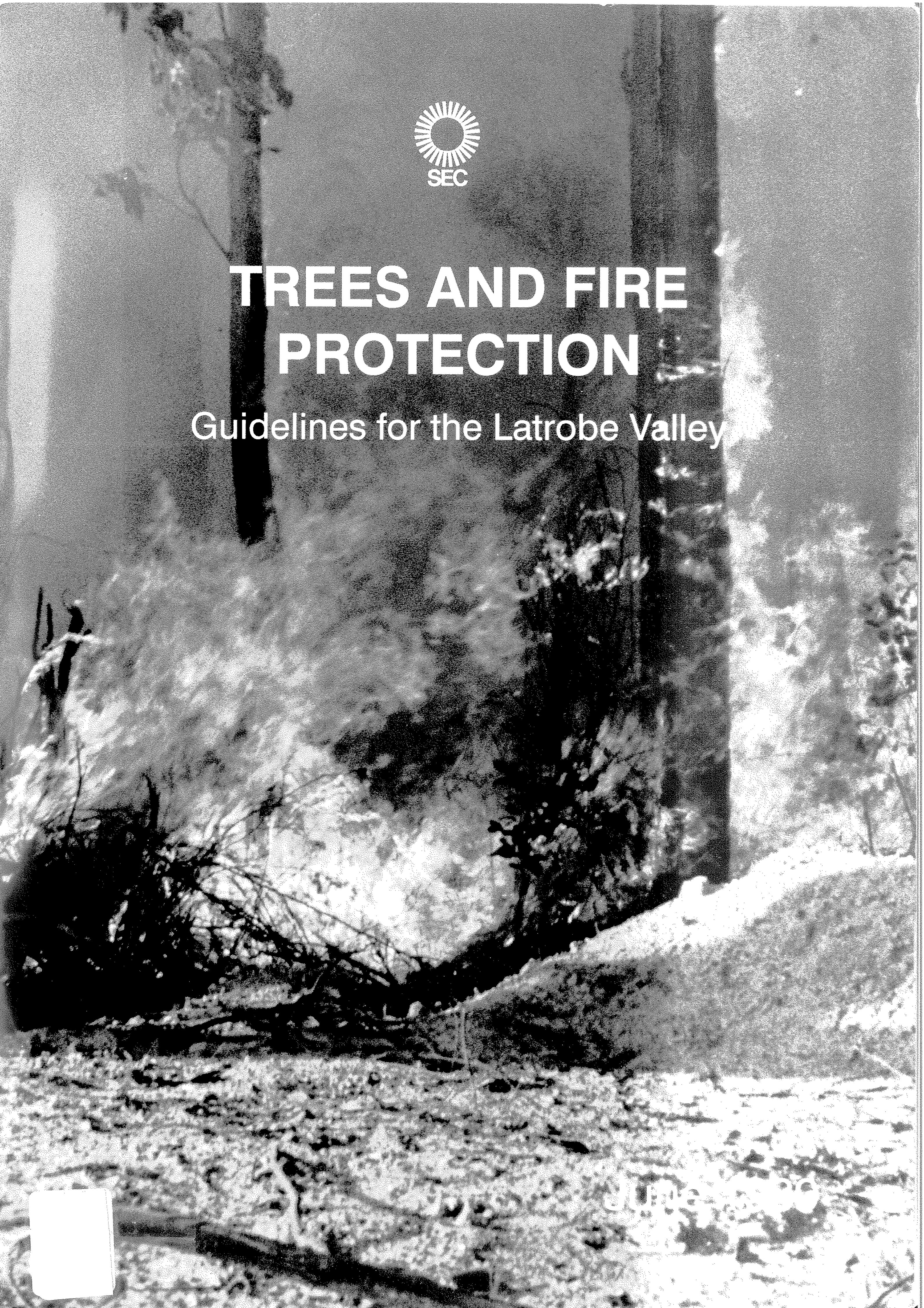


SEC

TREES AND FIRE PROTECTION

Guidelines for the Latrobe Valley

June [illegible]

TREES AND FIRE PROTECTION

Guidelines for the Latrobe Valley.

JUNE 1989

LAND SERVICES
SEC
Quality & Service

By D Francis
A Tegart

PREFACE

We have drawn heavily on existing literature to support our own experiences and knowledge of the technical concepts contained in this paper. We are most aware of the sporadic nature of disastrous wildfires and, sadly, of the ebb and flow of community fire risk consciousness. Yet there is a certainty that disastrous fires will reoccur and there is a continuous need to evaluate the methodology of fire protection and it's significance in land management decisions.

Land management planning occurs in two stages; firstly, looking at the scope of the plan and secondly, a more detailed and thorough assessment of all contributing elements. We believe this document fills one void in the second stage.

We greatly appreciate the range of valuable comments and positive suggestions we received following the wide distribution of our draft documentation both within and outside the SECV.

David Francis
Andrew Tegart

TABLE OF CONTENTS

TREES AND FIRE PROTECTION GUIDELINES FOR THE LATROBE VALLEY

1 INTRODUCTION

The SEC plants significant numbers of trees in the Latrobe Valley as part of its landscaping and land rehabilitation responsibilities.

An important consideration for the SEC in discharging this responsibility must be the threat of rural fires. The SEC needs to consider not only the protection of its own substantial assets but also the fire risk to adjacent landholders. Open cut mines, with their large areas of exposed coal, are particularly at risk from major fires.

It is well recognised that the careful selection and placement of trees can enhance the local environment and reduce the risk of rural fires. Fire protection is an important factor in the many considerations affecting land managment decisions. Where necessary, low flammability tree species planted in an open woodland pattern is the Commission's preference in achieving a balance between fire protection and other environmental considerations.

This paper outlines the guidelines to be followed in establishing low fire risk revegetation areas. The paper should be considered in conjunction with guidelines established in:

SECV Latrobe Valley Open Cuts Fire Protection Policy 1984 (reference 1)

Policy for the Protection of SECV Latrobe Valley Assets from Rural Fire 1986 (2)

SECV Rehabilitation Policy for Open Cuts and Overburden Disposal Areas 1986 (3)

2 DISCUSSION

There are a number of technical characteristics of trees and fire behaviour which influence the selection, distribution and management of vegetation in such a fire sensitive region.

The following discussion summarizes a number of the key principles and culminates in a case study on wetland construction that examines the application of these principles.

2.1 Trees and Bushfires

The propagation of a fire through any combination of grasses, shrubs or trees is a very complex chemical, physical and environmentally controlled process. Modify any of the chemical, physical or environmental factors involved and the intensity, speed, shape and controllability of a fire will change.

Techniques of fire suppression capitalise and build on those factors which are not conducive to sustenance of the fire and keep most aware of those factors that contribute or add to the impetus of the fire. Thus, any land management action, including tree establishment and maintenance, should aim not to further complicate wildfire behaviour and its ultimate control; if this consideration is overlooked then not only are residents and assets put at further risk, but the hazard to firefighters is also extended.

Features associated with the selection and establishment of trees, which have the most impact on the spread and intensity of fires include:

- flammability characteristics of woody plants
- the spatial arrangement (in three dimensions) of the plantation;
- the topography; and
- the degree of site and tree maintenance.

