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Forest Fuels in Unthinned Radiata Pine Stands

SUMMARY

Forest fuels in unthinned 12-year-old radiata pine stands in Merriang Plantation, north-east Victoria are described. Quantity and distribution of fuels on the forest floor and in tree crowns are dealt with separately, and provide basic information for fire management decisions.

Regression equations are developed for determining crown volume, the density of needles and branchwood in tree crowns and the weight of fuel components in tree crowns. The regressions are recommended for simulating the silvicultural and utilisation effects of thinning treatments.

The information assists with the initial task of assessing fuel hazards in plantations. Further research in fuel management in plantations is suggested.

INTRODUCTION

Fire behaviour is a function of site, weather and fuel factors. Countryman (1969), Wilson and Dell (1971) and Dodge (1972) noted that the fire manager can manipulate the fuels (including all living and dead cellulose material on the forest floor and in tree crowns) to reduce the fuel hazard, but the manger has very little influence over site or weather conditions.

Before developing plans for fuel management and hence fire management, one must fully describe the fuel situation; generally this has been a neglected aspect of fire research in Australia. Notable exceptions are descriptions for the jarrah forests (Peet 1971) and maritime pine stands (McCormick 1973) of Western Australia.

This paper describes the quantity and distribution of fuels on the forest floor and in tree crowns in unthinned 12-year-old radiata pine stands. Fuel weights are described within tree crowns by regression equations which relate oven-dried weight of fuel component to diameter breast height over bark (DBHOB). Used with an equation relating crown volume

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to DBHOB, the vertical distribution of fuel particles in tree crowns is described.

These equations can be used to simulate the effects of thinning treatments on removal from, and redistribution of, fuel components within forest stands. In addition, the information may be used in silvicultural and utilisation research.

METHODS

One hundred and seventy hectares of unthinned 12-year-old radiata pine stands in Merriang Plantation, north-east Victoria were studied. Mean stand details are listed in Table 1.

TABLE 1

Mean stand details for 170 ha of 12-year-old radiata pine stands in Merriang Plantation, north-east Victoria.

Stem diameter	17.1 cm
Number of stems per hectare	1407
Top height	16.64 m
Stand basal area	27.5 m^2/ha
Stand volume	139.5 m^3/ha

The appraisal of fuels was carried out in 2 stages;
(1) assessment of fuels on the forest floor, and
(2) assessment of fuels in tree crowns.

Fuels on the Forest Floor

Fine and coarse fuels were assessed separately using different techniques.

In this study, fine fuels include woody material less than 6 mm diameter, needle litter (partly or undecomposed pine needles) and duff (advanced or fully decomposed pine needles). Coarse fuels include all woody material greater than 6 mm diameter.

Fine fuels were estimated using one hundred, 0.5 m^2 randomly located plots (Munger and Matthews 1941, Dell and Ward 1971). Fuels on the plots were collected and oven-dried in the laboratory at 105°C.

Bulk density of needle litter and duff were derived from volume and weight measurements on the plots.

The line intersect technique described by Van Wagner (1968) was used for coarse fuels. One hundred 30 m transects were randomly located through the area.

Fuels in Tree Crowns

The method previously used by Kittredge (1944), Loomis et al. (1966), and Landis and Morgen (1975) was adopted for determining the quantity and distribution of fuel components in tree crowns. The technique involved the collection of all fuel material, excluding merchantable stem (i.e. stem wood greater than 10 cm diameter), in the tree crown from 12 randomly selected trees within the stands sampled. The collected samples were transported to the laboratory and oven-dried at 105°C.

Oven-dried weights of merchantable stem were determined using wood density figures together with volume measurement of the stem. The density figure of 395 kg/m^3 determined by Wright (pers. comm.) agreed closely with the figure of 382 kg/m^3 determined from 120 samples of stemwood. Wright's figure was used because it was based on more intensive sampling and had a smaller error.

Data from the samplings were analysed to derive regression equations relating oven-dried weight of fuel components and DBHOB. Knowledge of the diameter distribution of 12-year-old stands enabled the use of the derived relationships to determine the quantity of fuel components in tree crowns.

Detailed measurement of crowns at the time of collection of samples provided information on the distribution of fuel weight and sectional crown volume throughout the crowns.

RESULTS AND DISCUSSION

Fuels on the Forest Floor

The total quantity of fuels on the forest floor averaged 22.71 tonnes/hectare, made up of duff, coarse fuels, needle litter, and fine fuels in the proportions of 0.43, 0.32, 0.22 and 0.03 respectively. Duff and needle litter were more or less continuous and showed little variation in quantity from point to point compared with other components. The average quantity of duff and needle litter was 9.83 t/ha and 4.92 t/ha respectively (Table 2). Consequently in these 12-year-old stands, the needle litter/duff ratio was 0.50 compared with 0.12 and 0.75 for 38-year-old and 9-year-old stands respectively (Williams unpub. data). Thus the duff layer is still building up and the rate of needle fall is greater than decomposition.

