

Forecaster Fork and Sweep Model

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EXECUTIVE SUMMARY

FORECASTER FORK AND SWEEP MODEL

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THE PROBLEM

Forking and sweep are important in that they can cause significant downgrade in the value of a tree. One of the new developments in the ATLAS Forecaster yield prediction system is the inclusion of both generic forking and sweep models. There has been very little in the way of research work done on the occurrence of sweep and forking in radiata pine. The default user defined parameters used in ATLAS Forecaster were not based on any published studies.

COOP INITIATIVES

The Plantation Management Cooperative has provided many of the functions and models in ATLAS Forecaster. The Cooperative continues to support research projects that either investigate the functionality, or supports the use of ATLAS Forecaster. In October 2006 the Cooperative voted to undertake this project.

THIS PROJECT

The goal of this project is to determine the sensitivity of the yield and value prediction to changes in the forking and sweep models' parameters. It is hoped that this report will inform users of the relative importance of the different parameters in these models.

RESULTS

This report provides a summary of the impact of changing the user defined parameters for both the forking and sweep models, as well as an indication of the sort of values that can be expected from real data for each of the parameters. The results indicated that the forking model parameter; Forking Height and the sweep model parameter; Number of Sweep Regions and Length of Region are more important than the other parameters in terms of predicting value.

IMPLICATIONS FOR THE COOP

This provides Cooperative members who are ATLAS Forecaster users with some useful guidelines on the use of the forking and sweep models.

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INTRODUCTION

Forking and sweep are important in that they can cause significant downgrade in the value of a tree. One of the new developments in the ATLAS Forecaster yield prediction system is the inclusion of both a generic forking and sweep model. These allow users to account for the impacts of sweep and forking in their yield modelling exercises.

There has been very little in the way of research work done on the occurrence of sweep and forking in radiata pine. In the 1950's, G. Duff did calculate conversion factors for determining the volume of a forked tree (Duff 1956). The Stand Growth Modelling Cooperative is currently starting to investigate the impact of forking on branch growth modelling. The defaults user defined parameters used in ATLAS Forecaster were not based on any published studies. The goal of this project is to determine the sensitivity of the yield and value prediction to changes in the forking and sweep models' parameters. It is hoped that this report will inform users of the relative importance of the different parameters in these models.

Overview of Forking Model

The ATLAS Forecaster forking model “allows a proportion of stems to have two or more leaders. It does not permit more than one level of forking, but the point of forking can be anywhere between pruned height (or breast height on an unpruned stem) and twice breast height below the stem height”

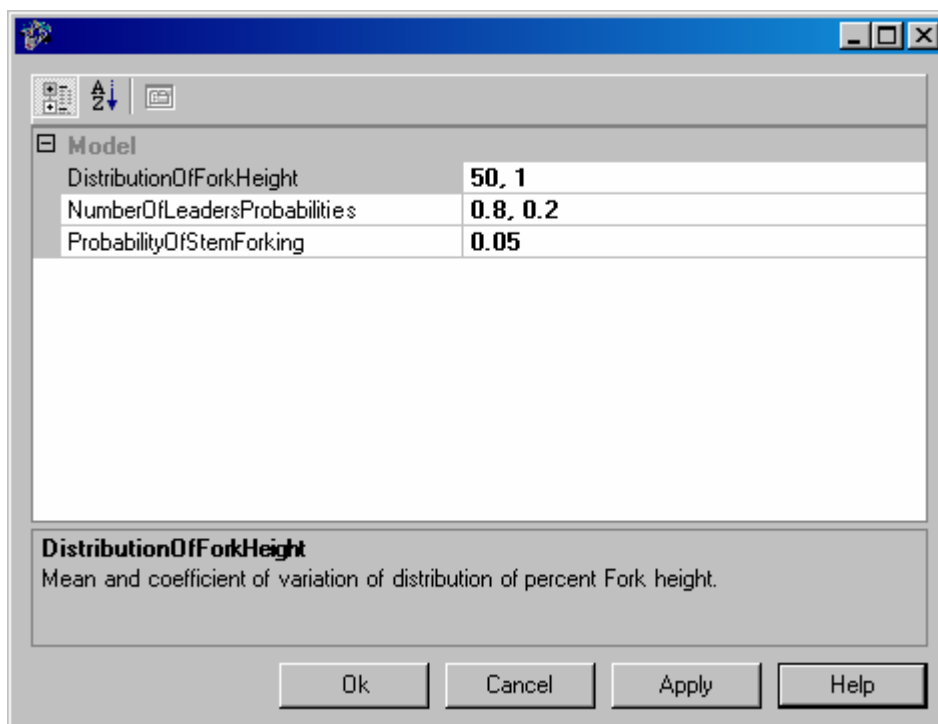


Figure 1. The forking model parameter window in ATLAS Forecaster

The generic forking model has three parameters (Figure 1):

- The height of the forking is modelled using the normal distribution. The model requires a mean and coefficient of variation (std deviation/mean) of the percentage fork height. This is a percentage of the interval between pruned height (or breast height on an unpruned stem) and twice breast height below the stem height.

- The probability of a stem forking. The default of 5% (0.05) assumes that 1 in 20 stems will be forked.
- The probabilities of 2, 3, 4 ... leaders.

More information on the forking model can be found in either the ATLAS Forecaster manual or the online help.

Overview of Sweep Model

The ATLAS Forecaster sweep model is based on the ATLAS Cruiser sweep description system. Sweep is defined as a lack of straightness for all or part of a tree. It is an important characteristic as many log grades are restricted by the amount of deflection or sweep they are allowed. The term deflection means the amount a tree or log deviates away from a straight axis.

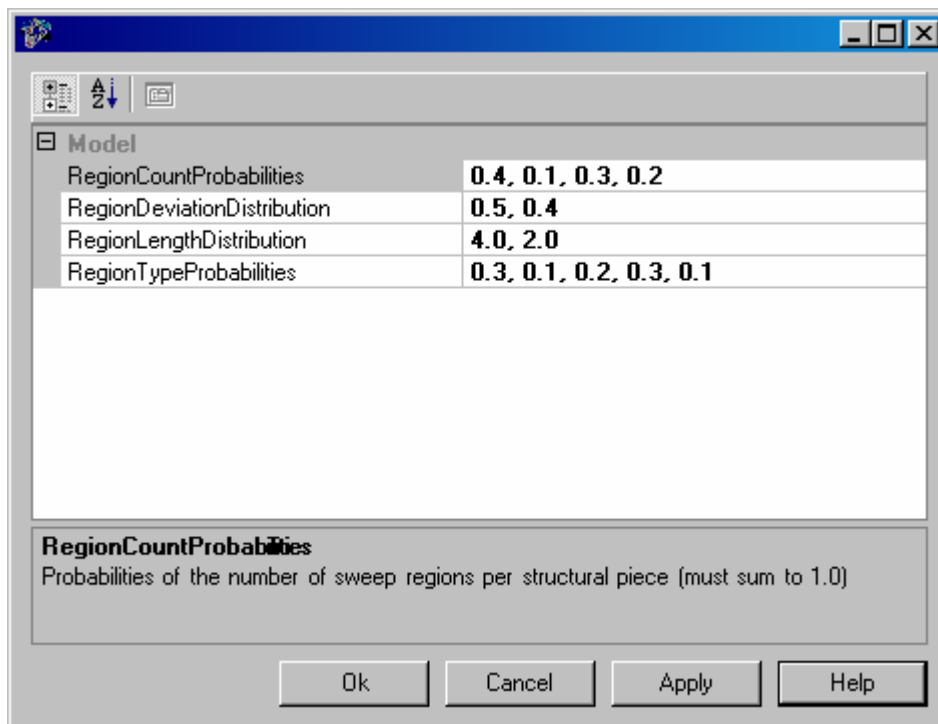




Figure 2. The sweep model parameter window in ATLAS Forecaster.

