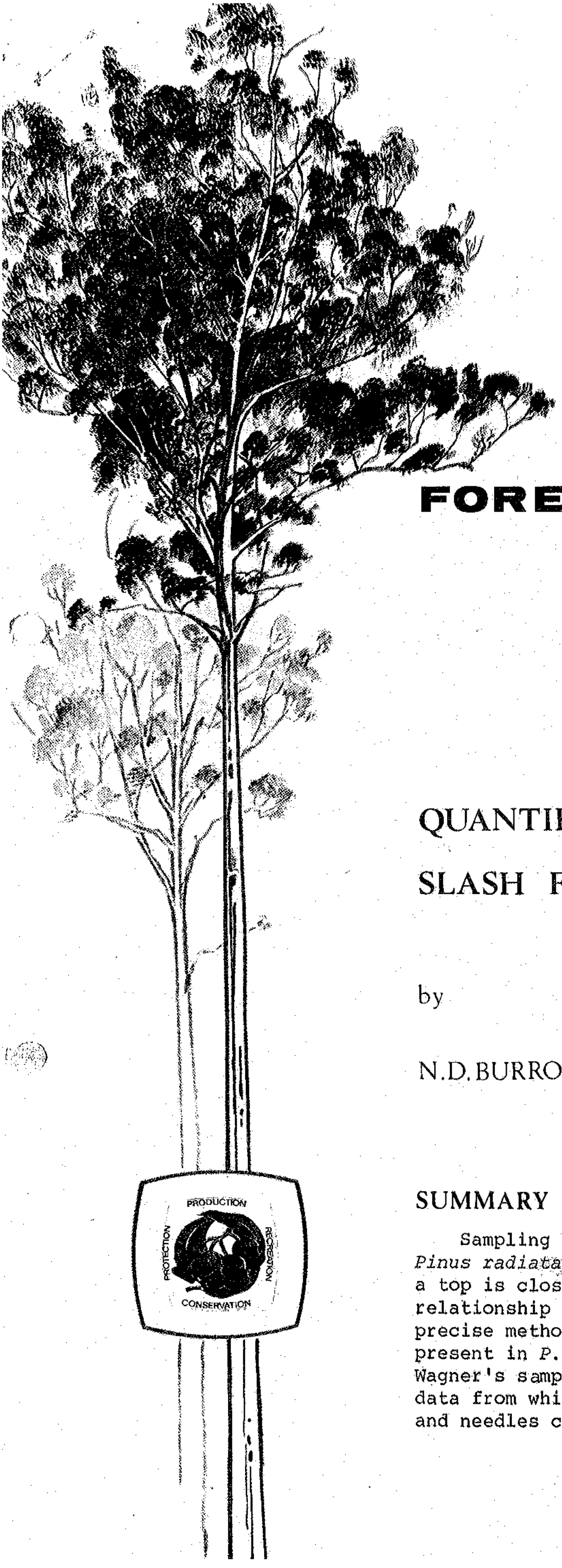

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QUANTIFYING *Pinus radiata* SLASH FUELS

by

N.D. BURROWS

SUMMARY

Sampling of residual tops in 5- and 11-year-old *Pinus radiata* D. Don stands showed that the biomass of a top is closely related to its stem diameter. This relationship is used as the basis for a simple and precise method of quantifying the additional fuel present in *P. radiata* plantations after thinning. Van Wagner's sample line technique is used to gather the data from which the weights of stem wood, branch wood and needles can be calculated.

INTRODUCTION

In plantations of *Pinus radiata* D. Don, residual tops are by far the greatest component of flash fuel and of the total additional fuel quantity resulting from both commercial and non-commercial thinning operations. Since the varying quantities of residual tops present a range of fire hazards, a means of quantifying them is essential in order to be able to gauge the hazard.

This study aimed at developing a practical, simple and precise means of assessing the biomass of residual tops by seeking a relationship between the basal stem diameter of a residual top and its biomass. It was reasoned that if such a relationship existed, then sampling the residual tops for a stem wood volume using Van Wagner's (1968) method would give a reliable indication of top biomass.

Residual tops were considered to be composed of three fuel types based on fuel size. The first and most flammable of these fuels is the needle component. Branch wood is the next most flammable fuel, and all woody material up to 1.5 cm in diameter is placed in this category. The least flammable fuel type is the stem wood, which includes all woody material comprising the stem section of the residual top.

Both 5- and 11-year-old *P. radiata* stands were studied. Stands of these ages are the most vulnerable to fire because they contain large quantities of thinning residue and are physiologically susceptible to fire.