2.1.1 FLAMMABILITY CHARACTERISTICS OF WOODY PLANTS

Dry dead grass, leaves, bark and twigs are those materials which ignite and burn easily.

Vegetation must be raised to its ignition point (that is the temperature at which it begins to burn) before it will burst into flames. For example, cellulose ignites at 325°C (4). Fuels in front of the fire are heated by electromagnetic waves (radiant heat), whereas fuel above the fire (eg shrub and tree crowns) is heated predominantly by hot rising air (convected heat) and often produces burning embers (5).

Trees and other vegetation have a number of important chemical and physical properties which vary their flammability in this combustion process. These are :

i Moisture Retention Properties of Leaves and Twigs

Moisture in the fire fuel promotes partial combustion and enhances smoke formation, whereby the evolution of heat is decreased. The rate of combustion is also lowered. Additionally the presence of water vapour within a flame substantially lowers its radiant heat output. Hence wet fuels burn less fiercely and radiation from the flames is less (6).

How easily green leaves burn depends largely on their moisture content. The moisture content in the leaves and twigs of living plants is governed by their physiological processes (uptake, transpiration, etc). The normal water content of the leaves of most Australian trees and shrubs is about 80 - 150% of their dry weight. Introduced deciduous trees have moisture contents of 200 - 300% and evergreen hardwoods and conifers have moisture contents less than 250% (7). Lush vegetation may have a moisture content up to 500% greater than its dry weight (5).

However, evergreen vegetation can be dried out by the advance radiant heat of an intense sustained wildfire, especially if the plants are also dehydrated because of dry soil and climatic conditions.

Some plant species are adapted to drought conditions, but all species have a minimum available moisture requirement to survive.

It will not be possible to grow to full size some of the species that have very high leaf moisture content on dry sites, because there is simply not enough available moisture to support this growth. Additionally, few tree species adapted to dry sites also have relatively high "normal" foliage water content. Species that have leaves with a small surface area/volume ratio reflect a species adapted to drought stress and which have a low leaf moisture content.

ii Ash or Mineral Content of Leaves

Some plant species that have high mineral contents in their foliage are more difficult to ignite. This is because some minerals promote smouldering or charring rather than flaming combustion. Most eucalypts and native species have ash or mineral contents in their leaves which are of less than 3% of oven-dry weight, while conifers have ash contents greater than 3% (8). Other evergreen and deciduous species generally have ash contents of 8% (8) with Tamarix spp. species having 40% and Myoporum insulare having 23% (9). The group of minerals which contain phosphorous and sulphur as salts are primarily responsible for reducing flammability. An obvious practical application lies in the selection of plants having low flammability because of their high mineral content.

A number of researchers have detected this correlation between the flammability of leaves and their mineral content. A good example demonstrating this correlation for various Australian plant species is provided by the following table adapted from King & Vines (6);

Species	Crude Ash %	Sulph. Ash %	Total Mineral %	+Relative ease of Burning
Tamarix	39.5	26.4	9.30	very bad
Phytolacca octandra	30.9	25.8	11.05	very bad
Physalis peruviana	30.0	22.1	6.10	very bad
Ficus fraseri	20.2	14.3	5.59	?
Bedfordia salicina	14.1	13.1	6.35	bad
Myoporum insulare	23.0	16.6	9.65	bad
Lantana camara	19.9	17.0	4.88	?
Solanum sporadotrichum	22.9	15.0	7.39	bad
Coprosma	14.4	11.8	4.88	bad
Solanum auriculatum	16.4	14.8	4.09	fair
Acacia longifolia, var. sophorae	21.7	11.6	7.39	fair
Dioscorea transversa	14.0	-	4.14	good
Acacia maidenii	10.2	6.9	2.86	good
Cissus antarctica	21.7	9.8	2.91	good
Legnephora moorei	11.1	-	2.56	fair
Eucalyptus acmenioides	10.0	5.8	2.43	good
Eucalyptus saligna	7.7	8.4	2.49	very good
Tristania conferta	12.7	5.9	2.66	very good
Eucalyptus ficifolia	7.1	6.9	2.49	very good
Orites excelsa	18.4	5.4	2.14	very good
Representative mixed eucalypt	7.0	4.2	1.82	excellent

+ Relative ease of burning represents a range of flammability for the sampled species extending from "very bad" to "excellent". "Very bad" means that flaming combustion could scarcely be maintained after withdrawing the leaf from a Bunsen flame, while "excellent" means that flaming combustion was easily maintained. It was found that each species could be placed in one of the classes contained in the above range with considerable certainty and reproducibility (6).

Mineral content can be supplemented by the presence of such fire retarding substances as inorganic salts - the most usual being NaCl. Many plants growing on saline soils inevitably absorb fairly large quantities of salt, which reduces their flammability, often quite considerably (7). Reduced flammability due to salt is generally a reflection of both -

a the tree's ability to tolerate relatively high salt concentrations, and
b the fact that the salt is prevalent on the site and not really because of a deliberate high salt uptake.

The foliage of Athel trees (Tamarix spp.) is notoriously hard to burn even when dry, due to the high concentration of salt it contains. Saltbush (Atriplex spp.), Blue bush (Maireana spp.) and Rhagodia spp. react similarly, while the reduced flammability of salt tolerant Eucalypts when growing in saline soils is believed to be due to the higher salt content of the leaves (7).

iii Presence of Volatile Oils and other Extractives.

Some green foliage contains volatile oils, resins and waxes which are extremely flammable (4). These high energy compounds are extremely important from the point of view of flammability, for they easily facilitate ignition at relatively low temperatures and also because most of the time they are at or near the surface of the plant parts particularly the leaves (10). Volatile oils will also stimulate combustion in moist fuels which would otherwise be non-inflammable (6,9,10). They have been found to produce a similar effect in leaves that have a high ash or mineral content; the burning rate of such leaves is very slow but it is substantially increased with the incorporation of a relatively small amount of volatile oil (8,9).

The volatile oils (terpenes) in, for example, eucalypt leaves facilitate flammability by significantly increasing the initial rate of combustion: they can form volatile mixtures well in advance of the flame front in a fire and account for the high flammability of many Australian forests as well as the common occurrence of crown fires (11).

The living leaves of many Eucalypts contain volatile oils in concentrations ranging from 0.5 - 4% (12); members on the family Myrtaceae including eucalypts, tea-trees, melaleucas and bottlebrushes contain volatile oils in the range 0.1 - 5% with most in the range1.0 - 2.5% (7) and conifers generally range from 0 - 2% although some cedars and pines can reach as much as 6% (10).

Added to this oil content is the character of the oil in itself; low ignition points characterise those oils found in the Myrtaceae plant family (13). In most species the ignition point is below 100°, down to 80° for some eucalypts, compared with 180° - 200° for most introduced conifers and 350° for flammable gases such as carbon monoxide and methane (7).