The generic sweep model has four user definable parameters (Figure 2):

- **Region count Probabilities:** This is a list of the probabilities of finding zero, one, two, ... swept regions on the stem i.e (0.4, 0.1, 0.3, 0.2). The above example indicates 40% of stems will have zero swept regions, ie straight stems, 10% will have 1, 30% will have two and 20% will have three.
- **Region Deviation Distribution:** The mean and standard deviation of the distribution of proportional deviation. The example above shows a mean deviation of 0.5 of the DOB at the end of the swept region. The distribution of these proportional deviations is considered approximately normal.
- **Region Length Distribution:** The mean and standard deviation of the distribution of the length (m) of swept regions. In the example above the standard deviation is two metres and the mean is four metres. The distribution of these lengths is also considered approximately normal.

- Region Type Probabilities: These are the probabilities of the different types of sweep in the following order:



<p>Normal Sweep - Normal sweep deflects away from a straight axis then rejoins the original line of the stem axis.</p>	<p>Bend - The bend results in a change in direction of the stem's centre line. A bend often results from the phototropic straightening of the tip of a leaning stem.</p>	<p>Hockey Stick - A swept region of this shape can start at ground level or above a straight section. The centre line finishes in parallel to the original stem axis.</p>
		
<p>Leader Replacement - Similar to a hockey stick, except it has two curves in its shape rather than one. Typically results from a branch replacing the original leader.</p>	<p>Wobble - Wobble sweep type starts and finishes on the same axis but deviates in two different directions.</p>	

METHOD

Part 1: Sensitivity to changes in Parameters

Part 1 of this project was designed to test the sensitivity of Forecaster's volume and value prediction to changing the input parameters of the sweep and forking models. The project looked at the impact of changing the parameters independently of the other parameters. Some of the parameters have two variables associated to them, one being the mean, the other being standard deviation to describe a distribution from which a random value for the parameter is chosen. In these cases only the impact of the mean variable was investigated. It was assumed that if it was shown that it was important to collect field data on a particular parameter both the mean and variable could be calculated from that sample. The analysis was done using an average New Zealand site (300 index: 25 m³/ha/yr, Site Index: 29.9 m) with the following crop parameters.

Table 1. Forecaster Crop Level Parameters used in this Study

Parameter	Value
Year of Planting	2003
Stocking at Planting	1500
Current Year	2007
Stocking at Planting	1470
Quadratic Mean DBH	112 mm
Basal Area/ha	8.5 m ² /ha
Stem Basal Area CV%	12 %
MTH	5.2 m
Stem DBH Max	120 mm
Stem Height CV%	10 %

Two standard regimes (pruned and unpruned) were developed within the Forecaster system. These regimes are solely being used as a test bed for trialling the different fork and sweep model parameters.

Appearance Grade Regime

1. MeanDOS > 165 mm Prune to 600 stems/ha order from 'Largest DBH x Height' (3) with Maximum Pruned Height (m) of 2.4, Minimum Green Crown Remaining(m) of 0.2, Minimum Lift Length(m) of 0.2
Thin to waste to 'Residual' Stocking of 600 stems/ha, order from 'Fewest Pruning Lifts' (1)
2. MeanDOS > 170 mm Prune to 400 stems/ha order from 'Largest Pruned Height' (2) with Maximum Pruned Height(m) of 4.5, Minimum Green Crown Remaining(m) of 0.2, Minimum Lift Length(m) of 0.2
3. MeanDOS > 170 mm Prune to 317 stems/ha order from 'Largest Pruned Height' (2) with Maximum Pruned Height(m) of 6.5, Minimum Green Crown Remaining(m) of 0.2, Minimum Lift Length(m) of 0.2
Thin to waste to 'Residual' Stocking of 300 stems/ha, order from 'Fewest Pruning Lifts' (0)
4. Age > 30 years Clearfell using: Sweep and Forking
Stop

Structural Grade Regime

1. MeanTopHeight > 13 m Thin to waste to 'Residual' Stocking of 500 stems/ha, order from 'Smallest DBH x Height' (4)
2. Age > 30 years Clearfell using: Sweep and Forking
Stop

For both regimes a rotation age of 30 years was assumed. The standard MAF log grades were used with 2006 average stumpage prices (Table 2). Because of the interaction of the sweep model and sweep log product constraints, the log sweep constraints were modified (Pattern 2) to establish a greater gradient.

Table 2. The log grades used in this paper.

Name	Length (m)	Min SED (cm)	Max Branch (cm)	Pattern 1 (%)	Pattern 2 (%)	Price (\$/m3)
P1	4-6.2	40		25	5	\$ 80
P2	4-6.2	30		25	5	\$ 54
S1	4.95-6.1	40		25	25	\$ 53
S2	4.95-6.1	30		25	25	\$ 44
A Grade	12	30	12		50	\$ 37
J Grade	4-10m	20	12		50	\$ 34
Industrial	3.7-8.1	25	50	25	100	\$ 27
Pulp	3.7-8.1	10		200	200	\$ 1

Part 2: Developing Default Parameters

Cooperative members' pre-harvest inventory databases were used to obtain low, medium and high level values for each of the parameters. An assessment (which normally represents a stand) was used in the base unit for this exercise. These calculated parameter values were generated from a very restricted area of the country, so hence the values should only be used as a guide. Due to the confidential nature of pre-harvest inventory data, the author of this report is unable to publish the source of the data.

RESULTS

Part 1: Sensitivity to changes in Parameters

The following results show the impact of changing the parameters over an extreme range. It is important to remember that the forking and sweep models are applied after all the growth and silvicultural modelling has been applied to the crop trees.

FORKING MODEL

Forking Probability

Figure 3 shows that impact of forking probability to the predicted value per hectare. The forking probability is varied from 0 to 1, and given that this probability is applied to the crop trees it is highly unlikely that the forking probability will get close to 1. The loss in value is less than \$1000 per hectare for probability up to 0.3.

