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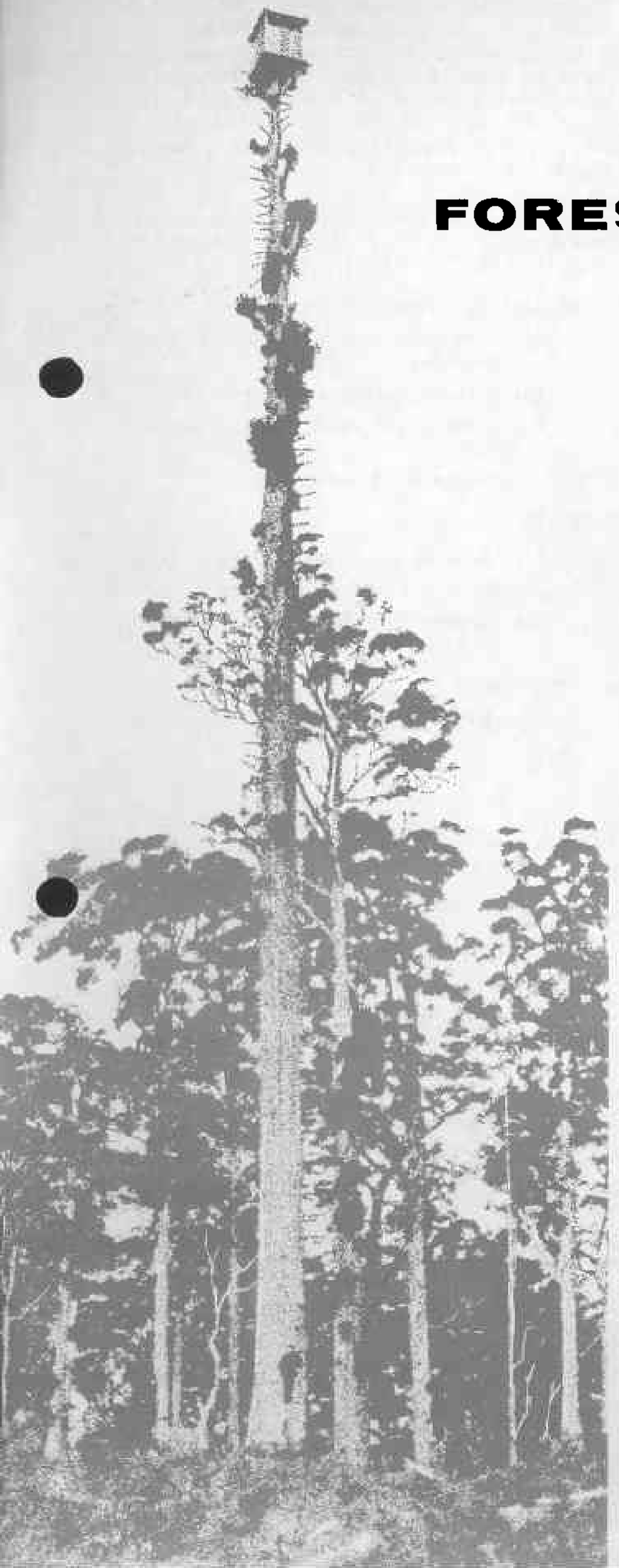

FORESTS DEPARTMENT
OF WESTERN AUSTRALIA
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MEASURING FOREST FUELS

by

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SUMMARY

Objective assessment techniques for estimating forest floor litter and sticks and understorey shrub fuels are described. The reliable and rapid techniques developed in the southern forest of Western Australia enable two men to assess proposed aircraft burns of 4,000–8,000 ha in 3–5 days.

Litter quantity in pine plantations and other valuable, high risk areas can be measured so that its distribution can be mapped. The sampling and mapping techniques described provide quantitative measures of fire risk arising from changes in fuels and provide a reliable basis for the planning of prescribed burning and other fire control operations.

INTRODUCTION

It is essential to know the quantity of fuels present in the forest area when prescribed burning is planned. Litter quantities can often be estimated in the office from records of past burning and forest canopy cover (Peet 1970). However, complications may be caused by insect infestation of trees crowns, trade cutting and incomplete burning. Other fuel components, such as forest understorey vegetation (here called scrub) and trash fuels made up of twigs and dead scrub, cannot be calculated from maps or records.

An objective method for the assessment of fuel quantity, based on direct measurements of litter depth, trash height, and scrub density and height, is therefore needed.

