

FUNCTIONS TO PREDICT AVERAGE PIECE SIZE AND AVERAGE HAUL VOLUME FOR NEW ZEALAND CLEARFELL CABLE LOGGING OPERATIONS

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ABSTRACT

Three functions, one for average piece size and two for average haul volume, are presented for clearfell tree-length cable logging operations in New Zealand Pinus radiata (D. Don) steep country plantations. All functions are based on stand mean tree volume.

INTRODUCTION

Many studies using industrial engineering techniques have been done overseas and in New Zealand on cable logging operations. Much of the the type of information contained in these studies is now being used by logging planners either directly or through computer planning packages.

Volume removed per unit area, average piece size, and haul volume (volume per cycle) have been shown to be some of the main factors affecting cable logging productivity and costs (Anon., 1972; Dykstra, 1974; Lisland, 1975; Murphy, 1979) and are often included in production estimating equations. Other factors, such as machine selection, logging gang experience and motivation, and extraction distance, also affect productivity and costs but are not dealt with here.

Although the volume removed per unit (a relatively easy parameter to obtain from stand records) is an important factor, it is the size of these pieces and their number that are relevant to the logging planner. Removing fifty 4 m^3 pieces is a vastly different proposition from removing the same volume consisting of four hundred pieces of 0.5 m^3 each. The more pieces there are to pick up the longer it takes to clean out an area, but the amount of time lost to rope shifts and setting shifts is less proportionately.

Providing functions to predict average piece size and average haul volume, based on easily obtained stand parameters such as mean tree volume, should help logging planners to make better use of existing and future time study information and more

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accurately calculate daily production and costs for cable logging systems.

During the past ten years the Forest Research Institute's Harvest Planning Group has measured more than two thousand individual haul volumes and six thousand piece volumes in over twenty cable logging studies. Many of the measurements from these studies form the data base for the functions described in Table 1.

All cable logging operations studied were in *P. radiata* plantations. In most instances the trees were felled downhill. A one-pass approach to harvesting each setting was adopted; that is, there was no pre-bunching prior to the main extraction phase, nor was there a follow-up extraction phase to remove top pieces. Terrain was generally steep although not particularly broken or gutted in the study areas.

Mean tree volume is defined in this paper as the merchantable volume (m^3 to a 10 cm top s.e.d.i.b.) of the tree of mean basal area. It was usually derived from the application of local volume tables to an inventory carried out prior to harvesting of the portion of the stand to be studied.

Piece size is defined as the underbark volume of an unprocessed merchantable length arriving at the landing. Average piece size refers to the arithmetic mean of all such pieces measured. Piece size was measured using a two-stage sampling method (Ellis, 1982).

AVERAGE PIECE SIZE FUNCTION

Tree-length logging is the normal practice for most cable loggings operations in New Zealand. In other words, cutting to length (or bucking) at the felling site is not normally practised. Despite this fact, the logging planner cannot plan on a one tree-one piece basis. Breakage during felling and extraction increases the number of pieces to be picked up and reduces the average piece size arriving at the landing. Figure 1 depicts the relationship between standing mean tree volume and average piece size. The regression line shown in Fig. 1 and below was forced through the origin. It can be expressed as follows:

Average piece size (m^3) = 1.132 (MTV) — 0.124 (MTV)²

where MTV is mean tree volume.

$n=13$ $r^2=0.99$ $F_{2/11}=1961$

It must be stressed that although hundreds of pieces were measured for each operation they were used to derive a single

TABLE 1: DATA BASE USED TO PREDICT FUNCTIONS FOR AVERAGE PIECE SIZE
AND AVERAGE HAUL VOLUME

<i>Machine</i>	<i>Machine Power Rating (kW)</i>	<i>Mean Tree Volume (m³)</i>	<i>Average Piece Size (m³)</i>	<i>No. of Pieces Measured</i>	<i>Ave. Haul Volume (m³)</i>	<i>No. of Hauls Measured</i>
1. Madill 071	213	1.11	1.16	393	2.99	152
2. Wilson Hauler	128	1.29	1.19	239	3.44	82
3. Madill 009	338	1.42	1.35	240	4.10	79
4. Madill 071	213	1.47	1.64	218	2.79	128
5. Madill 009	338	1.59	1.47	182	4.91	61
6. Wilson Hauler	128	1.61	1.62	231	-	-
7. Dispatch 1952z	340	2.01	1.57	574	3.72	241
8. Madill 009	338	3.04	-	-	4.40	-
9. Madill 009	338	3.40	2.56	545	5.89	219
10. Madill 009	338	3.40	2.37	287	4.95	138
11. Madill 009	338	4.45	2.55	84	5.96	36
12. Westminster	210	4.50	2.54	730	6.29	126
13. Madill 009	338	4.54	2.59	306	6.29	126
14. Madill 009	338	4.54	2.74	575	6.59	239

Note: Missing values in the table are due to data not being collected or non-typical conditions.