METHOD

In 11-year-old stands, trees were sampled on both high- and low-quality sites in the Blackwood Valley (Table 1). Stratum I stands are those which have a top height greater than 17.2 m at age 10, whilst Stratum II stands have a top height between 14.8 m and 17.2 m at age 10. For stands of ages different from this, the stratum classification is obtained from height/age growth curves.

Sample trees were selected to be representative of the crown classes normally removed under the Forests Department's 1974 thinning prescription

TABLE 1

Site quality and sampling intensity on 9 sample sites in 11-year-old *P. radiata* plantations in Nannup and Kirup Divisions, Blackwood Valley

Location	Site quality (stratum)	No. of samples
Nannup Division		
Lewana B1	1	10
Lewana B6	1	5
Lewana B3	2	15
Kirup Division		
Grimwade K11	1	6
Grimwade K12	1	10
Grimwade K14	2	10
Grimwade N1	2	6
Grimwade N7	2	5
Kelly	1	8
Total		75

(McKinnell, 1978). They were either subdominant or codominant trees. The stems of felled trees were segmented according to a series of diameter classes beginning with the 0-4 cm diameter class and continuing through to the 12-14 cm diameter class at intervals of 2 cm. Very little material larger than 14 cm diameter is not utilised in *P. radiata*. The mid-point of each of these diameter classes was then marked on the stem.

Diameter classes of 2 cm were used rather than individual diameter measurements because of the nature of branching in *P. radiata* and the variation in internodal length, which would not give a continuous relationship between stem diameter and biomass. The use of classes absorbed this variation.

Branches were pruned from the tops and labelled according to the top and the particular stem diameter class from which they came. For each branch, butt diameter was recorded and the oven-dry weight of needle material determined. The oven-dry weight of needle and woody branch material was then determined for each stem diameter class.

In addition, 100 sample trees were taken from a 5-year-old stand of *P. radiata*, and the data were combined with those from the 11-year-old trees to increase the reliability of the sampling. No stratification of sampling by site quality was possible in these stands, however, because at this age the trees are not sufficiently developed to express site variation.

RESULTS AND DISCUSSION

Branch butt diameter and oven-dry weight of branch wood are closely related (Fig. 1). The relationship between the two parameters can be described by the following equation:

$$\ell nY = 2.61\ell nX + 3.33$$

Where Y = oven-dry weight of branch wood (g)
X = branch butt diameter (cm)
Co-efficient of determination: $r^2 = 0.92$

Table 2 shows mean branch butt diameters and mean numbers of branches per top for each of the stem diameter classes.

Table 3 gives the mean oven-dry weight of needles for tops in both strata. Although there is a trend for needle weights to be heavier in Stratum I, as might be expected, the differences are not statistically significant and the data for both strata were pooled for further use.

From Tables 2 and 3 it can be seen that the quantities of the three fuel types in tops (needles, branches and stem wood) are proportional to the stem diameter. If a relationship can be established between stem diameter and stem wood weight, and also between stem wood weight and the other two fuel weights, then all three fuel components can be estimated from diameter data obtained by Van Wagner's (1968) method of sampling forest fuel. In this technique the tops intersected along a sample line are tallied into their respective diameter classes and used to calculate stem wood volume per hectare. Knowing the average basic density of the timber, this volume can be converted to weight.

Sampling tops from this area gave a mean wood basic density of 357 $kg{\cdot}m^{-3}$, which is in the range typical of juvenile wood of the species. From this sample,

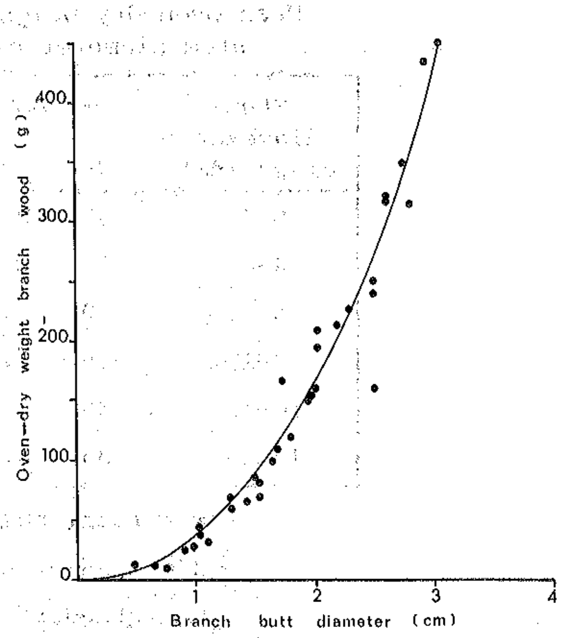

FIGURE 1: Relationship between branch butt diameter and oven-dry weight of branch wood (based on 5- and 11-year-old samples).