Much of the inherent differences in inflammability between species is due to differences in the content of volatile oils and other extractives (10).

iv Crown Density

A high crown density affects wildfire behaviour by influencing wind movement, shielding or absorbing radiant heat, filtering aerially borne embers and suppressing ground vegetatiion. Dense crowns also tend to indicate high foliage moisture contents as the tree could not support such a canopy without adequate available moisture. However, dense canopies often suppress lower branches of the tree and can cause build up of dead branch, twig and leaf debris within the tree crown and this is a real fire hazard : it can often occur in conifers and produces a continuous vertical distribution of well-aerated fuels from ground level into the tree canopy. Those tree species that have an efficient self-pruning habit, such as eucalypts, are less likely to cause the same problem as those species which are not self pruning. Gaps in vertical continuity of about 1½ flame heights will virtually preclude the fire from burning into the overhead stratum (10). However independent crown fires may occur in dense shrublands as in the case of dense tea-tree thickets which may burn even when the surface fuels are saturated with water : independent crown fires can also occur in dense unpruned conifer plantations (11) see Figure 1.

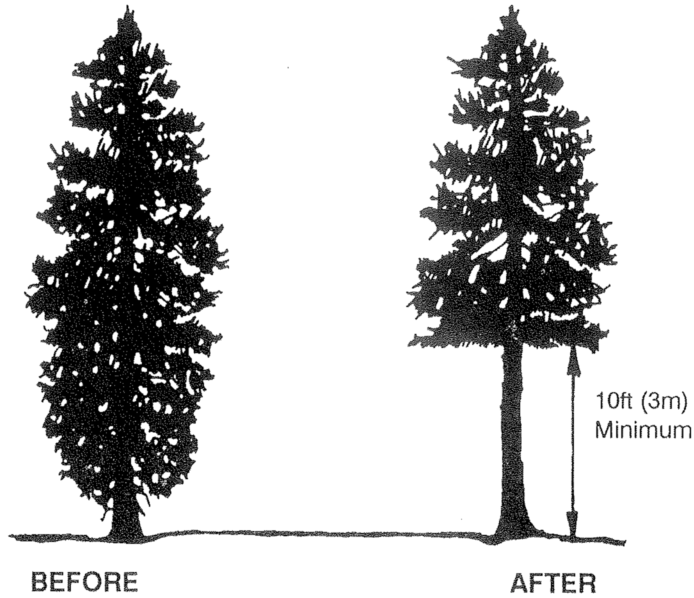


Fig 1. Pruning should remove the live and dead branches a minimum of 10ft (3m) from the ground. This reduces the probability of surface fires spreading into the crown. (from SCHMIDT et al 1987 (27))

Effect of crown density is further exemplified in eucalypt forests, where most of the trees do not tolerate deep shading, a considerable amount of light is admitted to the forest floor and often allows the growth of shrubs up to a few metres in height (5).Some shrub species are naturally flammable owing to, for example the oil content of their leaves, but the availability of shrubs as fuel generally depends on the amount of pre-heating to which they are exposed by fires burning in the surface litter. If the shrubs do ignite, their heat output and flaming may be sufficient to ignite the crowns of sapling and pole-sized Eucalypts or the understorey trees of other species which if these burn it may in turn be sufficient to cause ignition of the tree canopy. This demonstrates how crown density, by affecting the composition and quantity of understorey vegetation, has an effect on move ment of fire from ground level to tree canopy - it also shows that low crown densities will necessitate some artificial manipulation of understorey (and ground storey) fuels to prevent this passage of fire.

The effect is not restricted to Eucalypt forests, for example, fuels in conifer forests com monly form the same "ladder-like" pattern from the forest floor into the crowns of the main tree canopy (14); a diagramatic representation is attempted in figure 2.

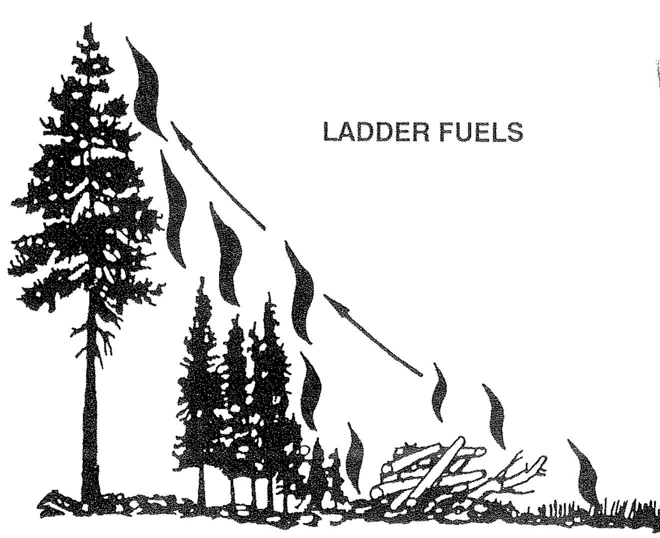


Fig 2. Fuels in this illustration form a ladder-like configuration that contributes to fire hazard. Removal of any of these fuels is similar to reducing rungs in a ladder.. it makes it harder for fires to climb the fuel ladder. (from SCHMIDT et al 1987 (14))

v Integrity of the Bark and How it is Shed

This is a particularly important factor and varies considerably between species. An accumulation of loose dead bark along the trunk of the tree is ideal fuel to carry fire from the ground up into the tree canopy. Gill and Ashton (1968) showed that, in eucalypts, fibrous bark as found on Stringybarks was more flammable than the subfibrous bark found on Peppermints which in turn was more flammable than the gum-type smooth barked species that shed (decorticate) dead bark in plates (15). Bark that sheds in long streamers which burn slowly and have good aerodynamic properties is the precursor for spotting during a fire : this involves ignited streamers of bark or "firebrands" being picked up by the wind and carried forward of the main fire front, then land and start new fires.

This mechanism was responsible for the ignition of Yallourn Open Cut Coal Mine in 1944, 1982 and 1983 from wildfires burning in nearby forests (2). In a number of Eucalypt fuels, spotting distances far exceed those recorded in overseas forests; distances of 30 km have been authenticated in Australia (5,10,11).

Such long distance spotting is characteristic of Eucalypt species with "candlebark" and it is often found on those trees with smooth bark at least on the upper trunk and above branches; eucalypts falling into this category include E.regnans, E.delegatensis, E.viminalis,E.rubida, E.fastigata, E.cypellocarpa. Rough barked eucalypts such as the stringybarks tend to have heavier less buoyant bark, but their capacity for concentrated mass short-distance spotting in the usual range of 3-5 kms is well known and most common; if the number of ignition points from mass spotting is high enough a firestorm effect can result.

Conifer plantations have been recorded in Australia as spotting to 3 Kms, but it is more frequently experienced at distances within 0-1 km range; the spotting media here is not bark but cone bracts or bunches of dead needles caught in the upper branches. The direction in which burning firebrands will be blown is often difficult to predict accurately as in a lot of cases the direction will be different to ground level wind direction.

vi Height of the Tree

The height of a tree affects virtually all of the features mentioned above in that taller trees generally achieve a greater separation of their crowns from ground level, have a greater impact on wind movement by providing a greater surface area resistant to wind, and they elevate potential spotting material further making it more susceptible to wind transport. Taller trees can act as a filter for high level air borne embers and thus reduce spotting movement. If the crown does burn however, the greater elevation makes spotting material more susceptible to wind transport. When the fuels to be lofted are already above the ground surface, (eg. barkplates, leaves, conifer cones), they can be lifted directly by the hot gases rising from fire in the ground litter below : conversely, when the fuels are lying on the ground surface it takes considerable turbulent energy to lift them into the convection column (10).

vii Tree Age

All plants become dried out as they get old and as they senesce more dead material is made available to fuel a fire. Figure 3 demonstrates a range of trees exhibiting various degrees of senescence and once ignited pose major difficulties to fire control.

