THE BREAKAGE OF PINUS RADIATA AT CLEARFELLING AND ITS EFFECT ON SAWLOG YIELD

H. M. N. LEES*

SYNOPSIS

Investigations were undertaken to give a better appreciation of factors that relate standing volume to recoverable sawlog yield.

It was noticed during clearfelling that stems of mature Pinus radiata *break at a diameter approximately equal to half breast height diameter. This indicates that volume to a 6 in. top diameter is of little value for estimating sawlog yield.*

Using a graphical method of analysis, it was found that, for the d.b.h. range 10 to 24 in., stem volume below the point of break was approximately constant at 86% of total stem volume; but this finding takes no account of additional losses caused by stem malformation or wastage.

The New Zealand Forest Service, Forest Research Institute, carried out a more detailed analysis of the data, and showed a more precise relationship for diameter at break to d.b.h. Total height was also found to be as effective as d.b.h. for estimating the diameter at point of break.

Further developments of this general approach are also suggested.

INTRODUCTION

Standing volume to a fixed top diameter has commonly been used as a basis for estimating recoverable sawlog yields. Volume to a top diameter of 4 in. or 6 in. has been most frequently used and, normally, further percentage reductions have been applied to allow for malformation and wastage. Nevertheless, agreement between estimated and actual sawlog yields has often been imprecise, except where the overall percentage reduction has been based on detailed previous experience. Reductions of between 5% and 35% have been used, but effectiveness has varied widely through the whole range. Thus there seems to be a need for a better appreciation of the factors involved, so that a more precise method of estimating sawlog yield can be developed for use when detailed previous experience is lacking.

As a start, the most promising line of approach to the problem appeared to be to see what happens when a tree is felled. It is only with this initial aspect of the problem that the following investigations were concerned.

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*Senior Forester, N.Z. Forest Service, Wellington.

PRELIMINARY INVESTIGATION

In October, 1965, during clearfelling operations of 34-year-old *Pinus radiata* in Golden Downs State Forest, Compartment 61, on an average slope of approximately 25 degrees, it was noted that tree stems broke when they hit the ground. Trees were felled downhill. The following measurements were taken during the successive felling of 19 trees: d.b.h., diameter of stem at point of break (d.p.b.), tree height *(i.e.,* stem length, butt to leader), and total length of sawlogs cut from the stem below the point of break. All trees had reasonably normal form. Analysis of these data showed the following:

(1) Total logged length averaged 55% (67 ft) of tree height (122 ft).

(2) The average d.b.h. of the 19 trees was 17.7 in. The average d.p.b. was 8.8 in. and d.p.b. appeared to be related to d.b.h.

(3) The volume of sawlogs averaged 72% of total stem volume (compared with the 6 in. top volume of 95.5%).

(4) The volume of stem above the point of break accounted for a large proportion of the remaining 28% of total stem volume — between 14 and 21% of total stem volume, depending on the method of analysis.

FURTHER INVESTIGATIONS

The results of the preliminary investigation suggested that further work might enable a relationship to be established between d.b.h. and d.p.b., and that, once established, this relationship might be of value for estimating recoverable sawlog yield. Accordingly, in December, 1965 a further 151 sets of paired data were collected, this time in Compartment 2, during clearfelling of 34-year-old *Pinus radiata,* and again on average slopes of approximately 25 degrees. In this case the only measurements taken were d.b.h. and d.p.b. Trees were again felled downhill.

The data were plotted, and a straight line showing d.p.b. equal to half d.b.h. drawn through the middle of the scatter. The result was so striking that it seemed worth while trying to establish the relationship more precisely. Accordingly, another 148 sets of paired data were collected, this time from Compartment 8, the species, age, slope, and felling being the same as in Compartment 2, but larger trees were present in the crop.

The d.b.h./d.p.b. data from the preliminary investigation, and from the two sets of paired measurements in Compartments 2 and 8 were plotted, and are shown in Fig. 1. Data from some trees noted to have been felled uphill have also been distinguished. Through the resulting scatter the straight line d.p.b. = $\frac{1}{2}$ d.b.h. has been drawn.