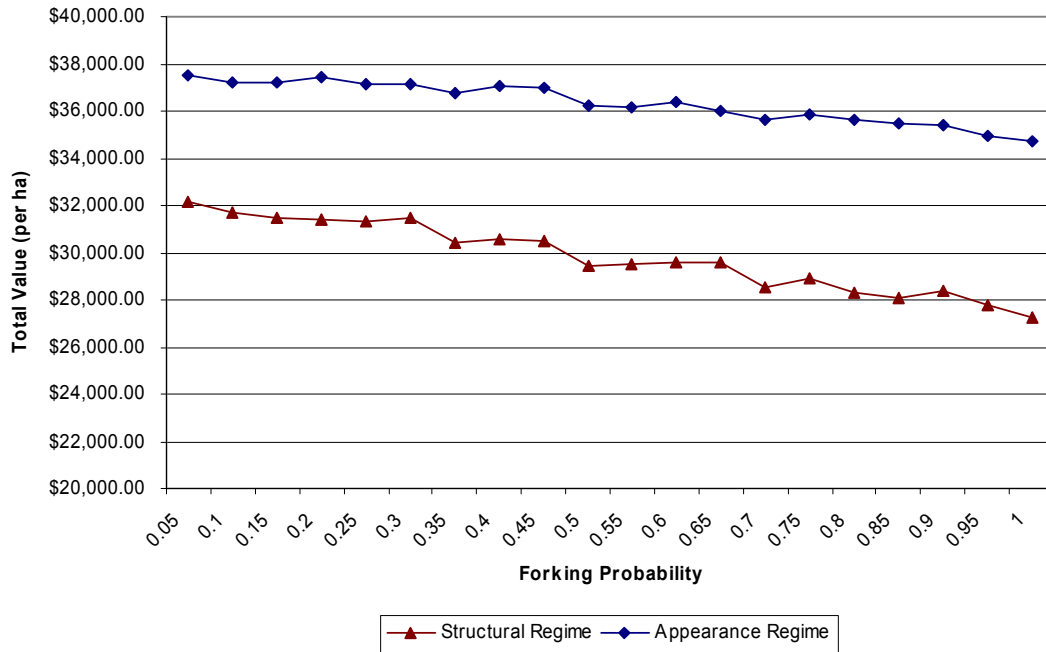


Figure 3. The impact of changes in forking probability on the predicted value.

The log grade mix for the appearance regimes is given in Figure 4. The main trend is that the amount of pulp and industrial grades increases in place of S2 grades. It should be noted that pruned volume is not affected by changes in forking probability, simply because the forking model does not allow forking to occur below the pruned height.

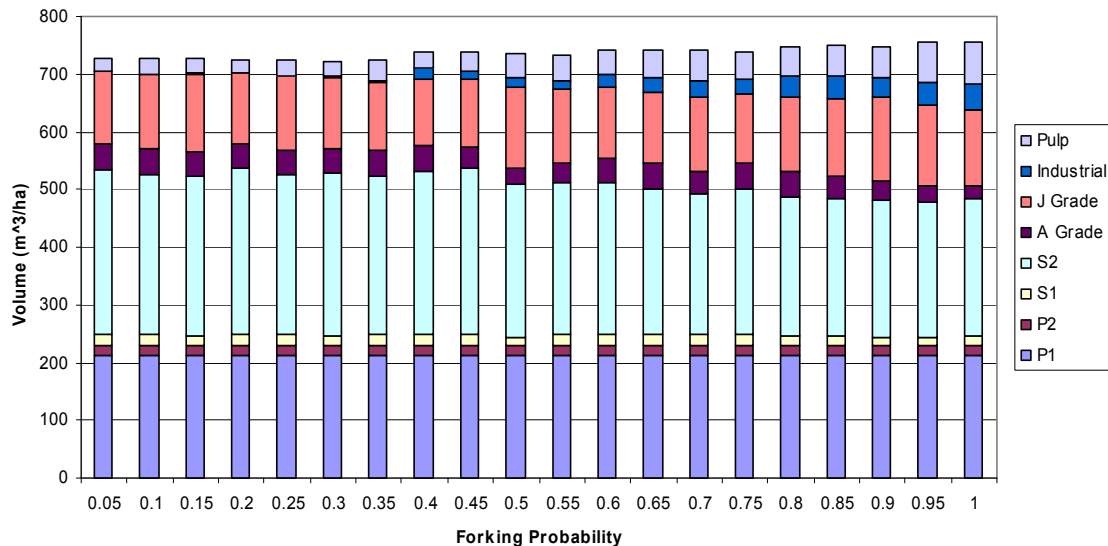


Figure 4. The impact of changes in forking probability on the predicted log grade recovery for the Appearance (“Pattern 1”) Regime.

Number of Leaders

Once a tree is forked, the model then decides the number of forks. It is important to remember that the volume above the fork is the same no matter how many leaders are generated. Figure 5 shows that there is very little impact on the predicted value. The impact of the number of leaders was modelled using a probability of forking of 0.5. The probability of the number of leaders was varied for all of the forked trees having three leaders to just two leaders.

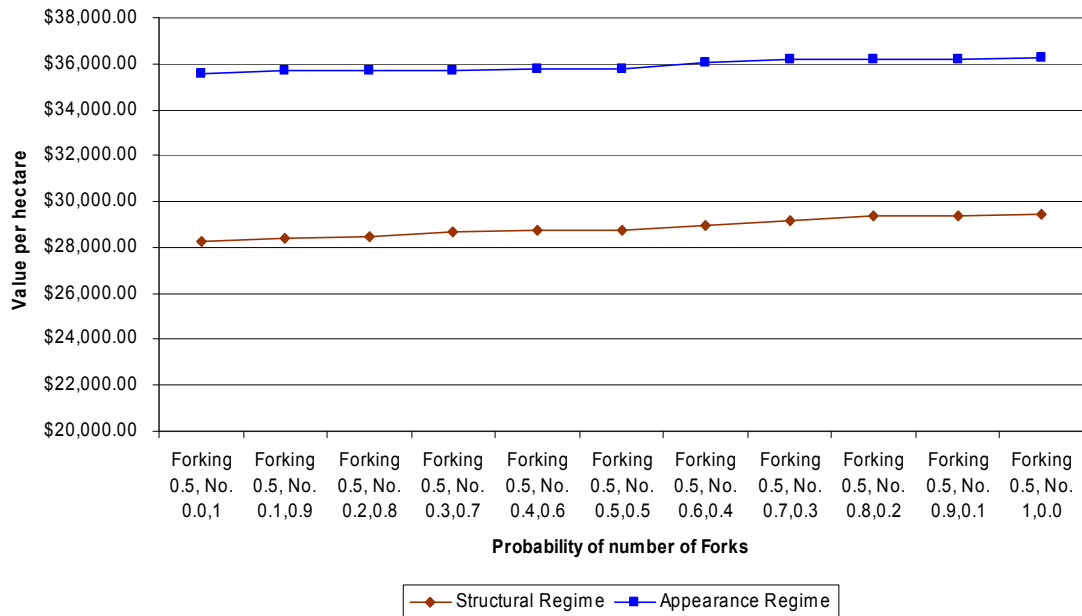


Figure 5. The impact of changes in number of leaders probability on the predicted value assuming a 0.5 probability of forking.

The forking model can model any number of leaders. It is important to remember when entering number of leaders' probability parameter that the probabilities add up to 1. There is no real difference in the product mix for the appearance regime (Figure 6).