Young trees have a greater proportion of living tissue and consequently have a higher moisture content relative to older trees.

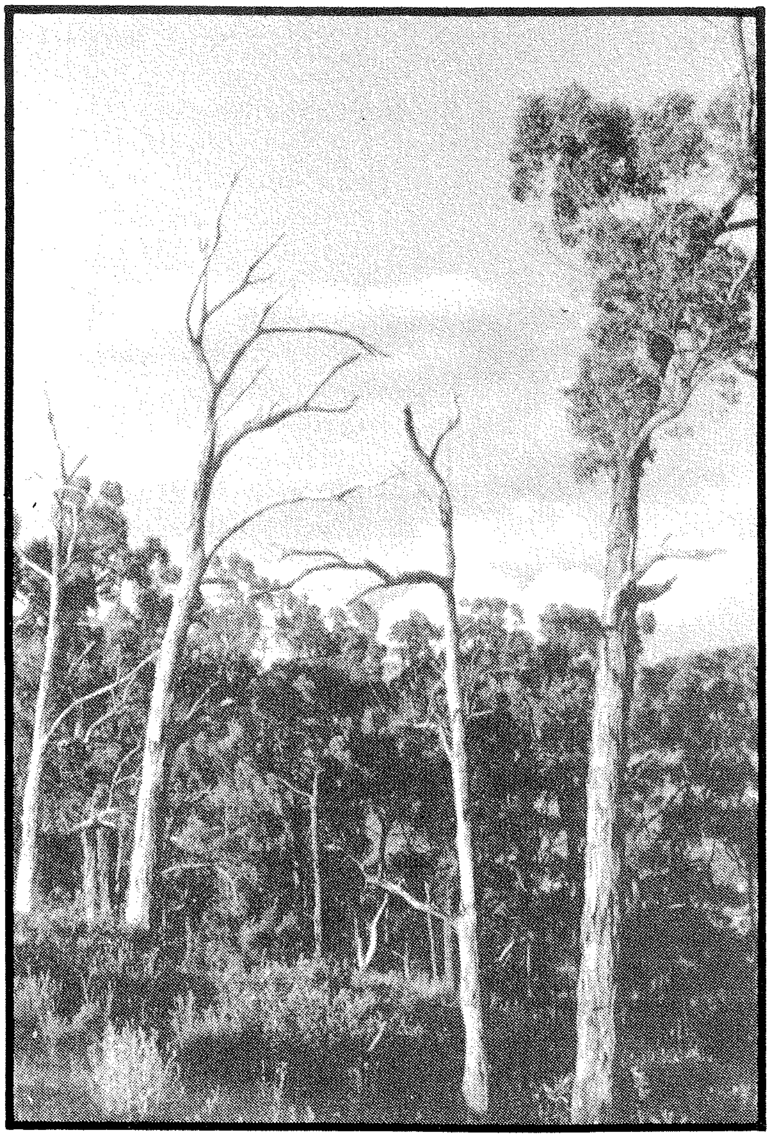


Fig 3.
Open Eucalypt forest near Yallourn in the Latrobe Valley containing a range of dead and dying trees. Dead timber ignites easily under wildfire conditions and if standing will elevate the fire and usually produce a shower of live embers. These embers can be transported further afield by wind. Such dead timber, especially once alight, are an obvious safety hazard to fire fighters.

viii Surface to Volume ratio of fuels

Thin fuels ignite more easily than thick fuels because they have less mass to be heated. Fuels with a large surface/volume ratio will ignite more easily than those of the same size with a smaller ratio because they will intercept more radiant heat (10). (Any combustible volatiles contained in the fuel can mix with oxygen only after diffusing across the fuel surface boundary layer and naturally the higher the surface/volume ratio the more advantageous it is for this diffusion to occur.)

Conifers have surface/volume ratios in the range of 189 - 380 cm^2/cm^3 (16,17). Most literature available on surface/volume ratios has its origins in North America : the table below is borrowed from this literature but it does serve to indicate the range of surface/ volume ratios exhibited for a variety of vegetation from grasses to small and wide broadleaf species to conifers to twigs (as represented by cylinders of varying diameters). A number of species listed below are commonly propagated in Australia.

Thickness and Surface/Volume Ratio of Some Common Forest Fuels
(from Chandler et al 1983 (10))

Material	Thickness (Cm)	*S/V Ratio
Medusahead (Taeniatherum asperum)	0.005	380
Wiregrass (Aristida stricta)	0.007	286
Pinegrass (Calamagrostis rubescens)	0.008	240
Beech Leaves (Fagus sylvatica)	0.009	222
Cheatgrass (Bromus tectorum)	0.011	189
Maple Leaves (Acer rubrum)	0.013	154
Western Larch Needles (Larix occidentalis)	0.014	184
Hickory Leaves (Carya spp.)	0.016	125
Scarlet Oak Leaves (Quercus coccinea)	0.018	111
Western Hemlock Needles (Tsuga heterophylla)	0.024	100
Rhododendron Leaves (Rhododendron catawbiense)	0.025	80
Madrone Leaves (Arbutus menziesii)	0.028	71
White Pine Needles (Pinus monticola)	0.034	91
Douglas Fir Needles (Pseudotsuga menziesii)	0.045	69
Engelman Spruce Needles (Picea engelmannii)	0.067	54
Norway Spruce Needles (Picea excelsa)	0.084	43
Twigs (Cylinders)	0.1	40
Twigs (Cylinders)	0.5	8
Twigs (Cylinders)	1.0	4
Twigs (Cylinders)	2.0	2

ix Regeneration Capacity

The regeneration capacity of trees does not itself affect wildfire behaviour, but it should be considered from the point of view that if a tree is killed by wildfire, then not only does it have to be replaced and "grown again", but also the dead material remaining must be treated so that it will not provide fuel for any future fire. For example, most of the eucalypt species have an ability to survive quite severe fires by epicormic and/or ligno-tuberous regrowth in a short period, thus avoiding the need for replacement. Introduced deciduous trees, such as poplars and willows, reshoot from roots, and oaks (Quercus spp.) reshoot from stumps when the fire killed crown and trunk is felled : most pines will not recover if more than half their foliage is burnt (18).

Morphological traits which enable plants to survive fires may be grouped into two categories : one group is characterised by vegetative regrowth, the plants typically possessing thick protective bark, lignotubers and dormant buds; the other group by production of large quantities of seeds protected from radiant heat by a variety of means such as capsules and hard seed coats (19).
It is not uncommon to find a combination of both strategies in the one species (11).

2.1.2 SPATIAL ARRANGEMENT OF A PLANTATION

Experience has shown that most difficulty in controlling fire occurs when fuels have a three-dimensional arrangement so that crown fires can develop (5).

In a plantation situation, well spaced trees present the least fire hazard, provided that underlying fuels are kept to a minimum. Many trees, which are not inherently fire-retarding, can be made relatively so by reducing fuel loads beneath them.