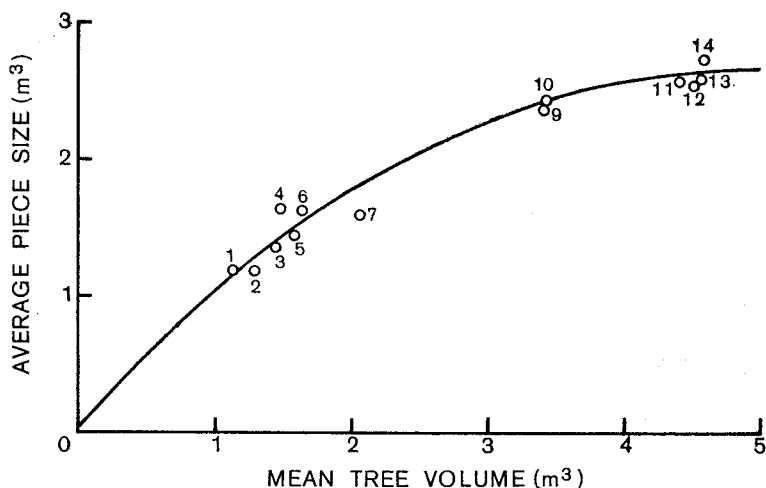


FIG. 1: Relationship between average piece size and mean tree volume for *P. radiata* clearfell cable-logging operations. Each data point represents a separate stand. See Table 1 for sample sizes.

average piece size figure for that operation. The regression should be applied only on a stand basis, not an individual tree basis.

It should also be noted that, as with all regressions, it is dangerous to use this one outside its data base limits. I would suggest that the regression is not used for stands with a mean tree volume of less than 1 m³ since little breakage occurs for trees below 1 m³ and small errors when calculating average piece size in this range can cause very large errors in daily production and cost prediction; the production/average piece size and cost/average piece size curves rise almost exponentially for pieces below 1 m³ (Mann, 1979; Terlesk, 1980).

Because of the form of the quadratic equation, predicted average piece size begins to fall rapidly for mean tree volumes greater than 6 m³. It is also suggested that the regression not be applied beyond 5 m³ mean tree volume.

In very broken terrain it would be expected that predicted average piece size would be slightly over-estimated by the regression. Sharp changes in slope, identified as important contributions to breakage during felling (Murphy, 1982a), would cause the tree to break into more pieces of a smaller size.

The trees forming the data base for the regression in most instances were felled downhill. Less breakage has been found for both old crop and second crop radiata pine directionally felled across slope with the stems kept parallel (Murphy 1982a,

b). For trees between 4 and 5 m³ mean tree volume, 5% increase in average piece size has been found for directionally felled trees (Murphy, 1982b). The regression may slightly under-estimate average piece size for directionally felled stands.

AVERAGE HAUL VOLUME FUNCTIONS

Two relationships are shown in Fig. 2. The solid line depicts the relationship between average haul volume and mean tree volume for one type of hauler, a Madill 009, which is the most common type in New Zealand steep country plantation harvesting. The derived function for this line is:

$$\text{Average haul volume (m}^3\text{)} = 3.347 + 0.619(\text{MTV}) \dots \text{Mac'ill 009}$$

$n=8 \quad r^2=0.71 \quad F_{1/6}=14.7$

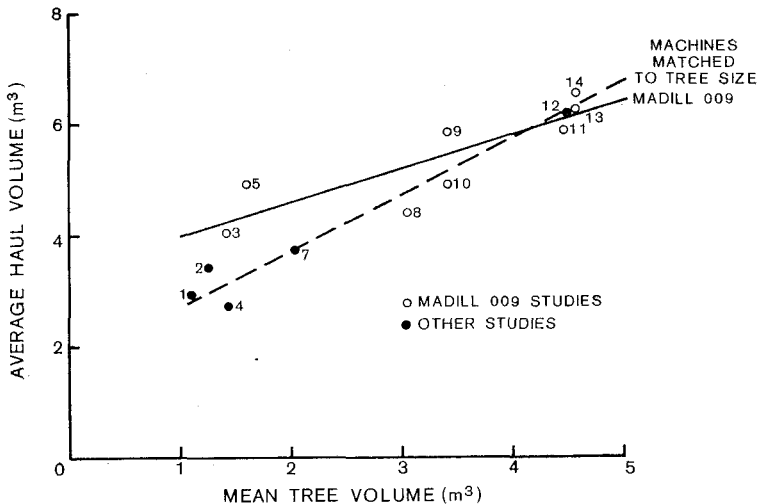


FIG. 2: Relationship between average haul volume and mean tree volume. Each data point represents a separate stand. See Table 1 for sample sizes.

The broken line depicts the relationship where, in my opinion, the machine used was more suited to the tree size being harvested. The regression was based on all the data points shown except for the two stands of less than 2 m³ mean tree volume where the Madill 009 was used. The Madill 009 would generally be considered by logging planners to be far over-powered and too costly for this tree size — although circumstances may sometimes necessitate its use. The derived function for this line is:

Average haul volume (m^3) = $1.759 + 1.006$ (MTV) . . . Machines matched

$$n = 11 \quad r^2 = 0.94 \quad F_{1/9} = 140.7$$

Again I would warn the user of these functions against using them outside their data base limits particularly at the lower end of their range, *i.e.*, below $1 m^3$.

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