For pine plantations and other valuable high risk areas, a system of mapping litter depths is needed for a quantitative measure of risks due to variation in fuel, which would provide a basis for deciding correct conditions for lighting.

METHOD

Litter Depth and Weight

Litter depth measurements were made with a gauge consisting of a wooden slide between metal rails attached to a scaled stand. The slide was inserted into a small hole made in the litter bed, the depth being read from the scale. The base should not rest on twigs, stones or other debris and there should not be any disturbance or mounding of the surrounding litter.

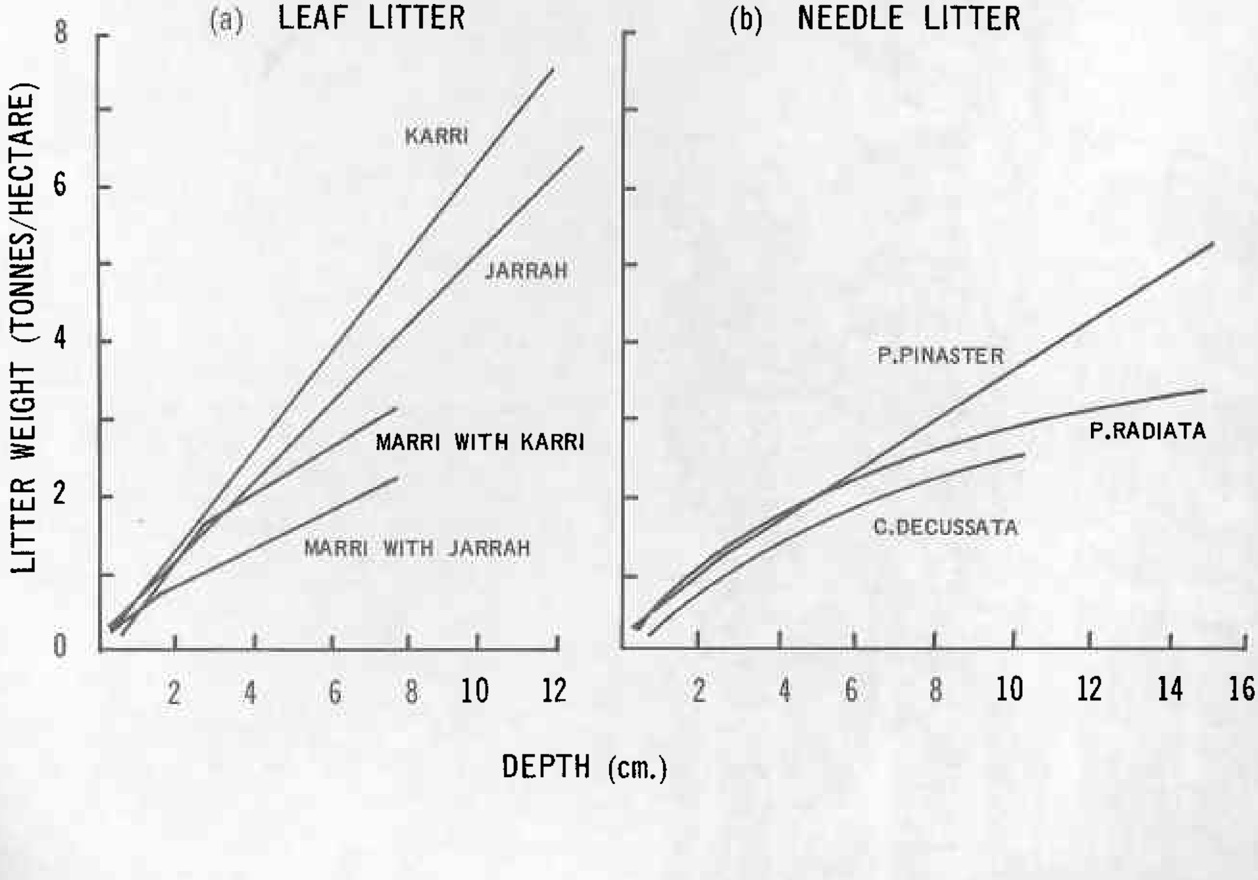
Measurements of litter weight and corresponding depths in four hardwood and three softwood forest types established a close relationship between litter depth and weight for each litter type. The relationships, shown graphically in Figures 1a and b were statistically significant at 95 percent level of confidence and the standard errors did not exceed 15 percent of the mean weight.

