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ABSTRACT

Results from this study allow DOS sampling to be rationalised in two ways. First by relating DOS size to potential log value. This allows the precision of DOS sampling (or confidence interval) to be set in accordance with its financial impact. Secondly alternative strategies for sampling DOS that may reduce the number of measurements needed are examined. The trade off in terms of confidence interval for differing numbers of trees per plot and plots per compartment is given. A sampling method of using a DOS/DBH ratio clearly offers advantages in reducing the number of DOS measurements required for a given level of precision.

The importance of sweep in pruned logs has been emphasised by relating levels of juvenile sweep to final log value. Three methods of measuring juvenile sweep in the field were tested. Using a straight height pole and categorising sweep into classes relative to stem diameter was found to be the most suitable.

MANAGEMENT OF IMPROVED RADIATA BREEDS COOPERATIVE

EXECUTIVE SUMMARY

SAMPLING DOS AND SWEEP AT THE TIME OF PRUNING

G.G. WEST, M.O. KIMBERLEY

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SAMPLING DOS AND SWEEP AT THE TIME OF PRUNING

INTRODUCTION

Defect core size and final log diameter are the two major factors that determine pruned log quality in radiata pine. As pruned stands grow to maturity the size and shape of the defect cores becomes concealed within the tree. At stand maturity good records of the defect core will be of considerable benefit to realising the intrinsic value of the pruned logs.

There are two aspects to defect core measurement at the time of pruning. One aspect is obtaining a measurement of DOS with a known precision at minimum cost. Limits of precision (confidence limits or probable limits of error, PLE) have been set by most forest growers measuring DOS. However most of these limits have seen set arbitrarily and are not related to the significance of DOS in terms of log value. Sampling DOS after pruning is reasonably expensive and time consuming for supervisors. Sampling techniques that reduce the number of measurements needed, would obviously result in cost savings.

The second aspect of defect core measurement is assessing stand sweep or sinuosity of the pruned section. Quantification of sweep at the time of pruning has generally been difficult to measure and hence often not recorded. However without this information records of DOS will only describe part of the defect core as it effects pruned log values.

OBJECTIVES

1. Examine the relationship of DOS to potential log value as predicted by SAWMOD and derive confidence limits for DOS as it affects log values.
2. Examine existing data on DOS variability to derive minimum sampling numbers by trees per plot and plot numbers per stratum or compartment.
3. Examine alternative sampling strategies for DOS to lower costs, but maintain the same precision.
4. Examine the relationship of juvenile sweep to potential log value as predicted by SAWMOD.
5. Examine and develop methods of measuring sweep in pruned stands that would add to the DOS records with a known precision but at a minimum cost.

1. EFFECT OF DOS ON LOG VALUE

To derive the relationship between DOS and potential log value a matrix of pruned log qualities was evaluated using program SAWMOD (Whiteside and McGregor, 1987). A range of DOS sizes was selected (130-270 mm) that covered most sites and pruning schedules in New Zealand. To allow for branch occlusion and a small amount of sweep, 70 mm was added to all DOS's to give a defect core size. Log small end diameter (s.e.d.) was set at 400 mm for one series and 500 mm for another. The matrix of pruned log variables is given in Appendix 1. A scenario of sawmill factors was adopted from the options in program SAWMOD. The sawmill scenario is given in Appendix 2. Two timber price lists were tested: 1) 1985 Domestic price list; 2) 1985 Export price list.

Figure 1 gives the results of the SAWMOD predictions. Both timber price list and log s.e.d. are shown to influence the level of the potential log value but not the relationship with DOS. The rate of change with DOS (or slope of the line) is similar for all four examples tested. If the rate of change/m^3 is taken as an average of \$3.5/one centimetre of DOS then confidence limits for DOS can be expressed in terms of value changes in pruned log value. These are given in Table 1.