Trees planted close together will enable easy carriage of fire from crown to crown. Trees that are well spaced cannot support such a crown fire. A good rule of thumb is to re move enough trees to reduce crown cover to less than 35% with a minimum of 3 metres (10 feet) of open space between crowns (20) - see figure 4.

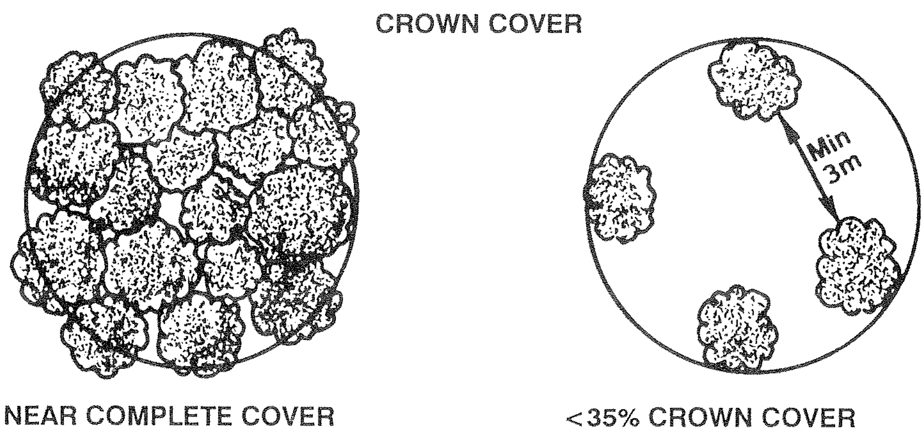


Fig 4. Stands should have crown cover at less than 35 percent with a minimum of 3m (or 10ft) between crowns. This greatly reduces the probability of fires spreading laterally from crown to crown. (from DENNIS 1983 (28))

It is therefore preferable to avoid dense clumps of trees and shrubs. Where clumps are needed they should be kept small and discrete and composed of low flammability characteristic species.

Parallel symmetrical rows can create wind tunnels and/or turbulence and can even modify wind flows to cause such unpredictable fire behaviour as fire whirlwinds. Any windbreak (including the highly efficient semi-permeable type) can cause erratic behav iour of wildfires that are larger than that area influenced by the windbreak on windy days. Conversely, well designed and maintained windbreaks can provide some additional localised protection to small areas in the lee of the windbreak by acting to reduce wind speed, by filtering aerially borne firebrands, by absorbing radiant heat and by deflecting heat and smoke laden winds (see Figure 5). Use of such windbreaks can be considered in specialised situations where localised protection is required.

Tree plantations that consist of a range of tree heights from shrub level to upper storey, only enhance the risk of fire moving from ground level to the canopy (refer back to figure 2) and it is essential that plantations of this type have the trees well spaced.

Spaced trees have the added benefit of facilitating access for both fire control operations and plantation maintenance activities.

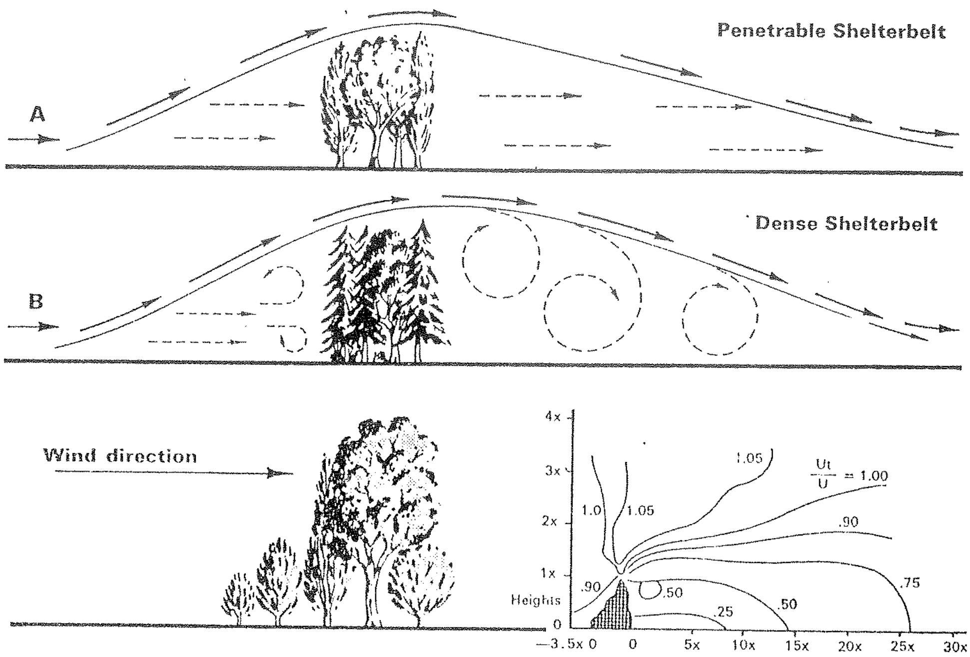


Fig 5a. The effects of windbreaks upon wind movement. (from Hall et al 1972 (25))
The effect of a 5 row shelterbelt on wind speed. A cross section of the belt is shown on the left, and changes in wind speed about the belt on the right. Distances and heights on the graph axes are expressed in multiples of shelterbelt height. The area lying between lines of value Ut/U = 0.25 and 0.50 would experience wind velocities ranging between one quarter and one half of those which would occur in the absence of the shelterbelt. (U = wind velocity without shelterbelt; Ut = wind velocity with shelterbelt in position.)