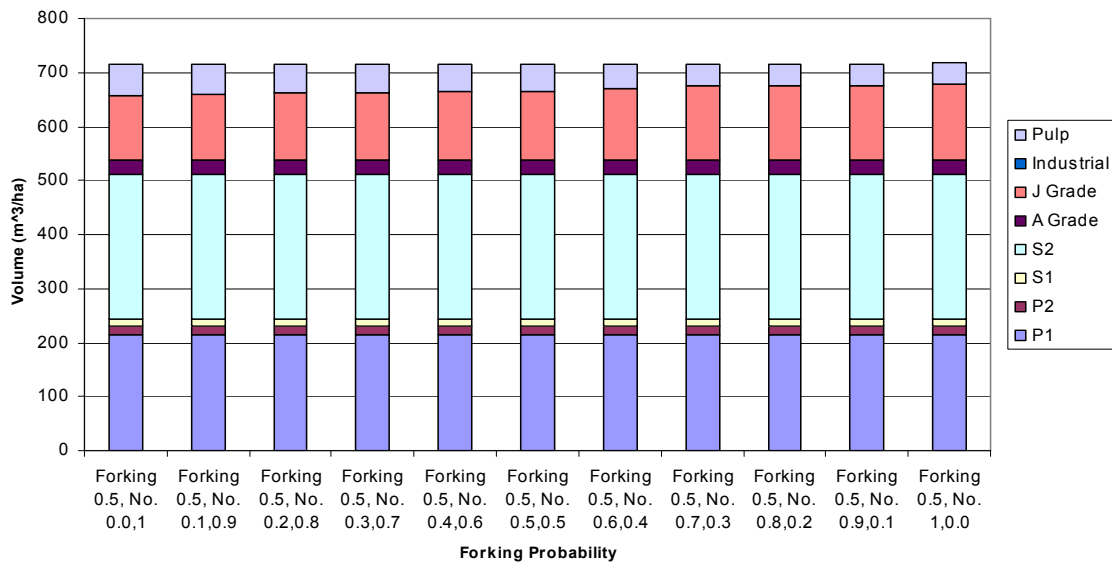


Figure 6. The impact of changes in number of leaders probability on the log grade recovery for the Appearance (“Pattern 1”) Regime assuming a 0.5 probability of forking.

Forking Height

Forking height is modelled as a percentage of the tree height. The parameters needed are the mean and coefficient of variation of the distribution of the forking height that is being modelled. Figure 7 shows the impact of varying the mean percentage of the height at which the forking occurs. The label on the x-axis first shows the percentage of forking (0.5), then the probability of leaders (0.3 and 0.7) and the forking height (HT mean percentage of height, coefficient of variation of percentage height (i.e. HT 30,1)).

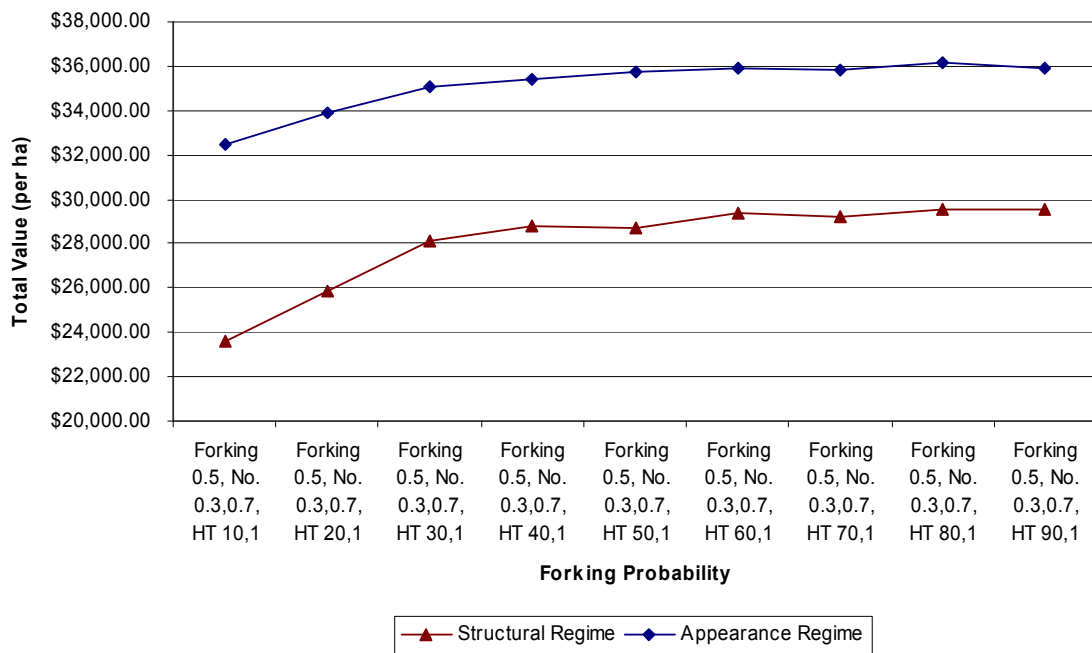


Figure 7. The impact of changing the mean of the forking height distribution on the predicted value. Assuming a 0.5 probability of forking and probabilities of number of leaders of 0.3, 0.7.

As could be expected there is a steep increase in the value as the height of the forking increases until 40%, after that the value stabilises. This is shown in the grade mix for the appearance regime in Figure 8.

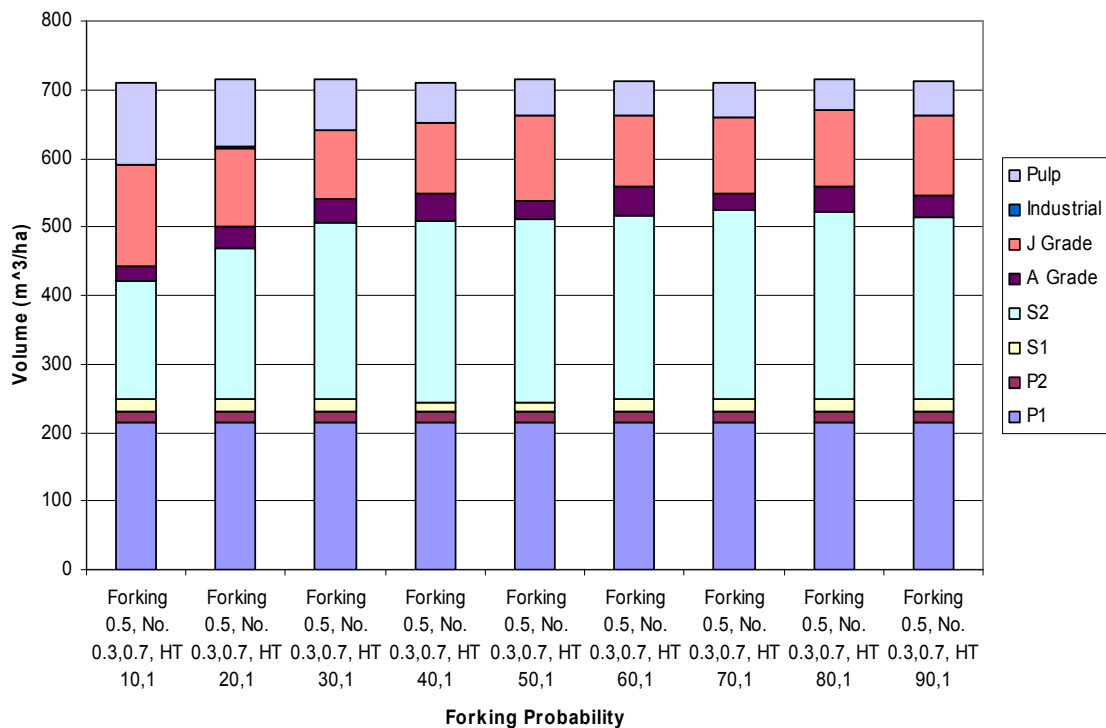


Figure 8. The impact of changing the mean of the forking height distribution on the log grade recovery for the Appearance (“Pattern 1”) Regime. Assuming a 0.5 probability of forking and probabilities of number of leaders of 0.3,0.7.