Figure 1

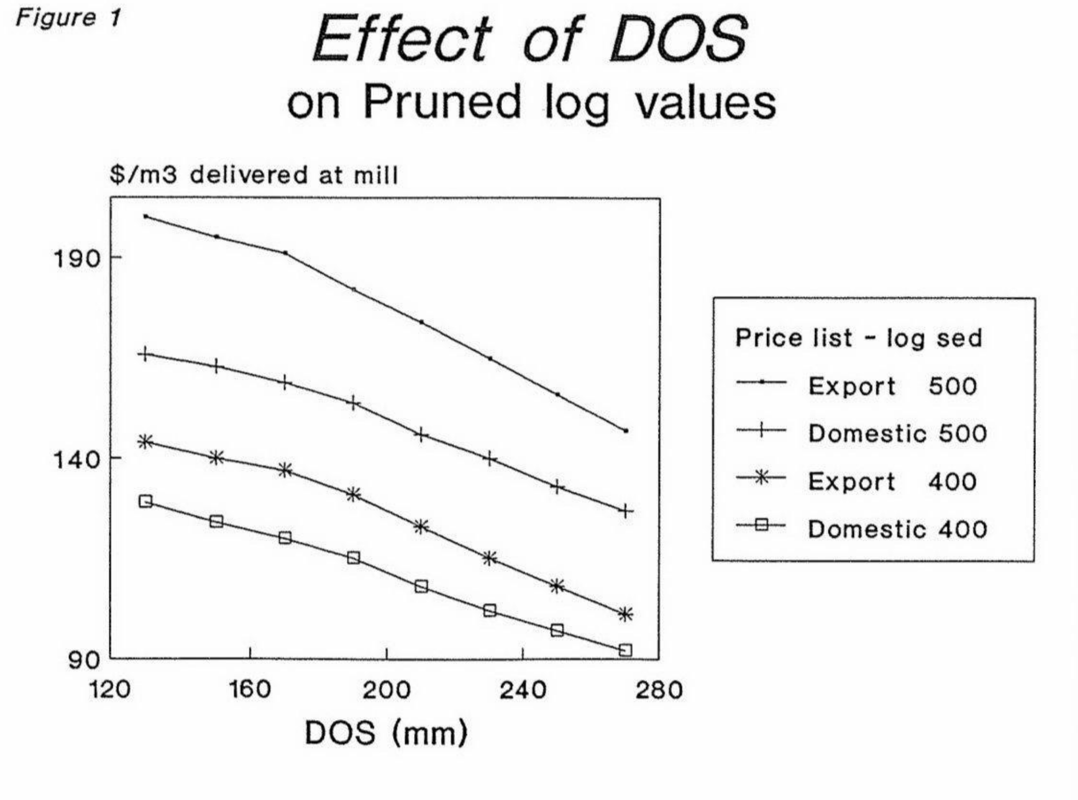


TABLE 1 - Effect of DOS on pruned log value

Change in DOS	Change in pruned log value ($\$/m^3$)
0.5	1.75
1.0	3.50
1.5	5.25
2.0	7.00
2.5	8.75
3.0	10.50

2. DOS SAMPLING NUMBERS

To examine the variability of DOS, data sets from a previous study (Knowles *et al.* 1987) that had at least five plots sampling the same compartment were selected. Two new data sets (Tohorakuri and Waitakere), recently collected by forest companies were added. Table 2 gives a description of the data sets. Standard deviation for DOS was calculation for within plot variation and between plot variation.

Using estimates of high, medium, and low variability (derived from the DOS data sets), confidence intervals were calculated for a matrix involving numbers of trees per plot and numbers of plots per compartment. Table 3 gives the matrix of confidence intervals.

TABLE 2 - DOS data details

Forest	No. plots	Plot size (ha)	Lift	No. trees in plot	DOS Standard deviation Within plot (cm)	Between plot (cm)
Eyrewell	10	0.05	Med.	17-20	3.0	1.4
Ngaumu	5	0.05	Low	26-39	2.5	1.9
	6	0.05	Med.	28-40	3.3	1.3
	6	0.05	High	27-43	2.6	2.9
Waitarere	9	0.05	Med.	13-14	2.7	1.4
	11	0.05	High	12-14	2.3	1.0
Mohaka	10	0.04	High	7-10	3.0	1.4
	7	0.04	Low	27-30	2.2	1.0
Tohorakuri	9	0.06	Low	5-6	2.7	1.3
Waitakere	9	0.06	High	5-12	3.2	1.0
	10	0.06	High	4-17	2.7	0.7

No. trees = 1164

TABLE 3 - 95% confidence intervals for sampling DOS (cm)

No. trees per plot	Number of plots							
	2	3	5	7	10	15	20	30
LOW VARIABILITY: (STANDARD DEVIATION BETWEEN PLOTS = 0.8, WITHIN PLOTS = 2.3)								
1	21.2	5.8	2.9	2.2	1.7	1.3	1.1	.9
2	15.3	4.2	2.1	1.6	1.2	.9	.8	.6
3	12.8	3.5	1.8	1.3	1.0	.8	.7	.5
5	10.3	2.9	1.4	1.1	.8	.6	.5	.4
7	9.1	2.5	1.3	.9	.7	.6	.5	.4
10	8.0	2.2	1.1	.8	.6	.5	.4	.3
15	7.0	1.9	1.0	.7	.6	.4	.4	.3
20	6.5	1.8	.9	.7	.5	.4	.3	.3
MEDIUM VARIABILITY: (STANDARD DEVIATION BETWEEN PLOTS = 1.4, WITHIN PLOTS = 2.6)								
1	25.8	7.1	3.6	2.7	2.1	1.6	1.3	1.1
2	19.8	5.5	2.7	2.0	1.6	1.2	1.0	.8
3	17.4	4.8	2.4	1.8	1.4	1.1	.9	.7
5	15.1	4.2	2.1	1.6	1.2	.9	.8	.6
7	14.0	3.9	1.9	1.4	1.1	.9	.7	.6
10	13.2	3.6	1.8	1.4	1.0	.8	.7	.5
15	12.5	3.4	1.7	1.3	1.0	.8	.6	.5
20	12.1	3.3	1.7	1.2	1.0	.7	.6	.5
HIGH VARIABILITY: (STANDARD DEVIATION BETWEEN PLOTS = 2.0, WITHIN PLOTS = 3.1)								
1	32.3	8.9	4.5	3.3	2.6	2.0	1.7	1.3
2	25.6	7.1	3.5	2.6	2.0	1.6	1.3	1.1
3	22.9	6.3	3.2	2.4	1.8	1.4	1.2	1.0
5	20.6	5.7	2.8	2.1	1.6	1.3	1.1	.9
7	19.4	5.4	2.7	2.0	1.5	1.2	1.0	.8
10	18.6	5.1	2.6	1.9	1.5	1.1	1.0	.8
15	17.9	4.9	2.5	1.8	1.4	1.1	.9	.7
20	17.4	4.8	2.4	1.8	1.4	1.1	.9	.7

3. SAMPLING STRATEGIES

As an alternative to direct measurement of DOS other strategies that may reduce the cost of sampling were examined. As DBH and other variables are more easily measured than DOS, estimating DOS from other variables may have advantages.

The methods tested were:

1. Direct measurement (i.e. sampling DOS directly);

2. A ratio estimator using DOS/DBH;

3. Regression estimators of DOS using
   (a) DBH
   (b) DBH and DOS height
   (c) DBH, DOS Ht, and Maximum Branch
   (d) DADOS
   (3) DADOS and Maximum Branch;

$$\text{where} \quad \text{DADOS} = \text{DBH} \frac{\text{Ht - DOS Ht}}{\text{Ht - 1.4}}$$

The ratio and regression methods require sampling DBH and other variables from a larger sample of trees, and use the relationships between these variables and a small sample of DOS to improve the estimate of DOS. The ratio method can be applied where more trees are measured for DBH than DOS within each plot and/or where extra DBH only plots are measured.