The litter types chosen represent the most common ones found in the southwest of Western Australia. They are:

(1) Leaf litter types–
- (a) karri (*Eucalyptus diversicolor* F. Muell) dominant,
- (b) jarrah (*E. marginata* Sm.) dominant,
- (c) marri (*E. calophylla* R.Br.) in karri surrounds.
- (d) marri in jarrah surrounds.

(2) Needle litter types–
- (e) Monterey pine (*Pinus radiata* D. Don),
- (f) Maritime pine (*P. pinaster* Ait.)
- (g) karri-oak (*Casuarina decussata* Benth) in karri surrounds.

FIGURE 1: *Litter depth and weight relationships for leaf and needle litter.*



Tests conducted in various litter types showed that a reliable depth estimate is obtained by taking twelve depth measurements in a straight line at 9.1 m intervals. This sampling intensity ensures that the mean is not greatly biased by local fuel irregularities such as those found in forest openings, on rock outcrops and at the tree base.

Trash Height and Weight

In nearly all karri forests and some marri and jarrah forests the fuel bed includes a trash layer made up of dead tree branches and scrub debris. When dry, this layer is an important fuel component which affects fire behaviour. It is a difficult fuel to assess and so far little has been done towards relating its weight or height to changes in fire behaviour. A rough relationship between trash height and weight was identified, but because of the large variation in the size and density of the individual components an accurate estimate of quantity was not possible.

The field technique used requires a trash top height measurement one metre either side of the litter depth measurements. The top height of trash is the general ceiling of the stick material excluding irregularities such as the occasional tall, upright dead branch. Table 1 lists the oven dry weight of trash for the corresponding trash top height.

TABLE 1

Trash Weight

DEPTH (Metres)	DENSE SCRUB		SPARSE SCRUB	
	Total Trash (tonnes/ha)	Less than 10 mm Diam. (tonnes/ha)	Total Trash (tonnes/ha)	Less than 10 mm Diam. (tonnes/ha)
0.2	12	7	8	3
0.4	25	15	15	7
0.6	37	22	23	10
0.8	49	30	31	14
1.0	62	37	39	17
1.2	74	44	46	21
1.4	86	52	54	24
1.6	98	59	62	28

Scrub Weight

Scrub foliage can slow the drying of litter on the ground but it adds to the fuel; as such it can determine whether or not ignition will occur and can control the degree of tree scorch and damage.

Previous methods of measuring scrub density, height and quantity have been subjective visual estimates based solely on the assessor's experience. An objective method of appraisal carried out at the same time as the ground fuel assessment has been devised. This method used a point sampling technique based on that of Levy and Madden (1933) and modified by Sneeuwjagt (1971). A thin, graduated rod is inserted vertically into the scrub. The number and height of the contacts made with the rod are then recorded.

To obtain scrub weight estimates, the scrub is classified into one of six structural types differentiated by density profiles and top heights. Each structural type can have a variety of dominant species types, but these must have a similar height-density profile in order to belong to that structural type. Also a particular scrub species can belong to more than one standard type depending on the age and development of the individual plant.

Figure 2 shows the density profiles of the six standard types, with each type broken down into sparse, medium and dense according to the average number of contacts per rod at each height interval.

A scrub community is typed by taking twenty point-samples randomly from both the sparse and dense communities within an area, and then preparing a scrub height-density histogram. This histogram is then matched with one of the six standard type histograms to give the structural type for the area. Scrub fuel weights listed in Table 2 for each of the six structural types are weighted according to the average cover density and top height of the scrub type. The table provides the oven-dry weights in tonnes per hectare for the total scrub, the scrub foliage and the foliage below 1.2 m. The latter is the amount normally burnt in mild prescribed fires.

Table 2 shown below, is an abbreviated form of the table actually used in practice. It gives only the extreme values for each type.

TABLE 2

Scrub Weight Table

Type	Average TopHeight (metres)	Total Live Scrub (tonnes/ha) D	M	S	Total Foliage (tonnes/ha) D	M	S	Foliage below 1 metre (tonnes/ha) D	M	S
1	8	40	34	30	8	7	6	1	1	1
	5	22	19	17	6	5	4	1	1	1
2	8	47	41	37	9	8	7	3	2	1
	5	31	28	24	7	6	5	2	2	1
3	3	18	12	7	5	4	3	1	1	1
	1	5	4	2	3	2	1	2	2	1
4	6	30	24	19	8	7	5	1	1	1
	4	18	12	6	5	4	2	1	1	1
5	6	34	26	19	7	6	5	1	1	1
	3	13	11	8	5	4	3	1	1	1
6	2	7	5	4	4	3	2	4	3	2
	1	2	2	1	2	1	1	2	1	1