SWEEP MODEL

The sweep model has in total four parameters, each with a number of variables. Unlike forking the impact of the sweep model are influenced by the level of the sweep constraints in the log grade descriptions.

Number of Sweep Regions

The number of sweep regions parameter is made up of a list of probabilities, each probability represents a number of possible swept regions. For example in Figure 7, six different numbers of sweep regions parameters are modelled. In the first parameter model (0.0, 0.0, 0.25, 0.75) the first probability represents the probability of having 0 swept regions, the next represents the probability of having 1 swept region, and so on.

Figure 9 shows that as the number of the sweep regions decreases the predicted value increases. The impact of the different log product sweep constraints are clearly shown in Figure 9. As gradient in the constraints increases, i.e. from pattern 1 to pattern 2, the impact of the number of sweep regions increases.

Figure 10 shows the log grade mix for the appearance regime using cutting pattern 2. As the number of the sweep region reduces, the high value products with the tighter sweep constraints (i.e. P1 and S2) product volumes increase. This corresponds to the increase in predicted value shown in Figure 9.

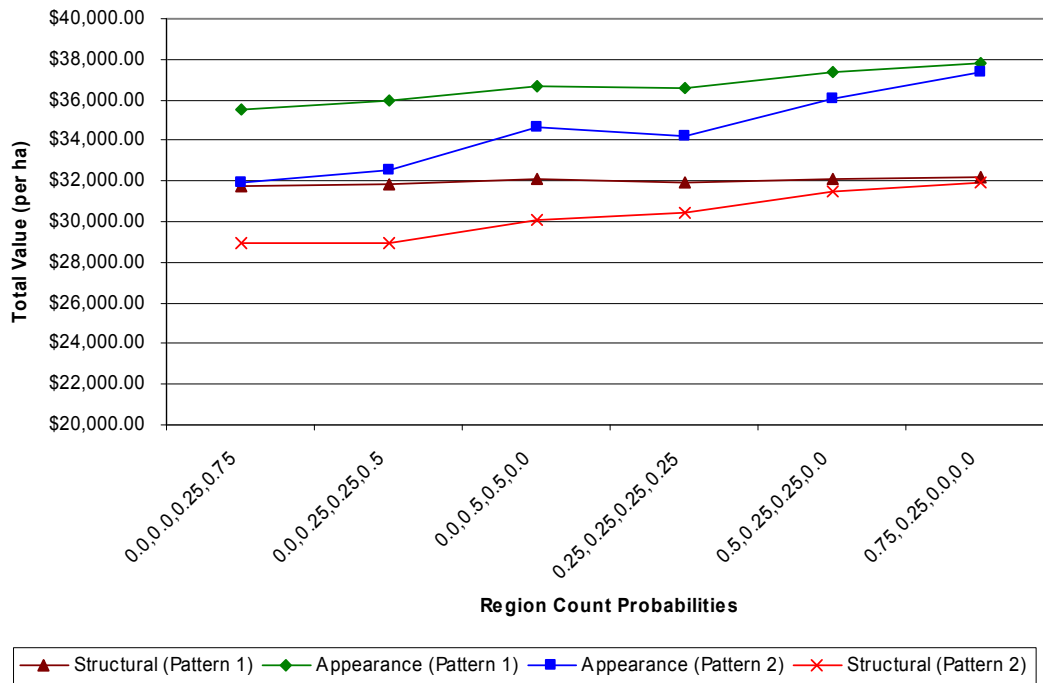


Figure 9. The impact of changing the number of sweep regions on predicted value.

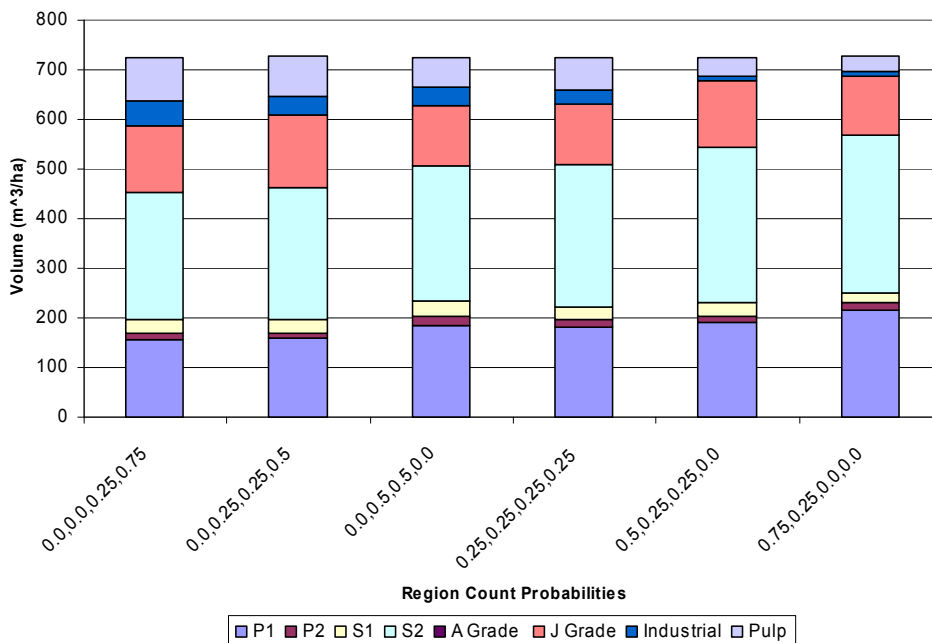


Figure 10. The impact of changing the number of sweep regions on predicted log grade mix of the Appearance Regime (Pattern 2).

Deviation Distribution (Diameter)

The amount of the deviation applied to each sweep region is chosen randomly from a normal distribution with a given mean and standard deviation. These two variables make up the deviation distribution parameter. Figure 11 and 12 show the impact of changing the mean of the deviation distribution on predicted value and log grade mix respectively.

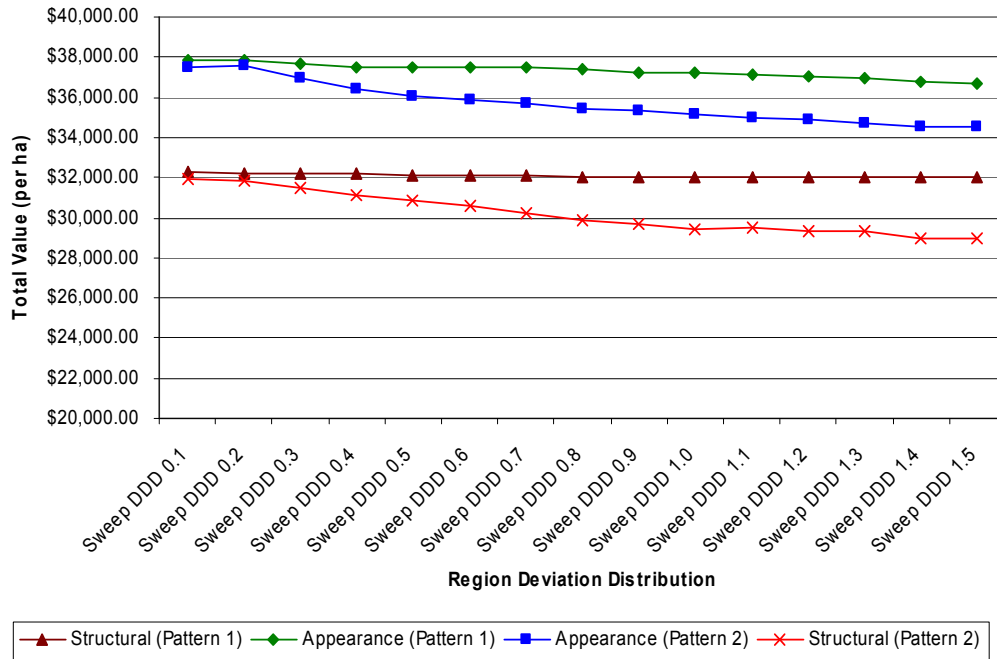


Figure 11. The impact of changing mean of the percentage diameter deviation distribution on predicted value.