To test the methods, the Monte Carlo technique of randomly sampling from the data base was used. Low and high variability data, from the Waitarere high lift and Ngaumu medium lift, respectively, were used. The procedure simulated the sampling of 10 plots, with 10 trees measured for DBH and two of these trees for DOS within each plot. Confidence intervals for each method are given in Table 4. Compared to direct measurement, the ratio method gives a considerable improvement in precision. The more complicated regression methods gave only a small improvement over this and only on the high variability site.

These results indicate that compared to direct measurement, the ratio method will reduce the number of samples needed to achieve the same level of precision. Where extra plots are used to sample only DBH, these may be used to further reduce the DOS sample. It is possible, using the variances and correlations in the data, to calculate the precision of ratio estimators for a variety of sampling strategies. Table 5 gives the sample sizes needed under a range of scenarios of DOS trees/plot, DBH trees/plot, and extra plots of DBH only, to achieve a confidence interval of 1.5 cm on a medium variability site. This table shows that using this method will clearly reduce the number of plots needed, e.g. with 2 DOS trees per plot and 2 DBH trees/plot the number of plots required is 11, (i.e. the same as direct sampling), but if 5 trees/plot are measured for DBH this reduces the number of plots required to 9. If 8 extra plots are measured for DBH only (e.g. as in an assessment of thinning) then this data can be used to reduce the number of plots required to 8. The formulas for calculating ratio estimators are given in Appendix 3.

TABLE 4 - Comparison of DOS estimation methods

Estimation method	Low variability site		High variability site	
	Mean	CI	Mean	CI
Direct	17.1	1.24	23.1	1.83
Ratio	17.2	1.07	23.1	1.43
Regression 1	17.2	1.10	23.0	1.41
Regression 2	17.2	1.15	23.0	1.37
Regression 3	17.2	1.20	23.0	1.44
Regression 4	17.2	1.20	23.0	1.41
Regression 5	17.2	1.22	23.1	1.47

10 plots
2 DOS trees
10 DBH trees

CI = 95% Confidence Interval

DISCUSSION AND CONCLUSIONS

Using the results presented here DOS sampling can be rationalised in terms of a desirable level of precision and plot numbers using alternative strategies for field sampling. Confidence limits can be set at a level that reflects a practical change in log value. The number of trees per plot and plots per stratum can be selected for three levels of variability.

TABLE 5 - Ratio sampling: Sample sizes required for a 95% Confidence Interval of 1.5 cm in a stand with medium variability

DOS trees/plot	DBH trees/plot	Extra plots of DBH only	DOS/DBH plots
1	1	0 13	17* 13
	2	0 11	14 11
	5	0 11	13 11
	10	0 11	12 11
	20	0 10	12 10
2	2	0 9	11* 9
	5	0 8	9 8
	10	0 8	9 8
	20	0 8	8 8
5	5	0 6	8* 6
	10	0 5	6 5
	20	0 5	6 5
10	10	0 6	7* 6
	20	0 5	6 5
20	20	0 5	6* 5

*this is the same as direct sampling

If the cost per plot is known, a manager can choose the best combination of numbers of trees per plot and numbers of plots per compartment that minimise sampling costs.

The DOS/DBH ratio method clearly offers advantages in reducing the number of DOS measurements. This is particularly where DBH is recorded for other purposes and where direct measurements of DOS in the second and third lifts are more difficult.

4. EFFECT OF SWEEP ON LOG VALUE

To derive the relationship between juvenile sweep (at the time of high pruning) and potential log value, a matrix of pruned log qualities were evaluated using program SAWMOD. A range of juvenile sweep values were selected (0-160 mm) and these were converted to mature log sweep values using a relationship derived from sawing study data (J. Tombleson and N. Woods pers. comm.) which relates deviation in pith to outside sweep deviation in mature logs. Prediction of defect core from DOS also included the effect of sweep as given in the regressions by Gosnell 1987. The conversion of juvenile sweep to mature sweep and defect core is given in Table 6. Two sizes of log s.e.d. (400 mm and 500 mm) and DOS (170 mm and 250 mm) were included in the matrix of pruned log variables (Appendix 4).

TABLE 6 - Effect of juvenile sweep on final log sweep and defect core for 5.4 m log length

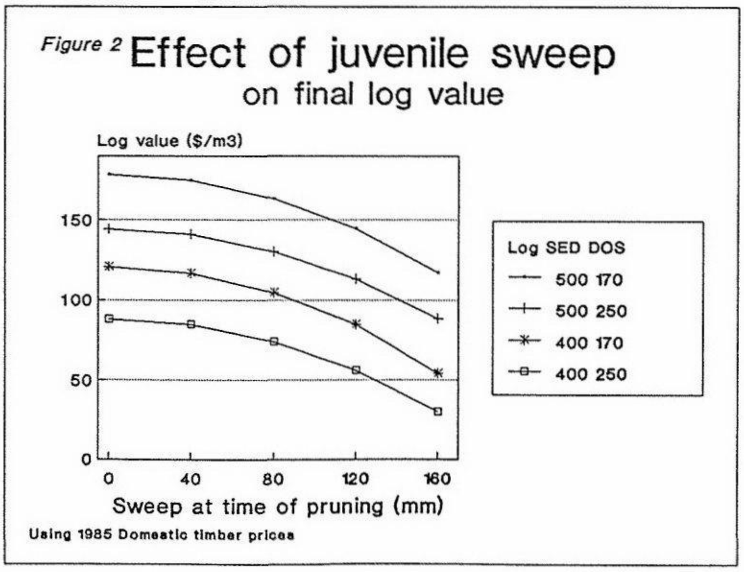
Juvenile sweep (mm ab)	Juvenile sweep (mm/m)	Final sweep (mm ab)	Final sweep (mm/m)	Defect core 170 DOS 40 MAXB	Defect core 250 DOS 80 MAXB
0	0	0	0	252	341
40	7.4	28.6	5.3	255	344
80	14.8	56.2	10.4	262	351
120	22.2	83.2	15.4	273	362
160	29.6	110.7	20.5	289	378