TABLE 2

Mean branch butt diameters and mean number of branches for different stem diameter classes

Stem diameter class (cm)	N	$\bar{X}_1$	CV_1	$\bar{X}_2$	CV_2
0-4	40	-	-	-	-
4-6	40	0.90	10.6	12	17.4
6-8	40	1.55	17.3	34	27.6
8-10	40	1.84	15.4	49	38.0
10-12	50	1.89	16.2	68	33.0
12	50	2.07	19.2	83	45.4

N = total number of tops sampled

$\bar{X}_1$ = mean branch butt diameter (cm)

CV_1 = co-efficient of variation for $\bar{X}_1$ (%)

$\bar{X}_2$ = mean number of branches

CV_2 = co-efficient of variation for $\bar{X}_2$ (%)

TABLE 3

Mean oven-dry weight of needles for different stem diameter classes, Strata I and II

Stem diameter class (cm)	Stratum I			Stratum II		
	N	$\bar{X}$	S	N	$\bar{X}$	S
0-4	30	0.26	0.11	30	0.23	0.07
4-6	30	0.50	0.12	30	0.50	0.14
6-8	39	2.22	0.52	36	1.89	0.43
8-10	39	3.75	0.86	36	2.20	0.75
10-12	35	5.68	1.15	35	5.30	0.80
12-14	35	8.19	1.11	35	7.65	1.19

N = total number of tops sampled

$\bar{X}$ = mean oven-dry weight of needles (kg)

S = standard deviation

stem diameter was found to decrease 1.2 cm per metre increase in length. The volume, hence the weight of wood in one top, can be calculated for each diameter class. The mid-point of each class was used in the calculations.

The total number of tops per hectare in each diameter class was found by dividing the total weight of stem wood for each class by the average weight of stem wood in one top.

The weight of branch wood for each stem diameter class was then found by determining the mean weight of branch

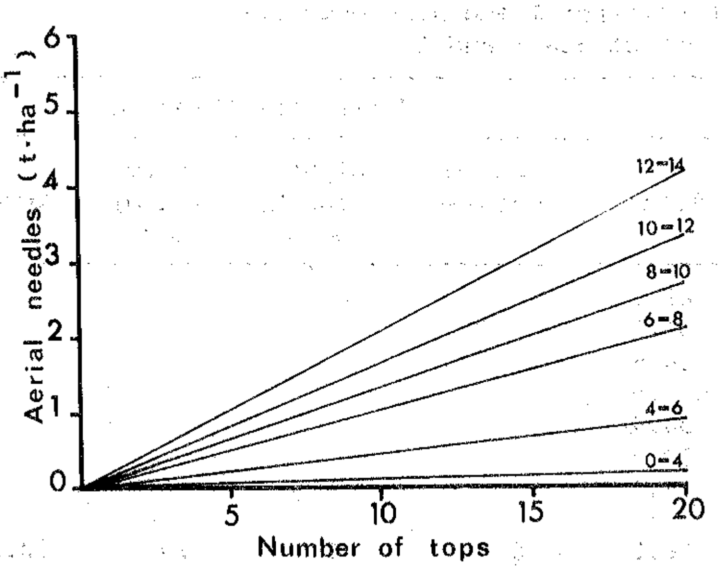

FIGURE 2: Oven-dry weight of needles ($t \cdot ha^{-1}$) for various numbers of tops intercepted by a 100 m sample line. The relationship is shown for each top diameter class (cm).

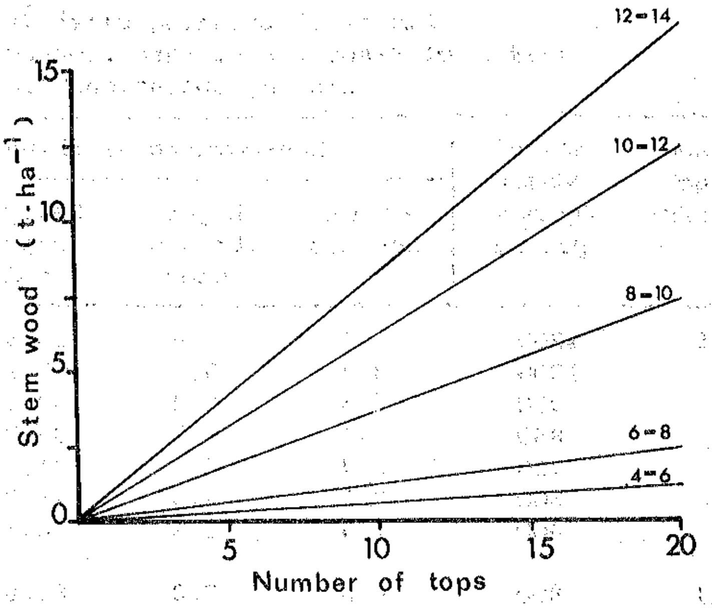

FIGURE 4: Oven-dry weight of stem wood ($t \cdot ha^{-1}$) for various numbers of tops intercepted by a 100 m sample line. The relationship is shown for each top diameter class (cm).