TABLE 2

Oven-dried weight and bulk density of fuel components on the forest floor in 12-year-old radiata pine stands.

Fuel component	Number of samples	* Mean O.D. wt. (t/ha)	* Mean bulk density (g/cm^3)
Coarse fuels	100	7.28 ± 3.06	—
Fine fuels	100	0.68 ± 0.16	—
Duff	100	9.83 ± 2.05	0.048 ± 0.010
Needle litter	100	4.92 ± 0.08	0.020 ± 0.005
Total fuels	100		

* Mean figures are given with ± the standard deviation ($p<0.05$)

Measurements of bulk density of needle litter and duff components, showed that although the depth of each of these layers was approximately 2 cm, the needle litter layer was better aerated than the duff layer. The bulk density of needle litter was 0.020 g/cm^3, and for duff was 0.048 g/cm^3 (Table 2). This is important since Brown (1968) found that compactness of fuel influences ignition probability, rate of combustion, and spread and drying pattern of fuel. Needle litter will dry out more rapidly than duff, and is more likely to provide the ignition medium for a fire.

Rate of combustion and spread of a fire will be very much greater in needle litter.

Fuels in Tree Crowns

Constants and co-efficients for regression equations relating oven-dried weight of fuel components and DBHOB are listed in Table 3. Together with the diameter distribution for the 12-year-old stands these enabled the determination of total oven-dried weight of fuels in the tree crowns. This together with percentage contribution of each component is shown in Table 4.

TABLE 3

Regressions derived to determine the oven-dried weight of standing fuel components from diameter breast height according to the equation $\log_{10} Y = a + b \log X$, where Y is oven-dried weight of fuel components (kg), X is DBHOB (cm), a is regression constant, b is regression co-efficient, R is correlation co-efficient, Syx is standard error of estimate, and Sb is standard error of co-efficient, b.

Fuel component	a	b	R	Syx	Sb
Total crown	—0.670	2.164	0.99	0.015	0.101
Total stem	—0.595	1.995	0.97	0.021	0.198
Non-merchantable stem-	2.516	—1.255	0.92	0.029	0.216
Branchwood	—2.285	2.827	0.97	0.040	0.223
Living and dead needles	—1.762	2.175	0.97	0.039	0.201
Living needles	—2.362	2.554	0.89	0.075	0.561

TABLE 4

Oven-dried weight (t/ha) of fuel components in tree crowns in 12-year-old radiata pine stands.

Fuel component	Oven-dried wt. (t/ha)	Fraction of total (%)
Merchantable stems	64.2	55
Non-merchantable stems	20.9	18
Living needles	7.7	7
Dead needles	2.4	2
Branchwood	20.3	18
(a) fine, living branchwood	4.3	4
(b) fine, dead branchwood	2.6	2
(c) coarse, living branchwood	8.3	7
(d) coarse, dead branchwood	5.1	5
Total crowns	115.5	100

On average, living needles in the crowns comprised 3 years growth of needles, so that mean annual growth of needles is 2.6 t/ha. Consequently, dead needle growth, and dead needles lodged on branches in the lower section of the crown (2.4 t/ha) is slightly less than mean annual needle growth. Overall the quantity of living and dead needles in tree crowns is twice that of dead needles on the forest floor.

The relative contribution of crown fuel components for various diameter trees is shown in Figure 1 and this shows that an increase in DBHOB is associated with a decrease in the contribution of the stem. However this is associated with an increase in branchwood so that the percentage of needles is relatively unchanged for varying diameters. This is important for a consideration of the effects of thinning treatments on fuel components resulting on the forest floor. For example, in a thinning operation the removal of the same quantity of stemwood by selecting larger trees, average DBHOB of 30 cm, compared with small trees, average DBHOB of 15 cm, results in 40 per cent more fuel deposited on the forest floor.