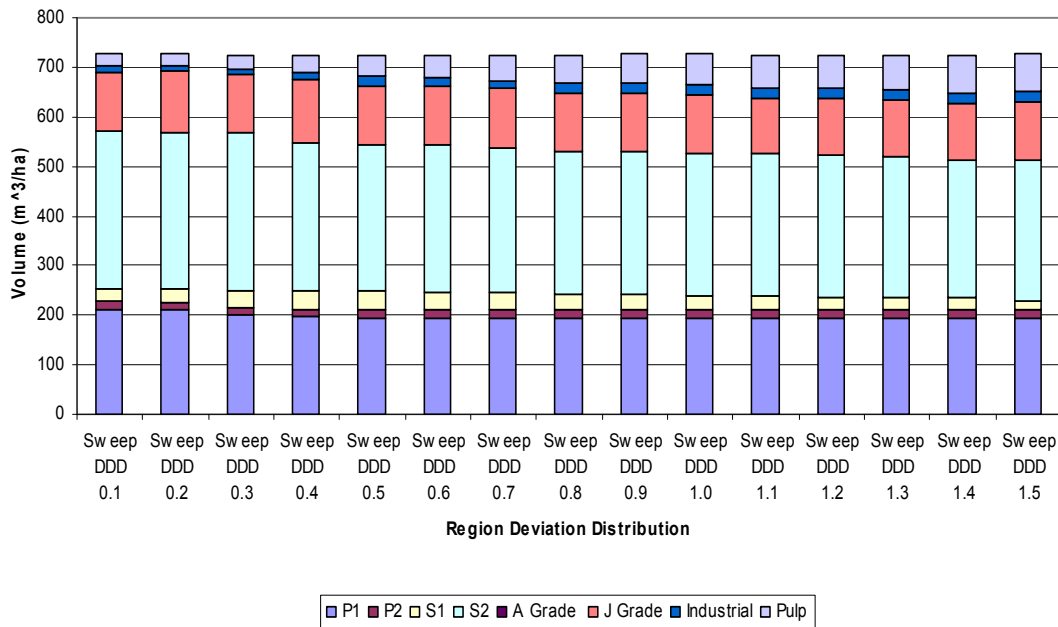


Figure 12. The impact of changing mean of the percentage diameter deviation distribution on predicted value.

Sweep Region Length

Value increases as the sweep region length increases (Figure 13). As the sweep length increases there are more opportunities for cutting straight logs out of the swept section. Under pattern 1 there is very little change in value as the length of the sweep region increases, however for the structural regime using pattern 2 the value increases noticeably between a sweep length of 3 and 5 metres.

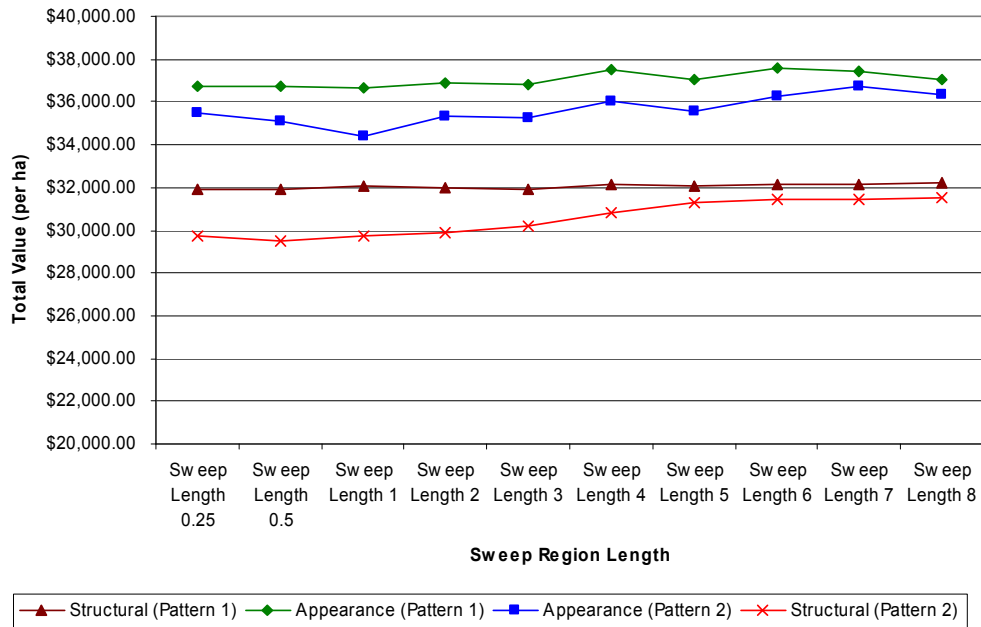


Figure 13. The impact of changing mean of the sweep region length distribution on predicted value.

There is no clear trend in the grade mix (Figure 14) for the appearance regime cut up using pattern 2.

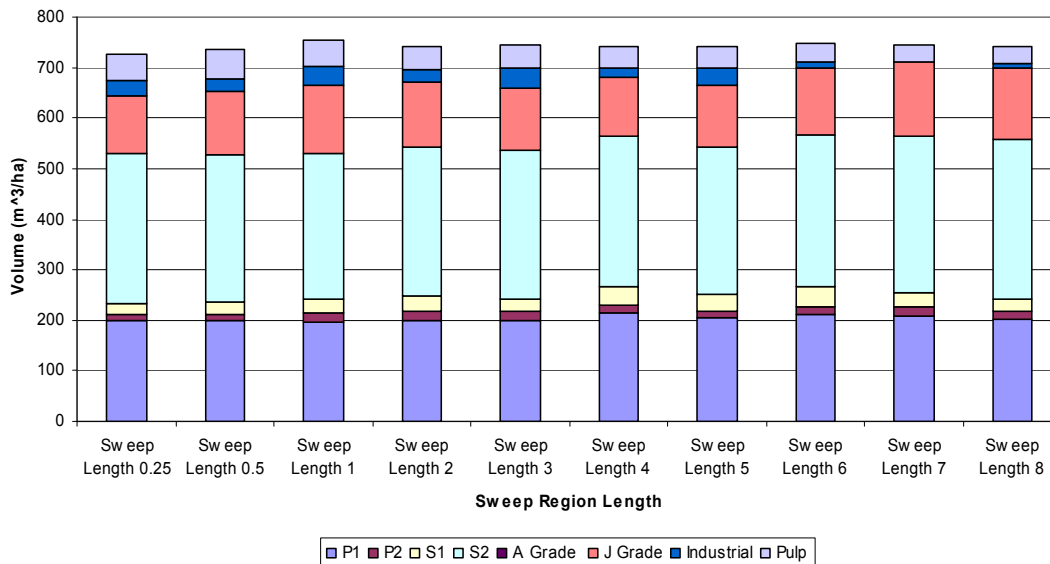


Figure 14. The impact of changing mean of the sweep region length distribution on predicted log mix for the Appearance Regime (Pattern 2).