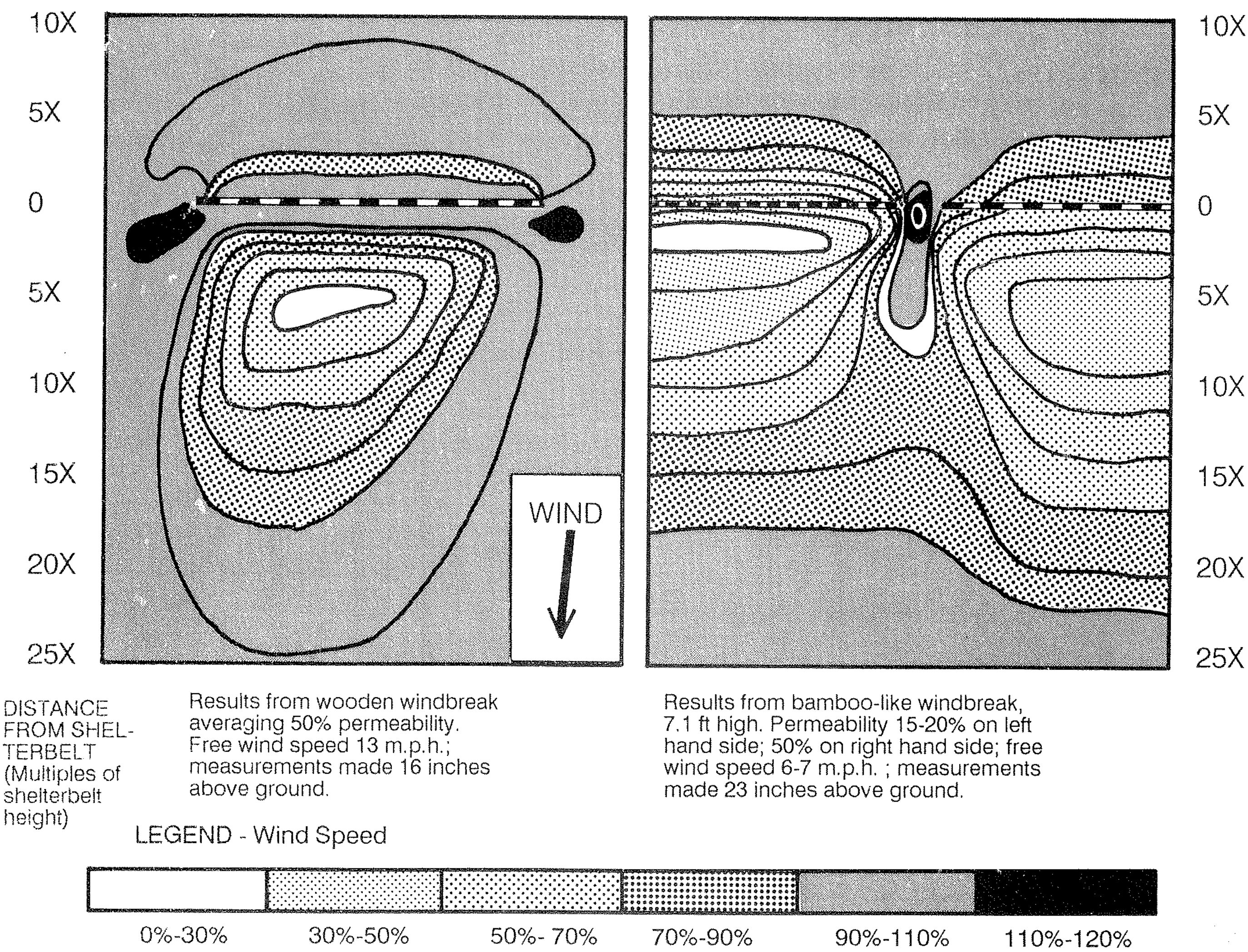


Fig 5b. Wind speed as a percentage of free wind speed. (adapted from HALL et al 1972)

2.1.3 EFFECT OF TOPOGRAPHY

Slope can modify the vertical spatial arrangement of fuels in the plantation in that trees planted lower down the slope have their canopies closer to the ground up the slope (refer Figure 6).

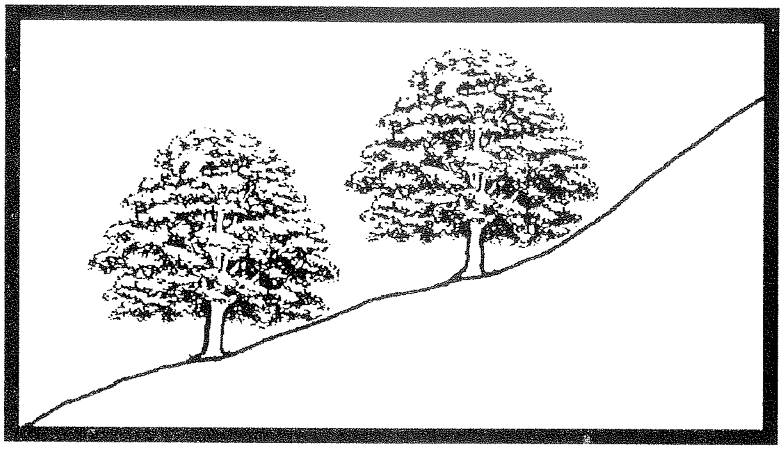


Fig 6. Canopies are closer to ground level upslope side of a tree than on downslope side.

Added to this effect, the increase in rate of fire spread up a slope further accentuates the need for open spacing of trees (rate of fire spread is doubled up a 10 degree slope and increases by a factor of 4 when burning up a 20 degree slope when compared to spread on level ground: every 10% increase in slope up to 30 degrees doubles the speed of bushfire) (5). This relationship between slope and rate of spread is commonly described by the equation

$r = r_o{}^{b\theta}$ where r = rate of spread up-slope
r_o = rate of spread on flat land
θ = the angle of degrees of the slope
b = a constant (= 0.0693)

This relationship may not hold above a slope angle of 30° as fuel discontinuities usually occur on steep slopes. The relationship is described by the graph shown in figure 7 (32).

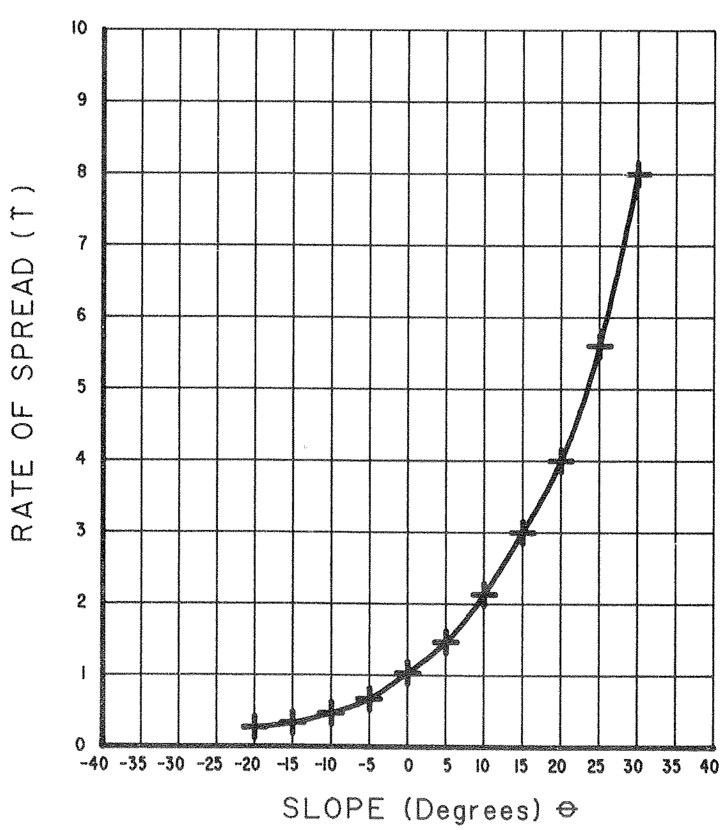


Fig 7. Graph of relationship between rate of fire spread and slope of site. (from reference 32)

A fire burning up slope under the influence of a following wind will almost inevitably throw spot fires forward of the fire and particularly, from the top of the slope. Trees conducive to the spotting process are particularly hazardous in such a situation. - refer Fig 8.