ab = absolute sweep for 5.4 m, MAXB = Maximum branch in DOS whorl

The scenario of sawmill factors is the same as given for the exercise relating DOS to log value (Appendix 2). Figure 2 gives the results of the SAWMOD predictions using the domestic timber price list. Results for the export timber price list were found to be very much the same as the domestic price list. Differences between log s.e.d. and DOS combinations were found to effect the level of the log values but not the relationship with sweep. As this relationship is not linear no simple rule of thumb on the change in sweep can be calculated. Table 7 gives the change in log value with the levels of sweep tested. For a tree with a stem diameter of 16 cm at the point of maximum sweep, 40 mm is equivalent to $\frac{1}{4}$ diameter and 80 cm is equivalent to $\frac{1}{2}$ diameter sweep categories.

TABLE 7 - Change in pruned log value due to juvenile sweep

Juvenile sweep	Change in pruned log value ($\$/m^3$)
0	0
40 ($\frac{1}{4}$D)	-3.7
80 ($\frac{1}{2}$D)	-14.8
120	-33.3
160	-60.5



5. MEASURING SWEEP

Measurement of sweep in young stands at the time of pruning has generally been found difficult. Previous attempts to develop methods of measuring sweep (Grallelis and Klomp 1982) generally resulted in sophisticated and time-consuming techniques designed for mature trees. What is needed for young stands is a method that can be easily carried out during normal quality control sampling. An objective of recording and sampling sweep is more likely to be one of being able to identify stands at maturity with very enlarged defect cores due to sweep than precisely recording a stand parameter. Unless the technique is simple and effective it will not be adopted by field staff. Discussions with industry revealed that on some forests a method of assessing sweep with a 4 m height pole is already practiced.

METHODS

Sweep can be measured in two ways; on the edge or silhouette of the tree - known as the edge-to-edge method, or from mid-diameter to mid-diameter - known as the centre-to-centre method. For young trees there is little difference between the two methods. This study will use both methods as required by the measuring instrument.

Three instruments were chosen for measuring sweep:

1. Harp

This instrument was developed by J. Beers and I. McKinley of FRI and consists of a 40 cm plastic frame that holds nylon strings at set distances apart. The instrument is held a preset distance from the eye of the operator by a string loop that passes behind the operator's head. When the operator is at a preset distance from the tree, sweep is measured between the harp strings. Sweep is measured in 5 cm classes (0-5, 5-10, >10 cm) on the outside edge of the tree.

2. Pole

This method is the most simple, involving the sweep to be estimated by holding a 6 m height pole against the tree. One side of the pole is positioned to give a straight line from mid-diameter at stump height (0.3 m) to mid-diameter at 5.8 height. Sweep is estimated relative to stem diameter at the height of maximum sweep. For this study a Hastings telescopic fibreglass height pole was used. Three sweep classes are used: 0-0.25 diameter, 0.25-0.50 diameter, >0.50 diameter.

3. S-gauge

This is a hand-held gauge that combined the concepts used in both the Harp and Pole methods. A 40 cm plastic frame is used to hold nylon strings similar to the harp. The central two strings are positioned to give both sides of a tapered form i.e. the outside edge of a straight sided juvenile butt log.

Additional strings outside of the central two are placed at one quarter and one half the distance between the central two strings. By holding the gauge in front of the operator's eye so that the tree fills the gap between the central two strings, sweep could be estimated relative to diameter by the other strings. Sweep is assessed in classes of 0-0.25 diameter, 0.25-0.50 diameter, >0.50 diameter.

FIELD TESTING

After preliminary field checking of instruments and minor adjustments, a field test was set up in Compartment 251 Kaingaroa Forest. This stand had just been third lift pruned to 6 m. Thirty trees were selected to cover the range of sweep present. Each tree was measured for DBH, height and pruned height. Sweep in the 0.3 m to 5.8 m zone was then measured using a 20 x 70 mm aluminium straight edge. The sweep was measured on the outside of the tree i.e. edge to edge method. Height that maximum sweep occurred was measured and side that sweep was measured on was marked with paint.

Three operators then used each of the three instruments to measure sweep independently on the 30 trees. Each tree was measured from the same side by using the paint mark as a reference point.

RESULTS

Results of the initial measurement are given in Table 8. Mean sweep was found to be 6.2 cm at 3 m height. As indicated in Figure 3 sweep measured was quite varied (this was due to a deliberate sampling selection) and mainly occurred between 2 and 4 m height. Analysis of the accuracy of the three sweep measuring instruments was undertaken in two ways. First using absolute sweep as measured by the straight edge and Harp and secondly using diameter related sweep classes as measured by the Pole and S-Gauge.