Sweep Type

Figure 15 shows the impact of some totally random sweep type distributions. The overall impact of the different distributions is not large. Even in the “pattern 2” cases the maximum difference is little more than \$1000 per ha.

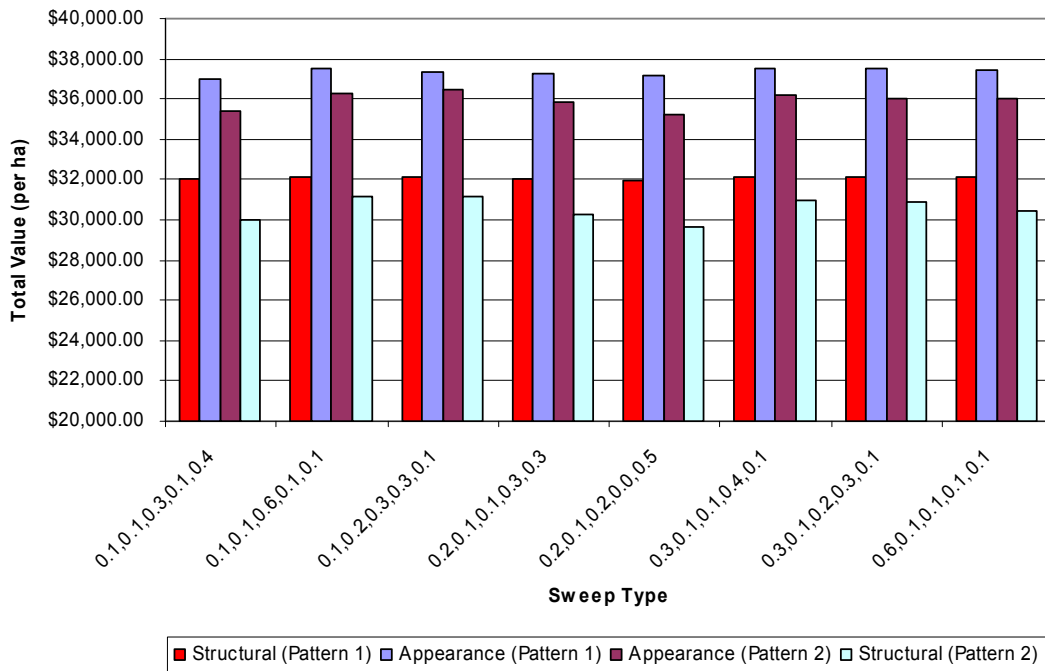


Figure 15. The impact of changing the sweep type on predicted value.

There are only a few small changes in the grade mix for the appearance grade using cutting pattern 2.

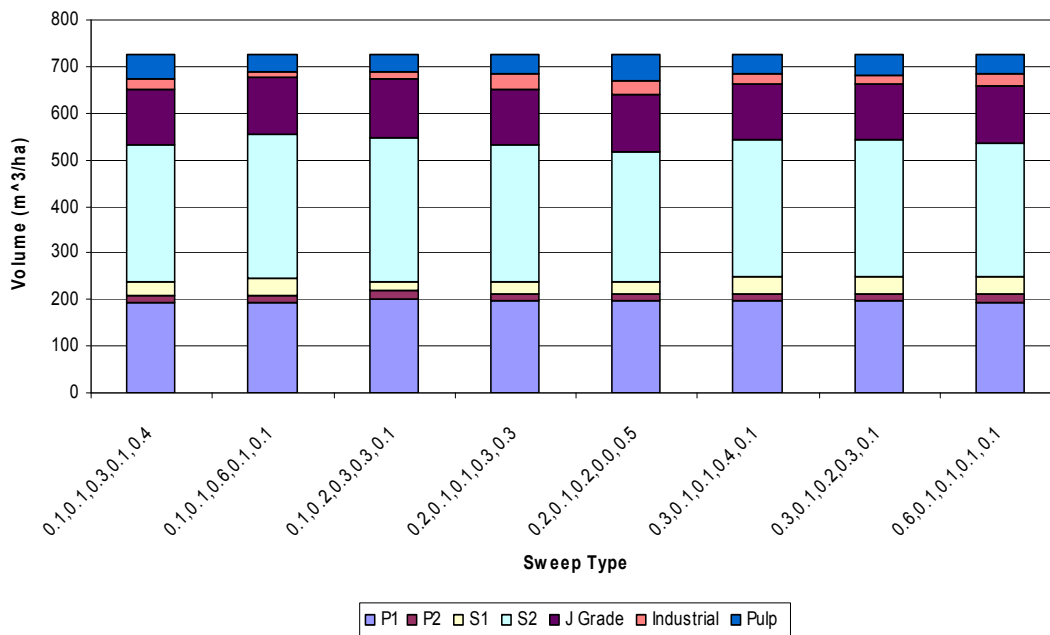


Figure 16. The impact of changing the sweep type on predicted log mix for the Appearance Regime (Pattern 2).

Part 2: Developing Default Parameters

Table 3 shows the low, medium and high values for some of the parameters in the Forecasters sweep and forking model. Remember these were generated from a very small database and only should be used as a guide. For ATLAS Cruiser users there is now a tool available that can extract the data required to calculate these numbers¹.

Table 3. Example Parameters (CAUTION: Please use with care, calculated from a small sample).

	Low	Medium	High
FORKING MODEL			
Probability of Forking	0.09	0.14	0.18
Number of Leaders	See Figure 17		
Height of Forking (mean, coefficient of variation)	23%,0.5	28%,0.6	31%,0.7
SWEEP MODEL			
Region Count Probabilities	See Figure 19		
Region Deviation Distribution (mean, standard deviation)	0.41,0.29	0.44,0.33	0.48,0.37
Region Length Distribution (mean, standard deviation)	3.6,3.4	4.3,4.3	5.10,4.8
Region Type Probabilities	See Figure 18		

For the parameters; Number of Leaders, Region Count Probabilities and Region Type Probabilities it is difficult to summarize using the low, medium and high values, therefore the results for each assessment/inventory has been graphed (Figures 15-17).