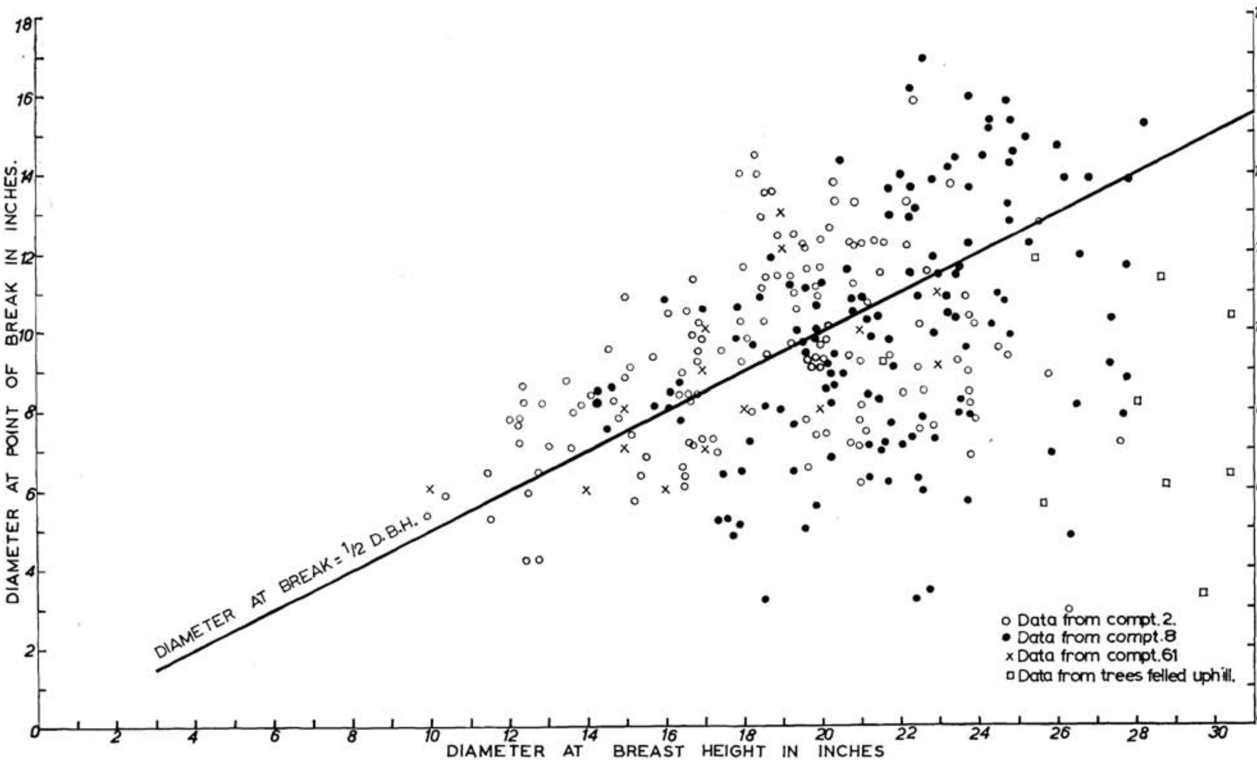

FIG. 1: *Diameter of* P. radiata *stems at point of break in clearfelling operations on 25° slopes at Golden Downs, plotted against d.b.h. (December, 1965).*

CONSIDERATION OF RESULTS

For clearfelling of 34-year-old *Pinus radiata* on average slopes of 25 degrees, consideration of Fig. 1 suggests the following:

(1) Since d.p.b. is nearly always greater than both 4 in. and 6 in., standing volume to a top diameter of 4 in. or 6 in. is not a suitable basis for estimating recoverable sawlog yields.

(2) The d.p.b. of trees felled uphill is very much less than of trees felled downhill.

(3) Though the scatter of data is wide, the expression d.p.b. = $\frac{1}{2}$ d.b.h. gives on the average a reasonable approximation for breast height diameters (o.b.) of 10 to 24 in.; but above this the relationship becomes curvilinear.

ESTIMATE OF MERCHANTABLE VOLUME BELOW POINT OF BREAK

Based on the third assumption above, the next objective was to express residual volume below the point of break as a percentage of total stem volume. This was effected graphically and in two steps. First, merchantable volume for each of a range of top diameters was plotted (as a percentage of total stem volume) against mean diameter at breast height — a family of graphs resulting, one graph for each top diameter from 4 in. to 12 in. The second step was to superimpose the relationship d.p.b. = $\frac{1}{2}$ d.b.h., obtained from Fig. 1. The result is shown in Fig. 2, Table 1.

TABLE 1.

Mean d.b.h. (in.)	*d.p.b. (in.)*	*Merchantable vol. to d.p.b. as % of total stem volume*
10	5	85½
12	6	85
14	7	85½
16	8	86
18	9	86½
20	10	86
22	11	86½
24	12	86½
		Mean 86%

CONCLUSION

The above relationship is a satisfactory one from a practical point of view, since it shows that for all diameters of 10 to 24 in. the volume of stem from butt to point of break is always approximately 86% of total stem volume. Or put another way, the volume above point of break is always ap-