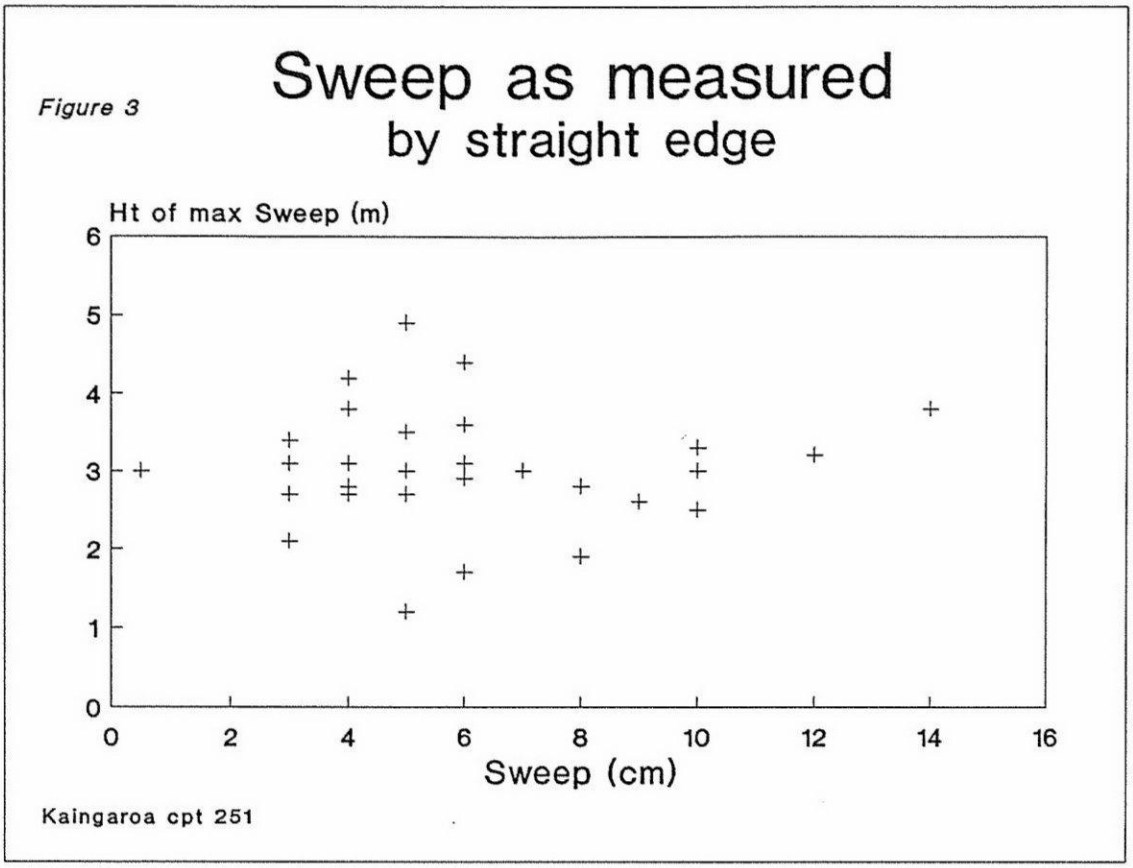


TABLE 8 - Stand measurements : Kaingaroa Cpt 251

	Mean	Std. deviation
Height (m)	11.2	0.8
DBH (cm)	19.2	1.9
Pruned Ht (m)	6.4	0.2
Sweep (cm)	6.2	3.1
Ht of sweep	3.0	0.8

Sample number = 30

ABSOLUTE SWEEP

Using a simple taper function of DBH/Ht - 1.4, measurements of sweep in diameter terms (half diameter etc.) were converted into absolute sweep. As sweep had been recorded in classes (e.g. 5-10 cm) the centre of the class was taken as an absolute value. Although some methods measured sweep using the centre to centre method and others used the edge to edge method, it was assumed that on such young trees this made no difference to the results. Sweep as measured by each method and operator is given in Table 9. The overall mean sweep measurement indicates the Harp to be slightly more accurate than the other two methods. However the Pole was found to be a little less variable between operators with the S-gauge consistently underestimating sweep. There is a noticeable bias with operator; with operator 1 consistently over estimating sweep and operator 3 consistently under estimating sweep.

TABLE 9 - Sweep by measurement method and operator (cm)

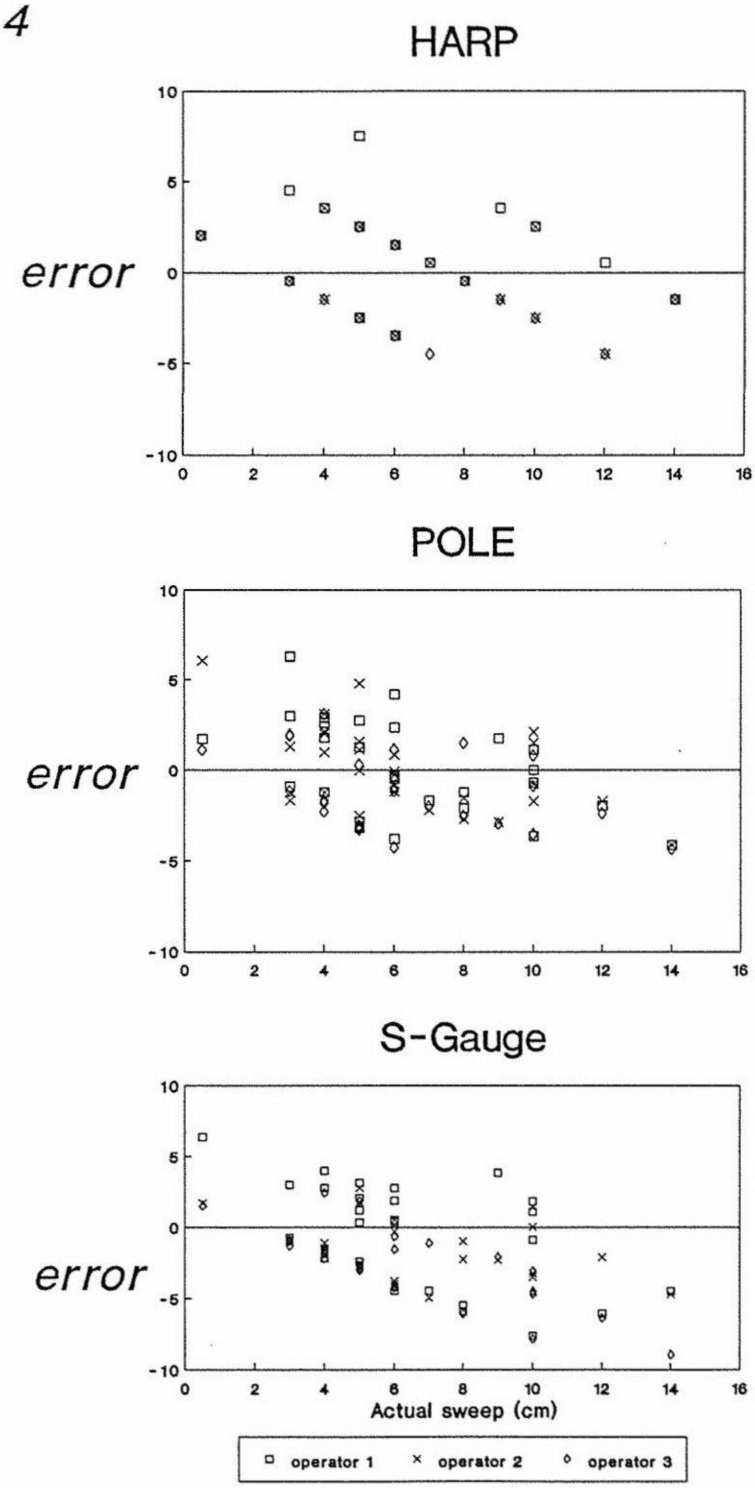
	OPERATOR			
	1	2	3	Mean
Harp	7.8	5.3	4.8	6.0
Pole	6.5	6.2	4.8	5.8
S-Gauge	5.7	4.6	3.4	4.6
Mean	6.7	5.4	4.3	