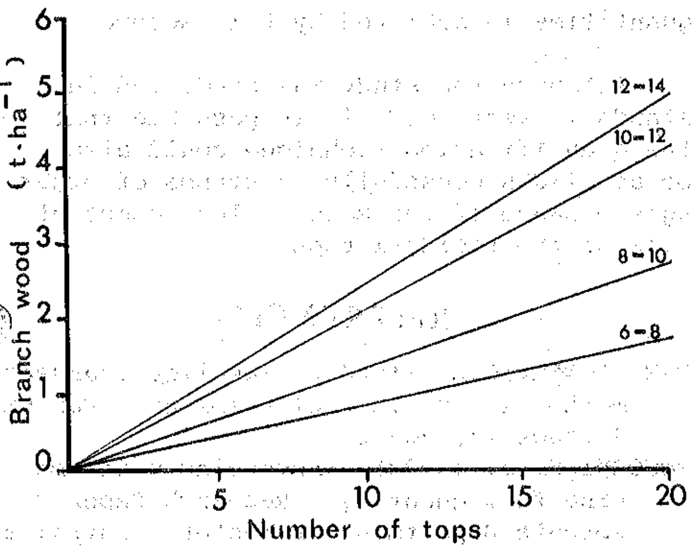

FIGURE 3: Oven-dry weight of branch wood ($t \cdot ha^{-1}$) for various numbers of tops intercepted by a 100 m sample line. The relationship is shown for each top diameter class (cm).

wood in one top (using the mean branch butt diameters given in Table 2 and the graph in Figure 1) and then multiplying this by the number of tops per hectare.

The weight of needles was calculated for each stem diameter class by multiplying the mean values for needle oven-dry weight (Table 3) by the number of tops per hectare in the stem diameter class.

Figures 2, 3 and 4 have been constructed using this method of fuel quantification. For each of the stem diameter classes they relate the weight per hectare of each of the three fuel types to the number of tops transected by sample lines 100 m in length.

Having established a relationship between stem diameter and the biomass of the various components of the top, the quantity of thinning slash can easily be determined if the number of thinned stems per hectare is known.

TABLE 4

Amount of thinning slash ($t \cdot ha^{-1}$) produced on basis of number of stems per hectare removed in commercial and non-commercial thinning operations (for both Strata I and II)

Stand age (years)	No. of stems removed per ha	Non-commercial thinning				Commercial thinning			
		Aerial needles	Light (branch) wood	Heavy (stem) wood	Total	Aerial needles	Light (branch) wood	Heavy (stem) wood	Total
5	1200	4.4	6.6	50.5	61.5				
	1000	3.7	5.5	42.1	51.3				
	950	3.5	5.2	39.9	48.6				
	850	3.1	4.7	35.7	43.5				
	750	2.7	4.1	31.6	38.4				
	600	2.2	3.3	25.2	30.7				
	400	1.4	2.2	20.5	24.1				
11	800	6.8	7.8	81.6	96.2	6.8	7.8	17.5	32.1
	700	5.9	6.9	71.4	84.2	5.9	6.9	15.3	28.1
	600	5.1	5.9	61.2	72.2	5.1	5.9	13.1	24.1
	500	4.2	4.9	51.0	60.1	4.2	4.9	10.9	20.0
	400	3.4	3.9	40.8	48.1	3.4	3.9	8.7	16.0
	300	2.5	2.9	30.6	36.0	2.5	2.9	6.5	[illegible]
	200	1.7	1.9	20.4	24.0	1.7	1.9	4.4	8.0

For a five-year-old stand, an average residual top butt diameter of 9 cm was used to calculate the thinning slash weight and for an 11-year-old stand, an average residual top butt diameter of 14 cm was used. The commercially thinned 11-year-old stand has a reduced component of stem wood following the extraction of logs down to a small-end diameter of 8 cm. The small-end diameter of extracted logs is highly variable, 8 cm being an average. The likely quantity of fuel following thinning at various intensities is shown in Table 4 for typical 5- and 11-year-old stands.

CONCLUSIONS

Assessment of the amount of additional fuel present in *P. radiata* stands using the technique developed during this study is not only accurate but also easy, so that the cost of quantification by this method would be reasonable.

The precision of fire behaviour predictions would doubtless be increased since a reliable assessment of fuel quantities is achieved by this method.

Although the study was conducted in stands 11 years old, it is possible that the quantification technique could also be applied successfully to stands of other ages because of the more or less constant size of the residual tops.

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