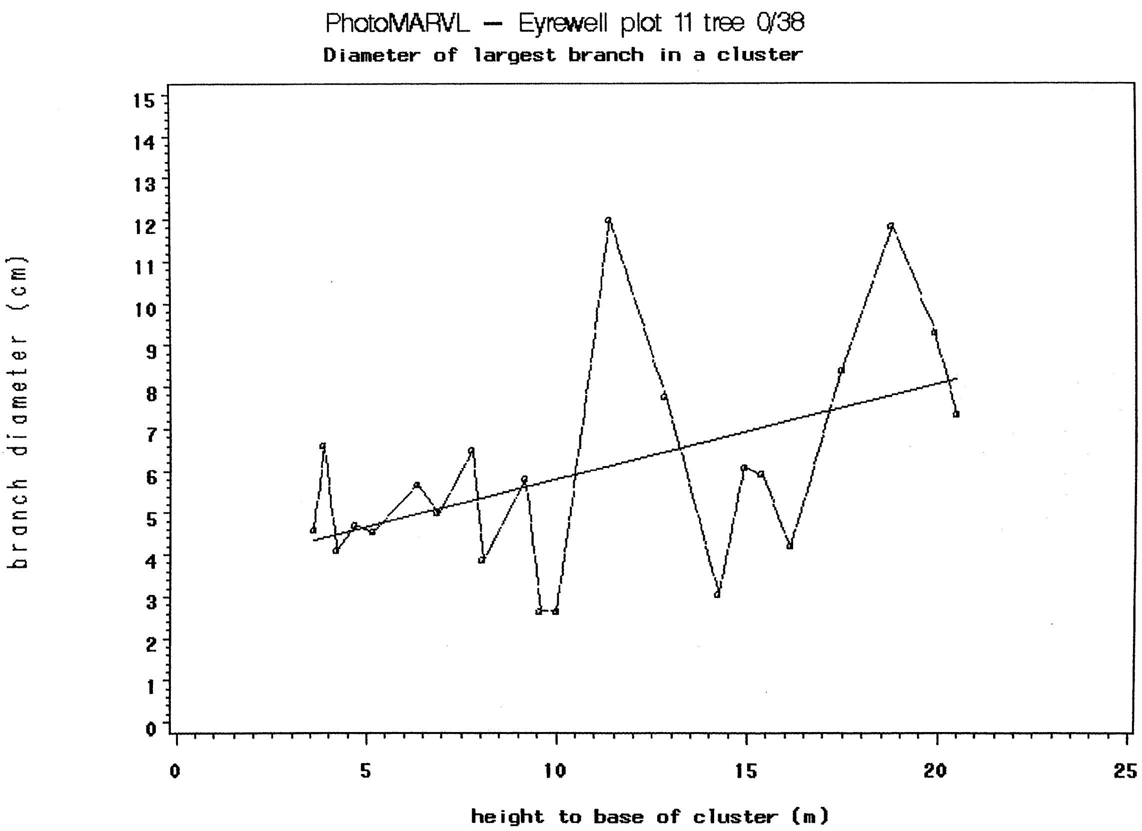


Figure 31

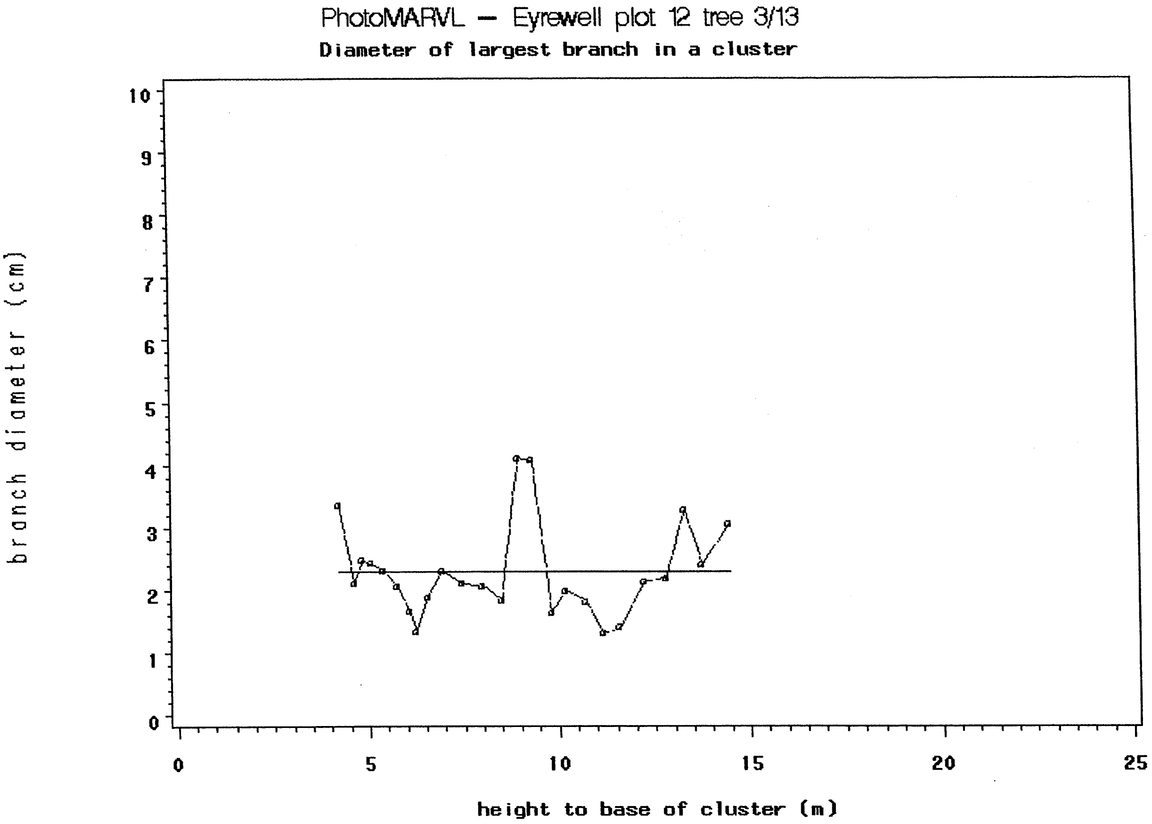


Figure 32

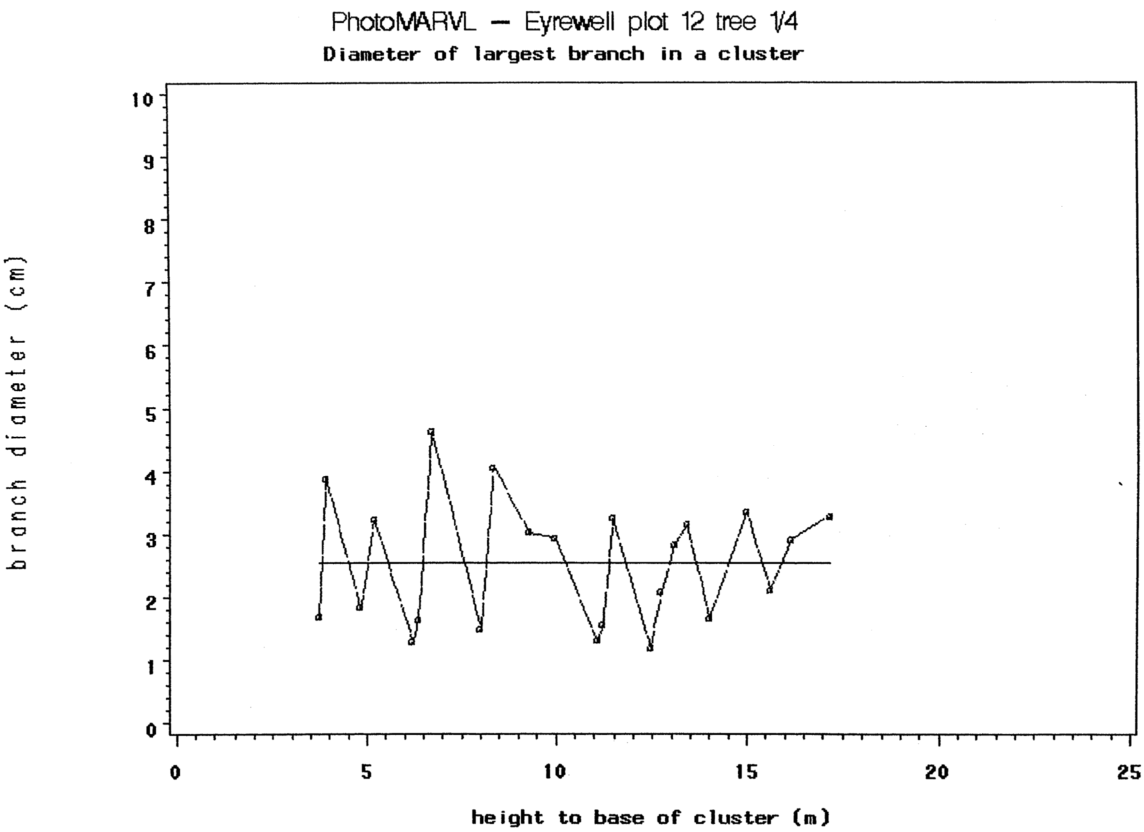