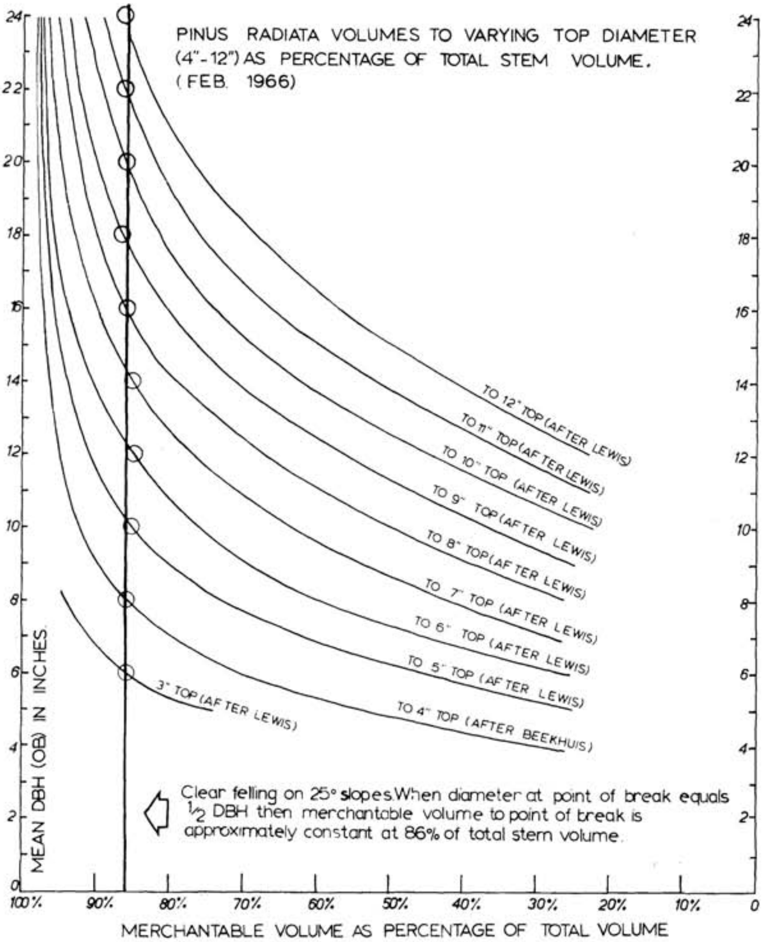

FIG. 2: *Merchantable volume, below point of stem breaking, as a percentage of total stem volume for trees of given d.b.h.o.b.*

proximately 14% of total stem volume. These findings are, however, subject to any inaccuracy in the assumption made in (3) above.

For 34-year-old *Pinus radiata* this relationship applied to clearfelling downhill on average slopes of 25 degrees. Under these conditions and when, for economic or other reasons, stem lengths above the point of break are seldom extracted, this reduction of 14% of total stem volume seems a reasonable first step towards estimating recoverable sawlog yields. It should perhaps also be remembered that, while on the one hand some large end lengths may be extracted, on the other hand, against this should be set the further breakage of felled stems which occurs when other trees fall on them.

SUBSEQUENT WORK

In order to find out whether the above considerations of breakage applied to thinning operations, 9 trees were felled downhill in a line, in an 18-year-old stand of *Pinus radiata* in Compartment 91, once again on an average slope of 25 degrees. The 9 trees averaged 75.5 ft in height, with a mean d.b.h. of 10.9 in. The mean d.p.b. was 1.3 in., at an average height of 71.0 ft. It was accordingly concluded that, under these conditions, loss from breakage on felling during thinning operations was negligible.

Since the above methods of analysis are rather crude, the data on diameter at point of break on clearfelling were sent to the New Zealand Forest Service, Forest Research Institute, Rotorua, so that more precise relationships could be established. The work was carried out by G. A. V. Bary under the direction of G. Duff. The results of these analyses have not been published, but in very brief and partial summary, they show the following:

(1) The relationship of d.p.b. and d.b.h. is very well expressed by an inverted parabola of the form $B = a + bD + cD^2$, where B is diameter at point of break, D is d.b.h., and a, b and c are constants.

(2) The parabolic curve form gave a significant improvement over the linear form.

(3) There was a significant difference between the curves derived from data for Compartment 2 and Compartment 8.

(4) By using limited height data available for Compartment 8, it was shown that d.p.b. is a linear function of height, and that measurement of total height is just as good a means of estimating d.p.b., as is measurement of d.b.h.

(5) For Compartment 8, volume to point of break was shown to be 84.4% of total stem volume, and for Compartment 2, to be 81.6%.

DISCUSSION

It should be stressed that the conclusions reached above are considered only a starting point, to which it may subsequently be possible to add suitable factors to take account of stem malformation and wastage. Moreover, it is considered very likely that the suggested 14% reduction of total stem volume, to give a starting point for estimating recoverable sawlog yield, will need to be varied to take account of differences in species, angle of slope, and topographical configuration. Differences in site may also affect strength properties of the stem, and thus alter the relationship of d.p.b. to d.b.h.

On the other hand, however, if for a particular forest and species the inverted parabolic relationship of d.p.b. to d.b.h. can be established, then, through the use of computer facilities, individual tree volumes to their diameters at point of break could be accumulated to give a more precise starting point for estimating recoverable sawlog yield. Moreover, by comparison of this information with individual tree volumes accumulated to a range of absolute top diameters, the volume of top lengths of stem, above the point of break, can be derived to give an estimate of subsidiary yield that can be taken to a desired top diameter — but, as before, allowance must still be made for stem malformation and wastage. It should also be possible to derive information on stem lengths, both above and below the point of break, and to compare these with stated exploitable log lengths, for the estimation of wastage factors.

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