NB Actual sweep measured with a straight edge was 6.2 cm

To examine the performance of each method relative to the degree of sweep, the error in measurement was calculated (i.e. compared to the straight edge). Figure 4 gives the results of error for each method. These results indicate for all methods a clear trend of overestimating sweep on trees with less than 4 cm sweep and underestimating on trees with over 10 cm sweep.

Error in sweep measurement

Figure 4



This trend is largely due to the broad sweep classes adopted in the study. Trees that were near straight were given the smallest class (0-5 cm or 0-$\frac{1}{4}$ diameter) and in absolute terms were given a sweep level more than that equal to the middle of the class. Trees with a lot of sweep were assessed as the largest class (>10 cm or >$\frac{1}{2}$ diameter) and in absolute terms were assumed to be half a class greater than this. Clearly some trees were much more than this and were under estimated.

SWEEP CLASSES

Using the taper function given above measurements of absolute sweep measured by the straight edge and Harp were converted to diameter-related sweep classes. Figure 5 compares the results of each instrument for all operators with the actual sweep as measured by the straight edge.

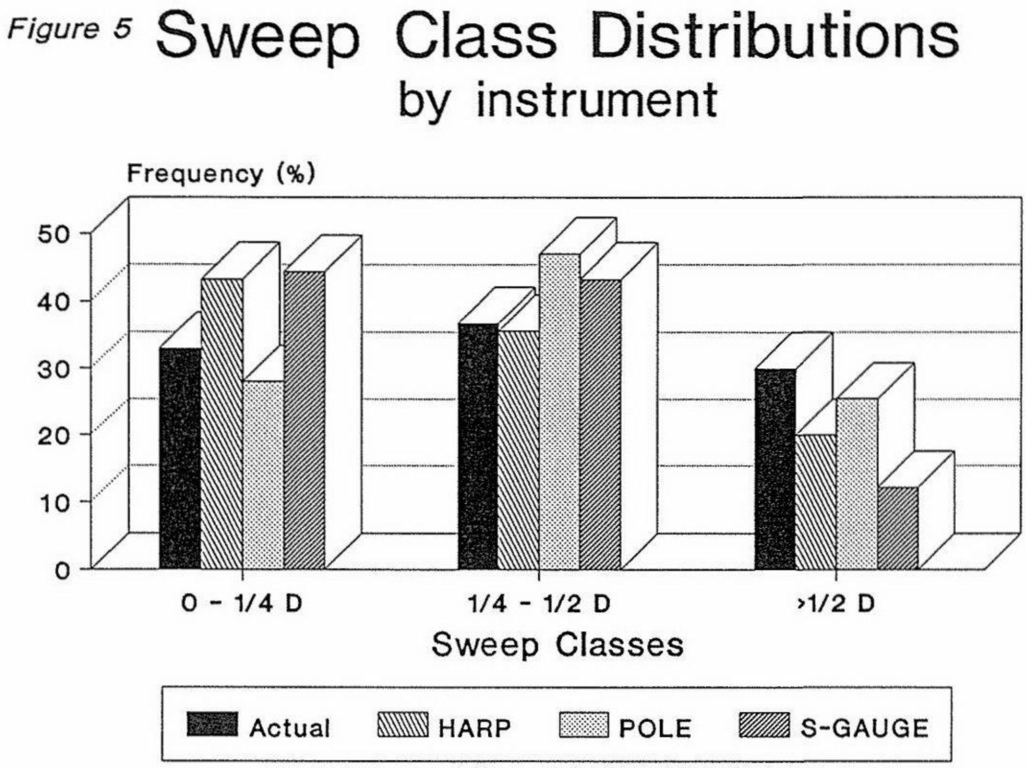
Both the Pole and Harp instrument are shown to be reasonably accurate at differentiating trees into the three categories. The S-Gauge appears to be biased towards over estimating the lower sweep classes.

Figure 6 gives results that compare operators over all three instruments. Clearly each operator shows some bias in their assessment of sweep. Operator 1 tended to slightly overestimate sweep while both operators 2 and 3 tended to underestimate sweep.