Figure 33

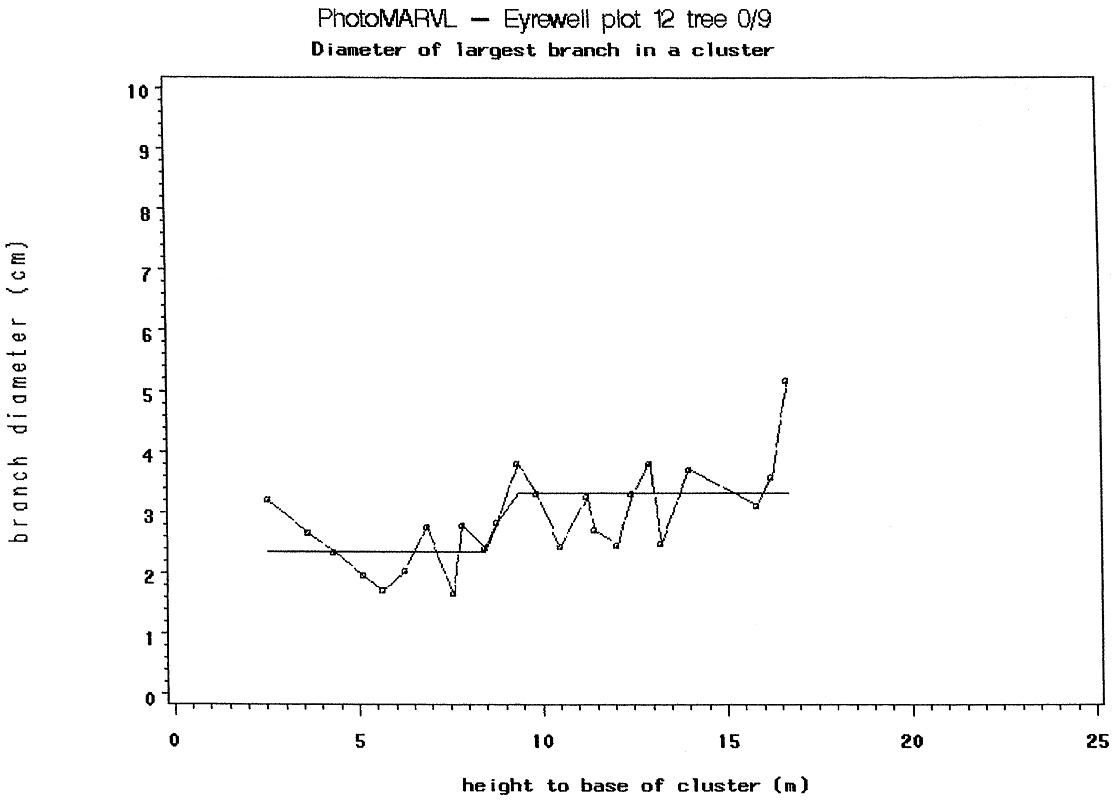
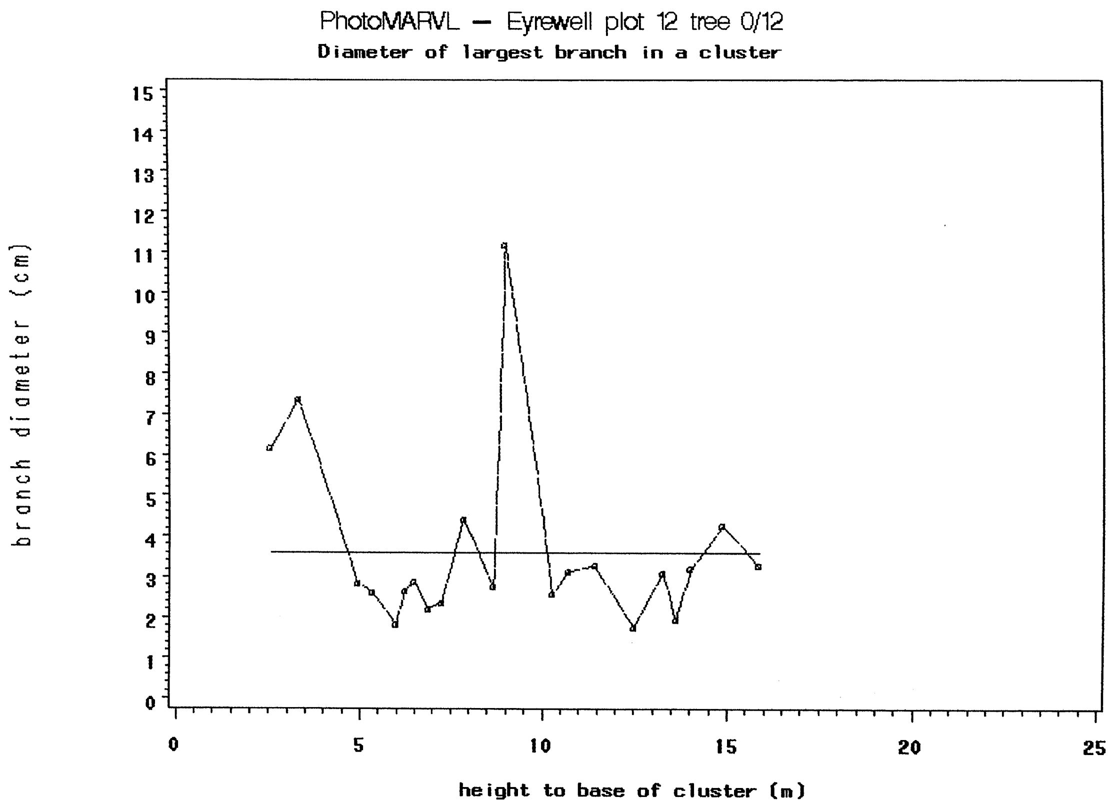
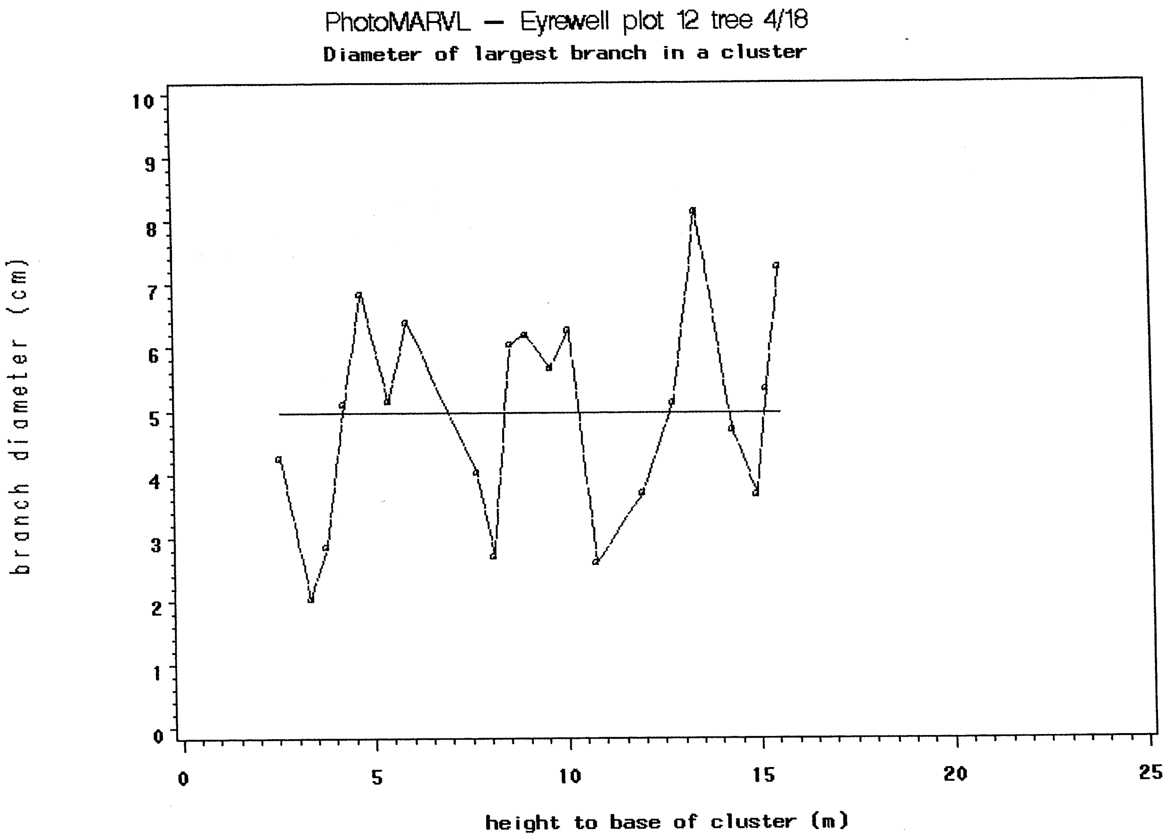


Figure 34



The image showed a change in leader at 9.3 m. The large branch at this point is a steep branch that was probably competing to be the leader.

Figure 35



PhotoMARVL — Eyrewell plot 12 tree 4/18
Diameter of largest branch in a cluster
branch diameter (cm)
0
1
2
3
4
5
6
7
8
9
10
0
5
10
15
20
25
height to base of cluster (m)