D = Dense scrub, M = Medium, S = Sparse

FIGURE 2: *Scrub height-density profiles of six standard scrub structural types.*

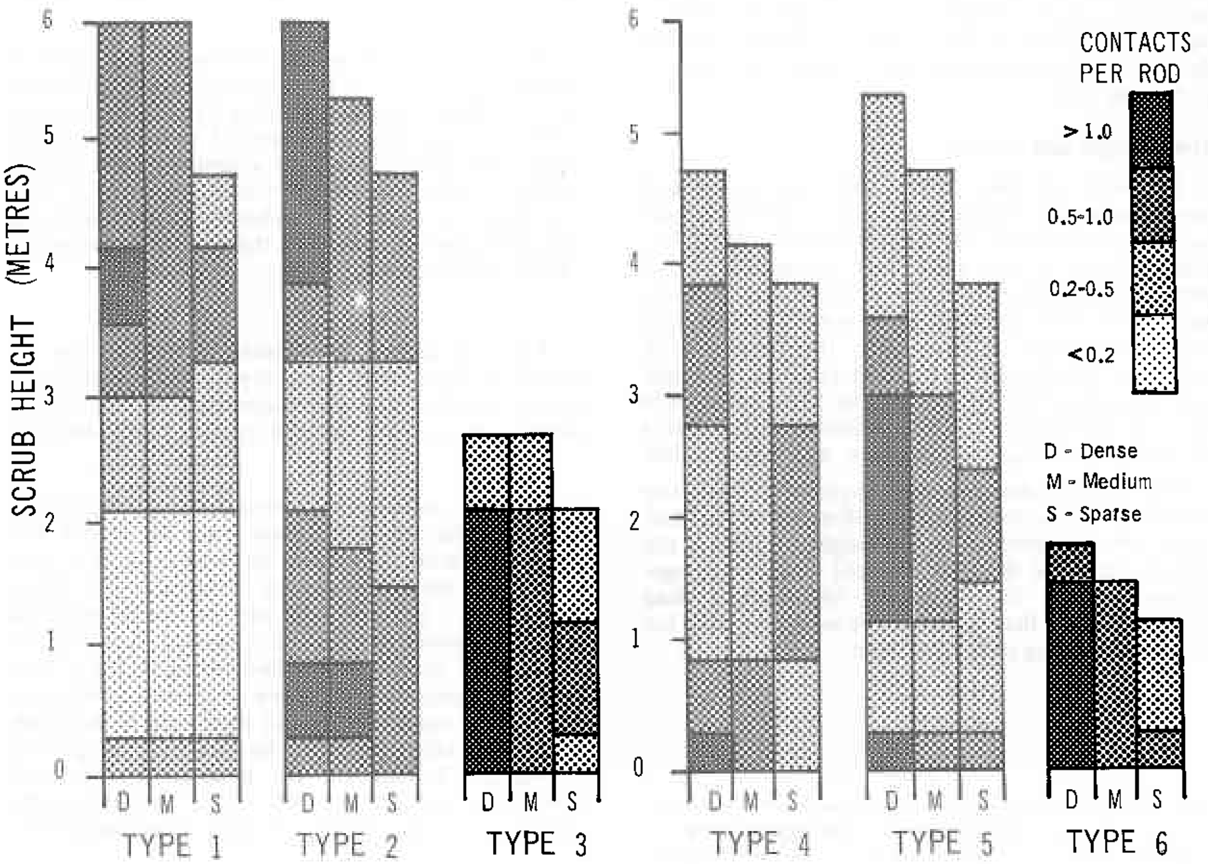


TABLE 3
Scrub Inflammability Factors

Foliage Characteristics and Flammability Rating	Scrub Structural Type					
	1	2	3	4	5	6
	Scrub Flammability Factor					
Poor Inflammability 1. Foliage Generally: often large (width 20 mm plus): fleshy, not dry; young, green; not cured; often widely spaced; contains little or no inflammable oils or resins. In Scrub community: dry inflammable grasses usually absent, dry live fuels often absent in lower structural strata. e.g. Hazel, Karri Wattle, *Ac. urophylla,* rushes.	1	2	3	3	2	3
Medium Inflammability 2. Foliage generally: medium size (width 8–20 mm) mature, but still green, less than ¼ foliage cured, often closely spaced; inflammable oils and resins may be present. In community: low scrub levels may contain dry, flammable grasses; foliage often close to ground. e.g. Netic, Blue Hovea, Shark's Teeth, bracken.	2	4	8	6	3	10
High Inflammability 3. Foliage generally: fine, small (width less than 4 mm) mature, often dry, mostly cured; often compact; often contains inflammable oils and resins. In community: lower scrub levels contain abundant inflammable grasses and other live or dead fuels close to ground. e.g. *A. pulchella, A. strigosa, Casuarina,* Kerosene grass.	3	6	20	10	8	20