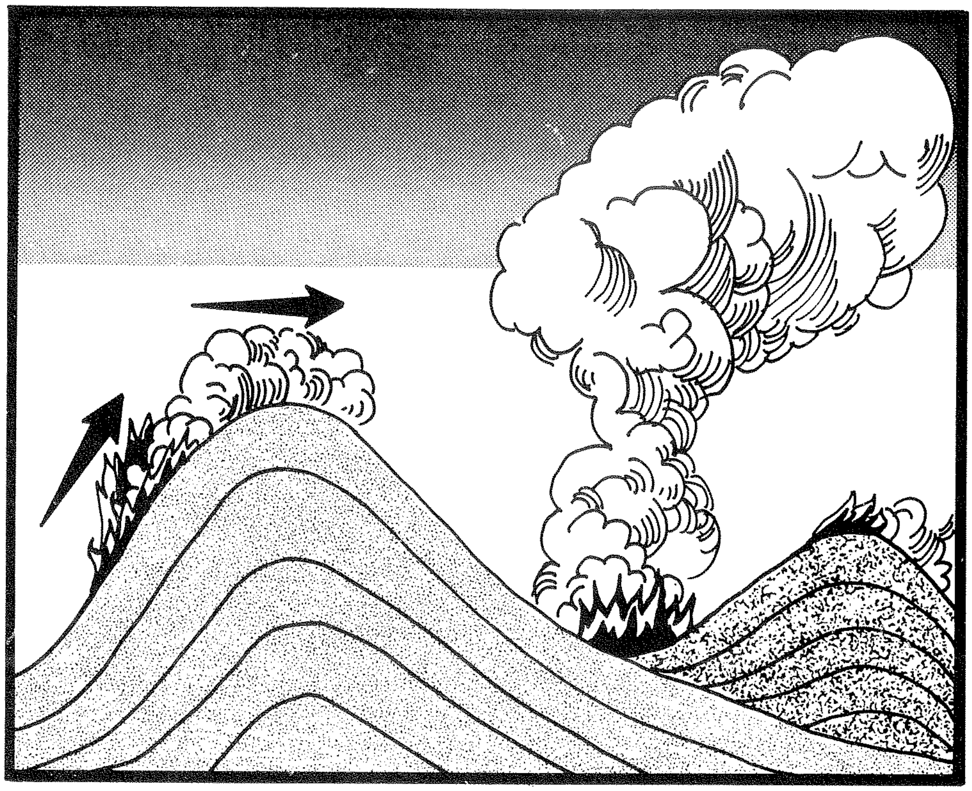


Fig 8. Schematic diagram illustrating the effect of strong winds in mountainous topography causing rapid upslope spread and initiating a spotting process from the ridge top.

Northerly and westerly aspects are more insolated at that time of the day when ambient temperatures are generally highest and relative humidity is at its lowest. These aspects are also more exposed to drying winds from the north and north west.

Consequently, northerly and westerly aspects are much more conducive to extreme wildfire behaviour than other aspects. Also these aspects are characteristically drier and often have shallower soils which necessitates both careful selection and spacing of tree species. Trees planted in such locations, should include species which have high foliage moisture contents and the lowest spotting potential, and all should be planted in an open "park-like" arrangement.

2.1.4 SITE AND TREE MAINTENANCE

During the first few years after planting, grass and other competing vegetation need to be controlled for fire protection purposes, as well as to enhance tree establishment.Fuel quantity plays a significant role in determining a fires intensity. The need for effective control of fuel quantity is clearly demonstrated by the graphs in figure 9 (32). These graphs are good approximations of BYRAM's mathematical relationship of fire intensity in grass and forest fuels.

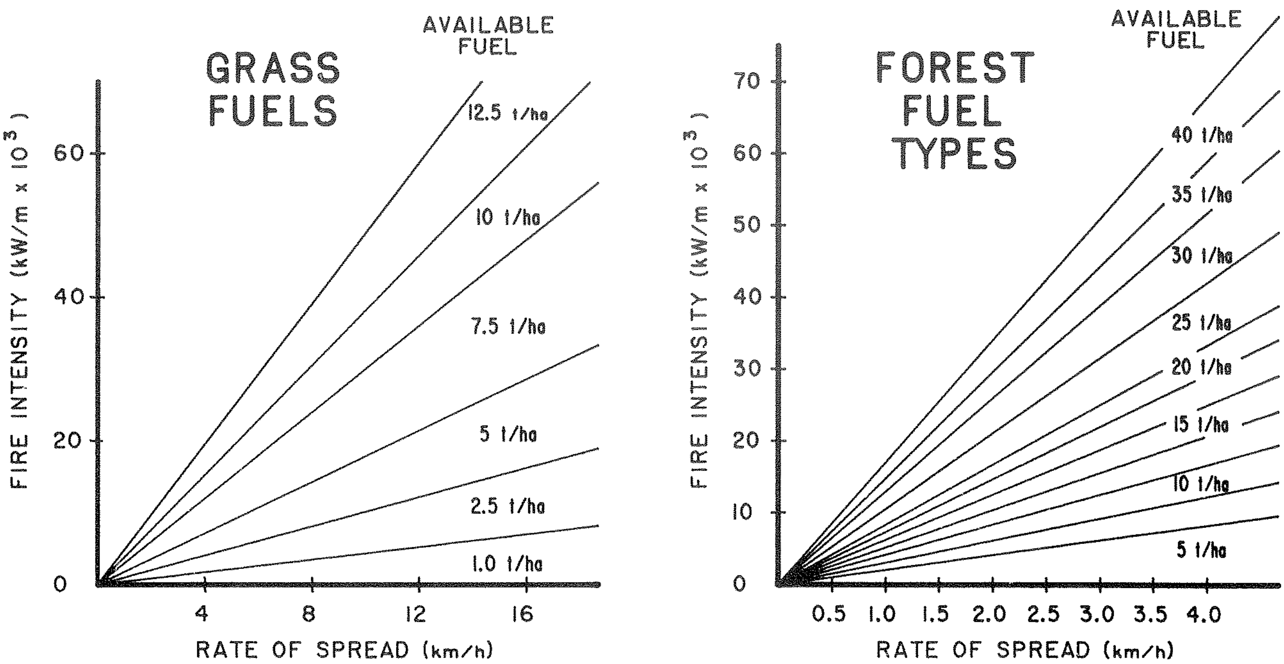
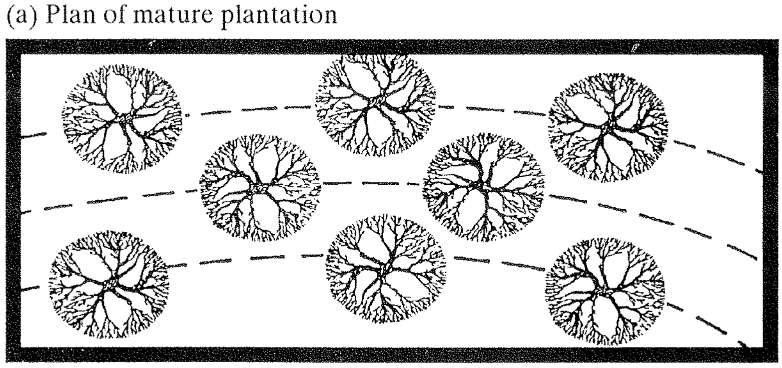


Fig 9. Fire Intensity Graphs. (Reference 32)

Economic considerations in controlling grass etc are important as costs can be significant. Open park-like planting should include individual guarding of trees, with guards of sufficient strength and dimension so as to allow sheep grazing between them; this is by far the cheapest method of site maintenance and fire protection.

Other areas that cannot be grazed until the trees are of a sufficient stature to withstand grazing pressure can be maintained by slashing, cultivation or poisoning - all of which are expensive compared to grazing, but it must be balanced against relative costs of fencing blocks of trees and "fencing" individual trees. Mechanical maintenance is made more economic by enhancing machinery access by planting trees in rows; row planting can be utilised without compromising any scattered tree landscape effect as demonstrated in Figure 10.