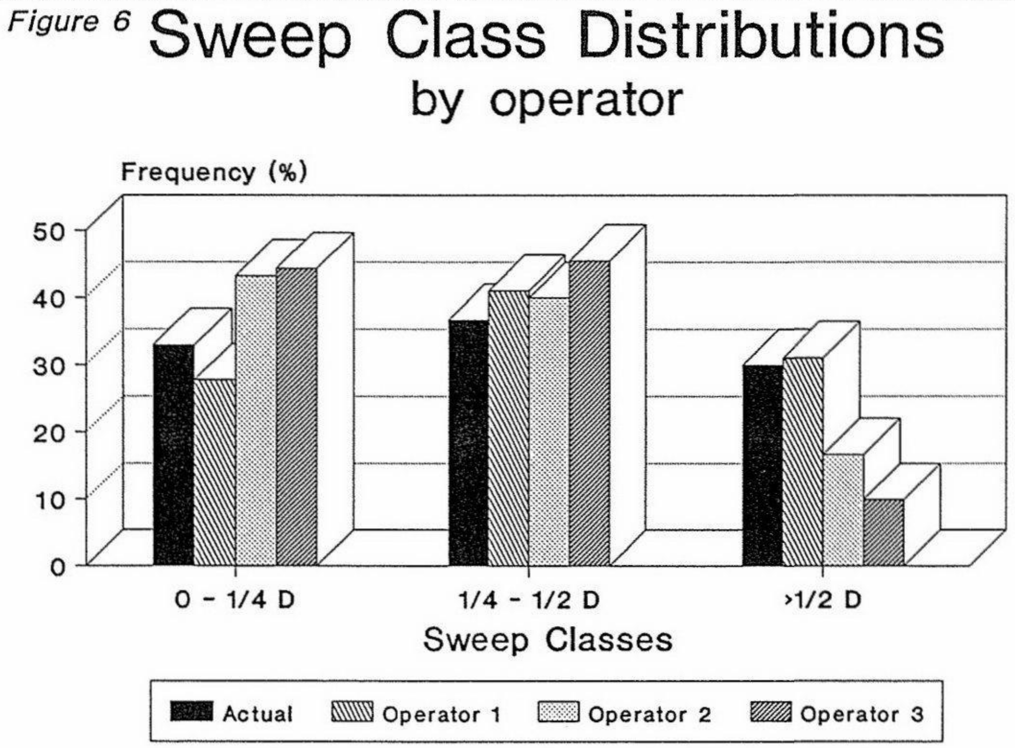
DISCUSSION AND CONCLUSIONS

The importance of sweep on pruned log values in the future will depend on several factors that could not be included in this study. Developments in sawmill technology to improve the conversion of swept logs has already occurred overseas. Cutting logs to short lengths or peeler bolts has not been tested in this study.

Predictions using SAWMOD in this study indicate that even minor levels of final sweep considerably effect pruned log values. Sweep deviation assessed at high pruning that is greater than 40 mm (or approx. $\frac{1}{4}$ diameter) will have a significant effect of reducing pruned log values. While no one level of sweep is identified as critical, selecting trees for pruning with sweep greater than 80 mm (approx. $\frac{1}{2}$ diameter) should be avoided. It is of some interest that the maximum sweep level tested (110.7 mm) is still within the P1 log grade sweep specification (for a 400 mm s.e.d.) but is predicted to have a value \$60 lower than a straight log.



Mean for instrument across all operators



Mean for operator across all instruments

Because the loss in potential pruned log value due to sweep is not linear and because sweep is categorised into classes, calculating confidence limits for sweep sampling in financial terms is not possible. Any chosen confidence limit will have different financial impacts depending on the sweep class and the number of trees in that class. If the classes used in this study are adopted, the > $\frac{1}{2}$ D class will have greatest impact on stand values. A ± 10% confidence limit in the frequency percentage in the > $\frac{1}{2}$ D class will equate to $4-5/$m^3$ change in mean log value. In practical terms it is probably simplest if every tree measured for DOS is assessed for sweep.

When ease of use and availability is taken into account the Pole method of assessment was found to be the best of the instruments tested. All operators found the pole to be approximately 50% faster than the other two instruments. If a height pole is used it needs to be straight, reasonably stiff and at least 5.8 m long. Measuring sweep in diameter related classes is probably the most practical method to use but will give results in terms of sweep class distributions and not mean values of absolute sweep.

This study indicated that even experienced staff are likely to have a bias in how much sweep they see. Assessments using a pole should occasionally be checked with careful measurements using a straight edge.

Although the sweep classes used in this study appear to be large, they are the minimum in terms of practical measurement with the instruments tested. Ultimately records of sweep and DOS will prove to be extremely valuable at stand maturity, particularly to know which stands have very small or large defect cores and which stands have low or high levels of sweep.

REFERENCES

GOSNELL, T. 1987: Equations for predicting defect core size for pruned radiata pine butt logs. Ministry of Forestry, FRI Bulletin No. 131.

GRALLELIS, S.A. and KLOMP, B.K. 1982: Systems for assessing malformation and quality in *P. radiata*. FRI Project record No. 989.

KNOWLES, R.L., WEST, G.G., KOEHLER, A.R. 1987: Predicting "diameter over stubs" in pruned stands of radiata pine. *Ministry of Forestry, FRI Bulletin No. 12.*

WHITESIDE, I.D., McGREGOR, M.J. 1987: Radiata pine sawlog evaluation using the sawing log-yield model. Pp. 124-246 *in* Kininmonth, J.A. (Comp.) Proceedings of Conversion Planning Conference. *Ministry of Forestry, FRI Bulletin No. 128.*

APPENDIX 1 - Pruned log variables to examine the effect of DOS on log values in SAWMOD

Sed (mm) m)	Length (m) (mm/m)	Taper (mm/ (kg)	Sweep (mm)	MBD (mm)	DOS	Max. DC	Pruned Iix	Mean DC	Max. Branch
400	5.4	13	5	400	130	200	0.25	184	40
400	5.4	13	5	400	150	220	0.25	203	40
400	5.4	13	5	400	170	240	0.25	221	40
400	5.4	13	5	400	190	260	0.25	239	40
400	5.4	13	5	400	210	280	0.25	258	40
400	5.4	13	5	400	230	300	0.25	276	40
400	5.4	13	5	400	250	320	0.25	313	40
400	5.4	13	5	400	270	340	0.25	313	40
500	5.4	13	5	400	130	200	0.25	184	40
500	5.4	13	5	400	150	220	0.25	203	40
500	5.4	13	5	400	170	240	0.25	221	40
500	5.4	13	5	400	190	260	0.25	239	40
500	5.4	13	5	400	210	280	0.25	258	40
500	5.4	13	5	400	230	300	0.25	276	40
500	5.4	13	5	400	250	320	0.25	294	40
500	5.4	13	5	400	270	340	0.25	313	40