Scrub assessment can be done in conjunction with the litter and trash fuel assessments. In addition to the scrub type other parameters are required to derive reliable scrub fuel loadings. These include scrub top height, estimated percentage of dead or cured scrub, and dominant species present. Because scrub inflammability varies with species, it is necessary to introduce a flammability factor based on the characteristics of the particular species, and the percentage of dry scrub.

Table 3 lists the flammability factors for the common scrub communities. The scrub foliar weight (Table 2) is multiplied by this factor to give the scrub fuel loading which is added to the litter and trash weight estimates.

FIELD APPLICATION

Sampling Intensity

The fuel sampling techniques described above allow for reliable estimation of fuel quantity on large areas. Three factors which must be considered when planning the sampling intensity and assessment procedure, determine the number and location of sampling sites required. The first consideration is the importance of the area in respect to the value of the timber, the presence of regeneration and its proximity to private property. The second is that sampling intensity must increase with diversity of the area sampled, whilst the third is the ease of access.

Stratified sampling is employed on large areas of 3,000–8,000ha. This will give the fire manager a range of fuel quantities and fire hazards on which to base his planning of burning prescriptions and lighting procedures.

Planning of Assessment Precedures

The location of sampling lines must be carefully planned. It is important to assess the full range of forest situations and fuel types in order to reduce costs and damage from the prescribed burning operations.

Sampling design is based on a combination of maps showing past burning patterns, forest types and canopy densities respectively.

A number of field tests have shown that the average forest requires a set of twelve 100 m traverses, with ten point samples taken along each. It takes a team of two men about 20 hours to complete the field sampling over an area of 6,000 ha. Further six manhours are needed to complete preparations and calculations in the office. The overall cost is small in comparison with the potential value of the timber at stake.

Fuel Contour Mapping

High-risk and valuable areas, including pine plantations and young hardwood regrowth stands, require a more accurate assessment of fuels than the large areas considered above. In such areas it is desirable to know the distribution as well as the quantity of fuels.

A fuel mapping technique has been developed (McCormick 1973) in which fuels within similar fuel depth-weight classes are joined together by iso-lines, providing a quantitative measure of risk arising from variations in fuel. The method used in pine platations incorporates the measurements of litter depths on a grid. Most stands can be measured on a 60 m x 60 m grid, but those with markedly variable fuels need to be sampled at a greater intensity. The edges must also be sampled as these zones often contain deep, dry litter beds which will burn hotter than the internal areas. Scrub fuels normally play a minor part in pine plantations fire behaviour and therefore are not sampled in detail.

Recently thinned stands also need to be assessed for ground fuel resulting from thinning. McCormick (1973) has shown that a strong relationship exists between the butt girth of the crown and the quantity of needles and twigs within it. He found that by measuring a random selection of crowns placed on the ground by thinning operations, the quantity of flash fuels present in a compartment can be determined. The derived weight can be added to the litter weight assessed by depthing and the total used in the burning prescription.

In young hardwood stands, which are normally not burnt for 15 to 20 years following regeneration treatment, unfavourable combination of heavy fuel accumulation and vulnerable trees results. Reliable and accurate burning prescriptions for such stands are essential and can only be achieved using the fuel contour mapping procedures described above for pines. However the sampling in hardwood regrowth areas does not need to be as intense as in pine stands, a 200 m x 220 m grid being adequate (Ward 1971).

The sampling results are entered on to maps already showing forest types and canopy densities, and if possible, topographic features. These maps form the basis of planning of prescribed burning and fire suppression operations.

CONCLUSIONS

Quantitative estimates of forest fuels required for prescribed burning and fire control practices can now be made objectively. Sampling procedures are more time consuming than the subjective methods previously employed, but assessment costs are negligible compared to possible losses of timber value and potential crop trees by fire through lack of understanding of fuel structure.

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