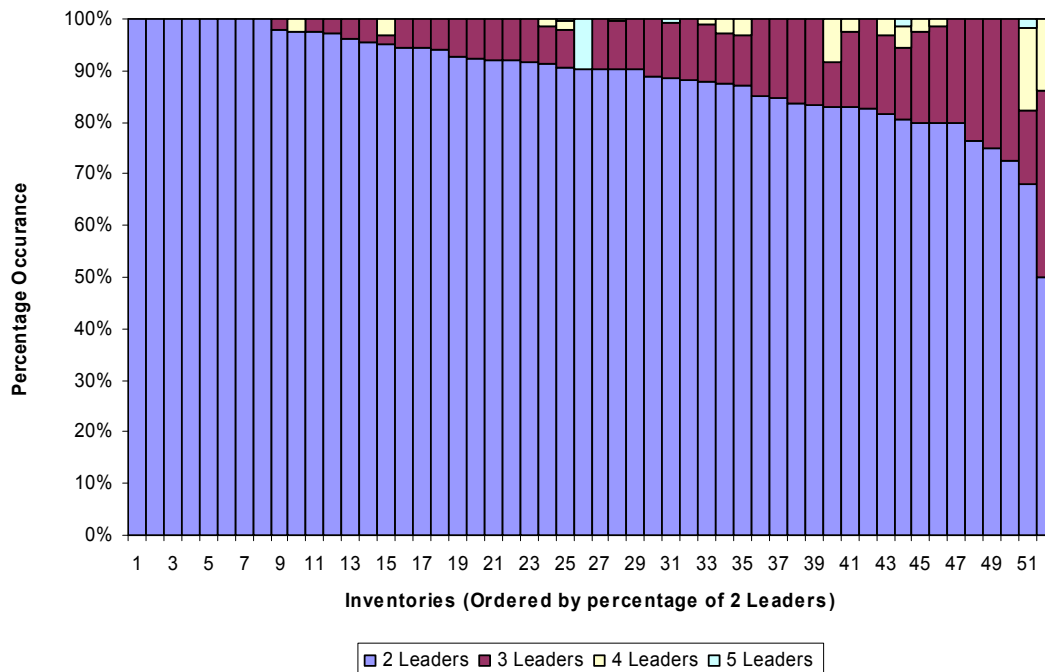


Figure 17. The probability of X number of leaders, if tree is forked.

¹ Please contact the author for further information.

Figure 17 shows that by far the most common number of leaders if a tree is forked is two.

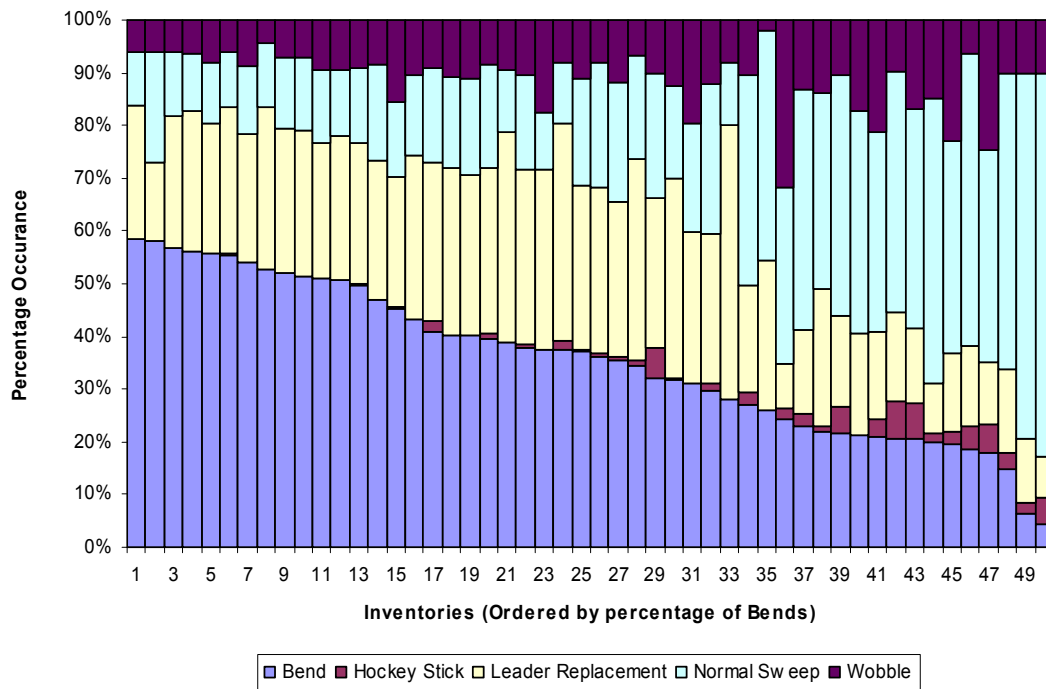


Figure 18. The probability of the different sweep types given a tree is forked.

There is no clear pattern in the type of sweep. Bend, leader replacement and normal sweep are the dominate forms of sweep in this sample of assessments. Hockey stick is rare and wobble is relative constant at about 10% throughout this sample of assessments.

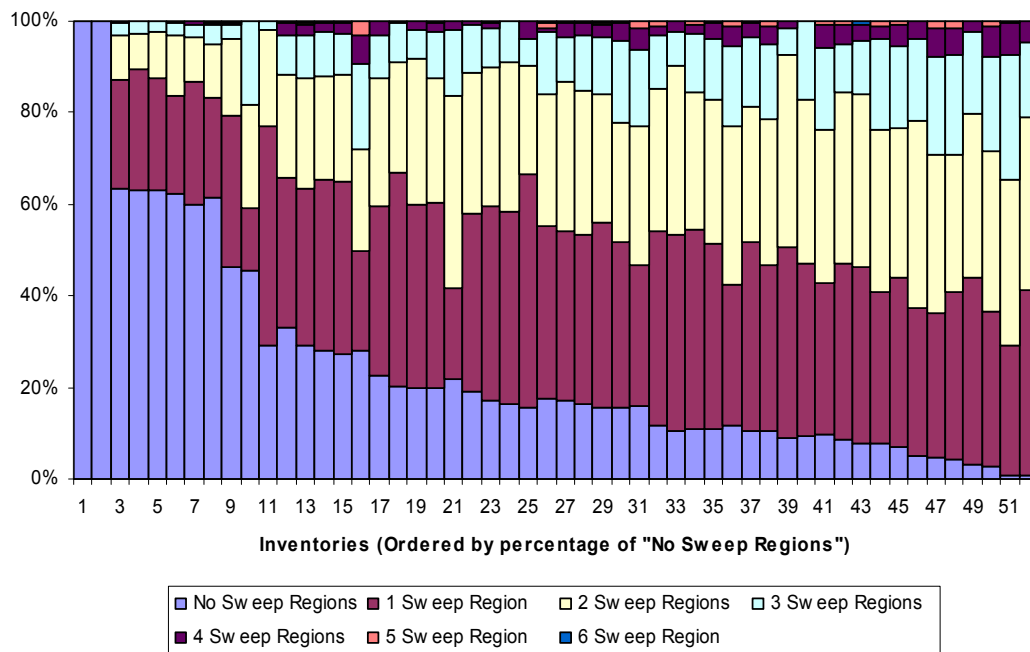


Figure 19. Number of Sweep Regions

The majority of trees sampled within this dataset have less than four sweep sections.

SUMMARY

In part 1 of this project the sensitivity of the prediction was studied over a wide range, in many cases substantially wider than would naturally occur. In part 2, a small sample of pre harvest inventory assessments were used to calculate a set of sweep and forking model parameters. It should be noted the sample of pre harvesting inventory assessment was taken from a small subset of the New Zealand radiata pine and hence should only be used as a guide.

Given the results in both Part 1 and 2 there are clearly some parameters that should be considered more carefully than others when setting up a “Function Set” in ATLAS Forecaster. The results indicated that the forking model parameter; Forking Height and the sweep model parameter; Number of Sweep Regions and Length of Region are more important than the other parameters in terms of predicting value. When dealing with the sweep model it is important to consider that the sweep model’s parameters interact with sweep constraints in the log grade description. Hence if there are large differences in the log grade sweep constraints than one should probably be more careful getting the most realistic parameters.

REFERENCE

Duff, G. 1956. Estimation of Volume of Forking Tress in Exotic Coniferous Stand in New Zealand. Forestry Research Note No. 6. New Zealand Forest Service.