RESIN POCKET FACTORS:

RPF1 1.3800 RPF2 0.4420 CS 0.3210

MBD = Mean basic density

DC = Defect core

Pruned Iix = Internode index of defect core

APPENDIX 2 - SAWMOD scenario

Base data for costs and prices :	Dec. 1985
Mill type :	No. 6 - Conventional Bandmill A
Number of shifts :	1
% uptime :	90
Mill cost per operating hour :	$1122
Mill capital cost :	$7.66 m
Return on capital invested :	8%
Sawmill conversion standard :	2
Timber loss factor :	4%
Sawpattern :	100% sawpattern 1
Timber price lists:	1985 Domestic price list
	1985 Export price list
Proportion of residue valued :	0.7
Residue valued as :	chips.

APPENDIX 3 - Formulas for ratio estimators

The ratio method can be applied where more trees are measured for DBH than DOS within each plot and/or where extra DBH only plots are measured.

Firstly, the ratio DOS/DBH is calculated for each DOS tree. Then the mean of these ratios is calculated. Then the mean DBH is calculated (including DBH only plots). The ratio estimator is then obtained as:

(mean ratio) x (mean DBH)

To calculate a 95% confidence interval for the ratio estimator, means of DOS/DBH ratios and DBHs are first obtained for each plot. Then the following are obtained.

var(ratio)	=	sample variance between plot ratio means
var1(DBH)	=	sample variance between plot DBH means including DBH only plots
var2(DBH)	=	sample variance between plot DBH means using DOS plots only
corr(ratio,DBH)	=	correlation coefficient between ratio and DBH means (using DOS plots only)
n1	=	the number of DOS plots
n2	=	the number of DBH plots (includes DBH only plots)
t(n1-1)	=	t-value at p = 0.05 for n1-1 degrees of freedom (obtain from t-table).

Then calculate the following:

k1	=	$(\text{mean DBH})^2 \times \text{var(ratio)}/\text{n1}$
k2	=	$(\text{mean ratio})^2 \times \text{var 1(DBH)}/\text{n2}$
k3	=	2 x mean DBH x mean ratio x corr (ratio,DBH) x Sqrt (var(ratio) x var2(DBH))/n2

Then, a 95% confidence interval is:

$$\pm \text{Sqrt}(k1 + k2 + k3) \times t_{(n1-1)}$$

The following is a worked example

Example:

Number of DBH and DOS plots = 5) (10 trees measured for DBH & 2 trees measured for DOS)

Number of DBH only plots = 5 (10 trees measured/plot).

Plot means:

	DBH	DOS	DOS/DBH
	105.2	130.0	1.235
	105.3	137.0	1.364
	118.5	162.0	1.218
	121.9	142.5	1.190
	122.4	157.5	1.314
	115.6	-	-
	131.3	-	-
	96.5	-	-
	134.5	-	-
	127.8	-	-
Mean	117.9	145.8	1.264
Variance	152.6	184.3	0.005233

Corr (ratio, DBH) = - 0.3912

$t_{(5-1)}$ = 2.78

Variance DBH (DOS plots only) = 76.04

Ratio estimator = 1.264 x 117.9 = 149.0

K_1 = $(117.9)^2 \times 0.005233/5$ = 14.55

K_2 = $(1.264)^2 \times 152.6/10$ = 24.38

K_3 = 2 x 117.9 x 1.264 x (-0.3912) x Sqrt (0.005233 x 76.04)/10 = 7.355

Then 95% confidence interval is:

149 ± Sqrt (14.55 + 24.38 - 7.355) x 2.78

= 149 ± 16

(Compare with direct DOS sampling method where a 95% confidence interval is : 146 ± 38).

APPENDIX 4 - Pruned log variables to examine the effect of sweep on log values in SAWMOD

Sed (mm)	Length (m)	Taper (mm/m)	Sweep (mm/m)	MBD (kg)	DOS (mm)	Max. DC (mm)	Pruned Iix	Mean DC	Max. Branch
400	5.4	13	0	400	170	234	0.25	211	40
400	5.4	13	5.3	400	170	237	0.25	213	40
400	5.4	13	10.4	400	170	244	0.25	220	40
400	5.4	13	15.4	400	170	255	0.25	230	40
400	5.4	13	20.5	400	170	271	0.25	244	40
400	5.4	13	0	400	250	320	0.25	288	80
400	5.4	13	5.3	400	250	322	0.25	290	80
400	5.4	13	10.4	400	250	329	0.25	296	80
400	5.4	13	15.4	400	250	341	0.25	307	80
400	5.4	13	20.5	400	250	357	0.25	321	80
500	5.4	13	0	400	170	234	0.25	211	40
500	5.4	13	5.3	400	170	237	0.25	213	40
500	5.4	13	10.4	400	170	244	0.25	220	40
500	5.4	13	15.4	400	170	255	0.25	230	40
500	5.4	13	20.5	400	170	271	0.25	290	40
500	5.4	13	0	400	250	320	0.25	288	80
500	5.4	13	5.3	400	250	322	0.25	290	80
500	5.4	13	10.4	400	250	329	0.25	296	80
500	5.4	13	15.4	400	250	341	0.25	307	80
500	5.4	13	20.5	400	250	357	0.25	321	

RESIN POCKET FACTORS:

RPF1 1.3800 RPF2 0.4420 CS 0.3210

MBD = Mean basic density

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