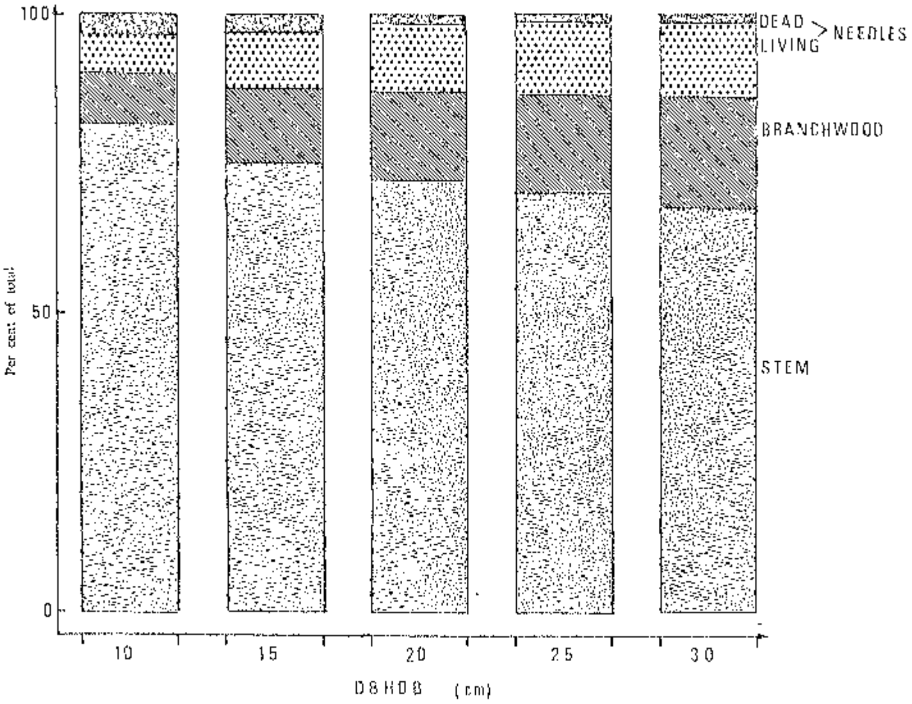

Figure 1
Percentage contribution of crown fuel components in 12-year-old radiata pine trees of varying DBHOB.

Considering branchwood, one third of it is fine fuel so that together with needles in the tree crown and needles and fine fuels on the forest floor, total fine fuel is 22.7 t/ha or 16 per cent of the total fuels. This percentage includes all fuel particles less than 6 mm diameter, but excludes the duff which, due to compactness acts more as a continuous fuel rather than as individual particles. This is important because fine fuels allow ignition and rapid spread of fire.

To investigate distribution of fuels in tree crowns, a regression relating crown volume and DBHOB was determined; this was of the form:

$\log_{10} Y = 1.961 \log_{10} X - 0.465$, where Y is the volume of the crown (m^3), and X is DBHOB (cm)
$R = 0.96$, $Syx = 0.027$, and $Sb = 0.197$

The volume of the dead section of crown showed no relation to the living crown volume and averaged 47 per cent of the total tree volume.

(The dead crown limit is arbitrarily taken as the whorl height at which dead fuels within the whorl constitute less than 10 per cent of the fuels within the whorl).

The density of dead needles in the dead section of crown tended to be constant at 64 g/m^3 (standard deviation (SD) = 16) but was more variable and lower than that for living needles in the living crown (130 g/m^3, SD = 18), and total needles in the total crown (98 g/m^3, SD = 17).

Needle and branchwood weight in tree crowns was normally distributed about the stem with a concentration of weight at a height of 9 m. Distribution of sectional crown volume tended to be skewed at the apex of the tree being concentrated at a height of 6 m.

These results enabled study of the density of needles and branchwood in the crowns. Density increased with tree height at a constant rate according to the equation.

$Y = 16.45\ X - 1.58$, where Y is tree height (m), and X is needle and branchwood density (kg/m^3) $R = 0.99$, $Syx = 0.16$, and $Sb = 0.60$.

The trend was expected since new growth is concentrated in the upper portion of the crown, and needles in the lower portion are dead or dying, or have been shed.

A lower density of needles and branchwood in the crown close to the ground indicates a lower potential for fires to carry into the crown from the forest floor and a reduced rate of spread compared with the upper crown. However, between the heights of 4 and 8 m, tree crowns are intermingled and form a continuous three-dimensional fuel complex which enables fires to spread from tree to tree with relative ease.

The effects of thinning and pruning are to disrupt the horizontal and vertical continuity of fuel so that three-dimensional spread of crown fires is made more difficult and would occur only under extreme weather conditions. However, these effects are confounded by the addition of fuel to the forest floor derived from the actual thinning or pruning operation. With additional fuel, fires on the forest floor will be more intense with higher rates of spread; this will tend to negate the benefits of having vertical and horizontal breaks in the crown fuel complex.

For thinning and pruning treatments to be of most benefit to the protection of plantations, research is required into the reduction, elimination or modification of additional fuels derived from the operations.

CONCLUSION

As fire control operations are becoming increasingly sophisticated the requirement for improved information on fuels and understanding of fuel systems will become more urgent. To this end, fuel quantity and distribution within 12-year-old radiata pine stands have been fully described and provide basic information for fire management decisions.

This description enables the plantation manager to quantify the fuel hazard in such stands and to consider the effects of cultural treatments on the protection of the stands. Post-thinning and pruning fuel hazards can be determined so that the control effort can be geared to meet situations likely to occur, or expenditure on hazard reduction can be justified.

Quantification of fuel hazards in plantations is the first step in their protection. Further research is needed to relate the hazard to expected fire behaviour. For example, parameters related to fire behaviour describing vertical distribution of fuel in tree crowns need to be defined and minimum levels required to support fire in tree crowns under varying conditions must be determined.

Following this, research is required to determine methods of reducing the hazard to less than critical levels through fuel management. These levels may be determined by the expected fire behaviour under extreme fire danger conditions, the risk to life and property, the degree of damage which can be accepted and the available suppression forces.

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