(a) Plan of mature plantation



(b) Elevation view of (a)

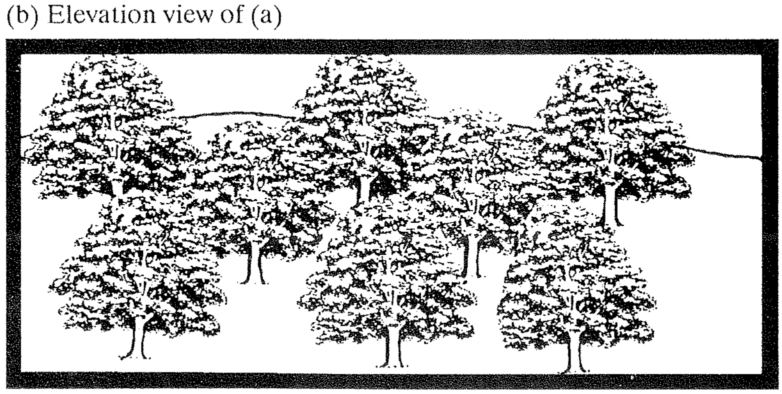


Fig 10. Utilization of curvilinear planting lines or rows to enhance both plantation maintenance and landscape value of a plantation.

As the trees grow and as canopies close, the lower inside branches of trees may become suppressed and dry out. Self pruning tree species, as mentioned earlier, will shed these lower limbs naturally, but other species, such as conifers, will require manual pruning to get rid of this accumulation of hazardous material and to retain the clean break between ground fuels and the tree canopy. Such a pruning operation is expensive and species that are self pruning and produce clean branch free boles should be preferred for plantation establishment in open cut environs.

Accumulation of flammable material such as dead leaves, bark, twigs and grasses within, under or adjacent to trees, is an added source of fuel for fires. Similarly it is important to remove any pruning debris from the site.

2.2 CASE STUDY : WETLAND CONSTRUCTION IN THE LATROBE VALLEY

Wetlands are reasonably common features of the Latrobe Valley rural landscape. The composition and type of vegetation species growing in these wetlands consist of a number of larger growing species such as Tea-tree, Paperbark and Phragmites, that are quite flammable; this feature has often been demonstrated in many rural wildfires. Gill et al (1981) have already commented on the ability of fire in Tea-tree to crown even with water saturated understoreys let alone without ground fire support (11).

Wetlands offer a number of well recognised benefits including wildlife habitat, flora conservation, landscape diversity etc. and can even be constructed to have other engineered benefits including filtration of sediment. In view of these values and the general interest in wetland development, we believe it is still possible to maintain most of these values without substantially compromising either the fire hazard or any fire suppression activity. As such in those landscapes consisting of primarily grass and herbaceous species with scattered tall trees (outlined in the previous text) and which are in fire hazardous environments, we recommend, based on our own experience and knowledge, that wetlands be constructed and maintained such that all of the following criteria are met, namely;

a The wetland contains permanent deepwater (>2.5 metres deep) that is free of "above water" (aerial) vegetation.

b All aerial vegetation be restricted to a narrow fringe surrounding the deep water body.

c The type of vegetation is controlled by careful construction and maintenance of the landform.

d The fringe of aerial vegetation is broken at regular intervals to disrupt the continuity of the aerial vegetation strip. These breaks should be constructed such that they discourage occupation by the riparian vegetation and also so that they provide vehicular access to the deep water body for use during such activities as fire fighting.

e No tree species that exceed approximately 6 metres in height at maturity should be interspersed with the more flammable wetland vegetation. Should wildfire occur, this will restrict the height of fuel through which fire can climb and consequently will help to reduce the potential spotting distance of a fire.

f The wetland should be fenced to prevent stock from entering desired wetland vegetation.

g Mineral earth fire breaks that are peripheral to the wetland community should be constructed and maintained to assist with the prevention of fire moving from pasture land into the wetland. Such a fire break would be best constructed as a vehicular track as this will aid general management and help restrict pasture species from encroaching into the wetland.

h The number of wetlands should be kept to less than 3% by area of the landscape and should be separated by a minimum of 500 metres distance.

All these elements have been combined into the simplified digramatic representation given in figure 11.

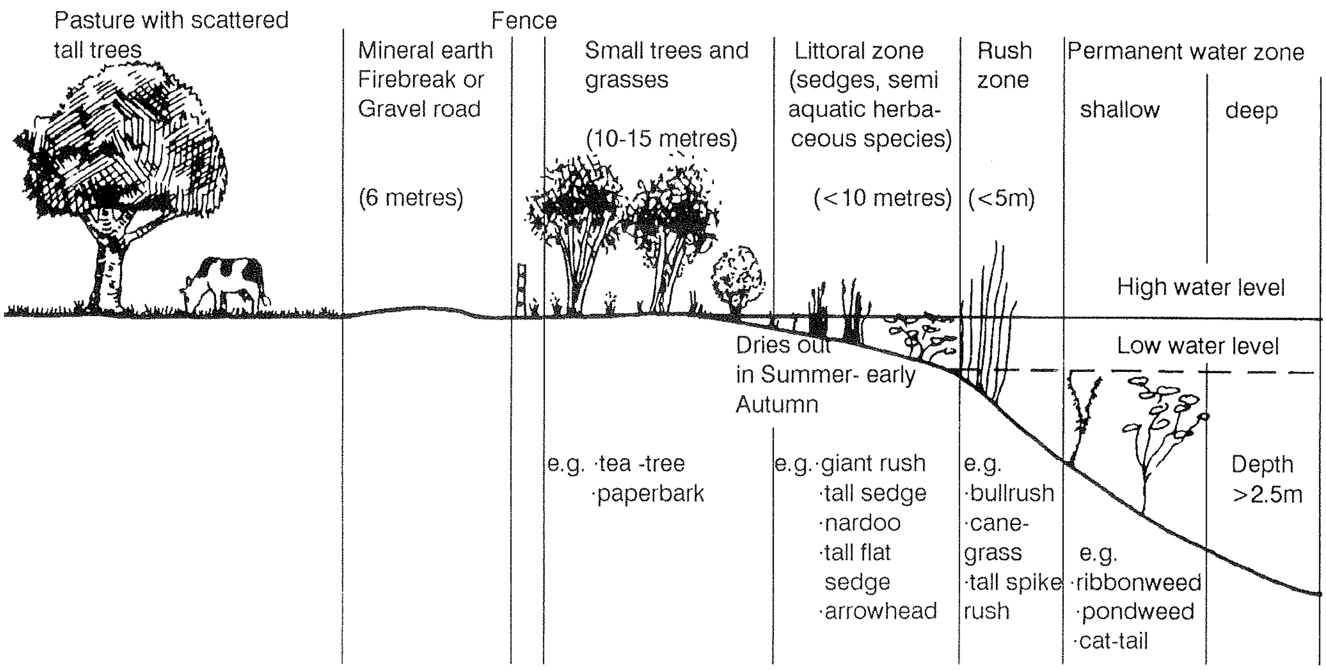


Fig 11a. Elevation view of recommended Wetland

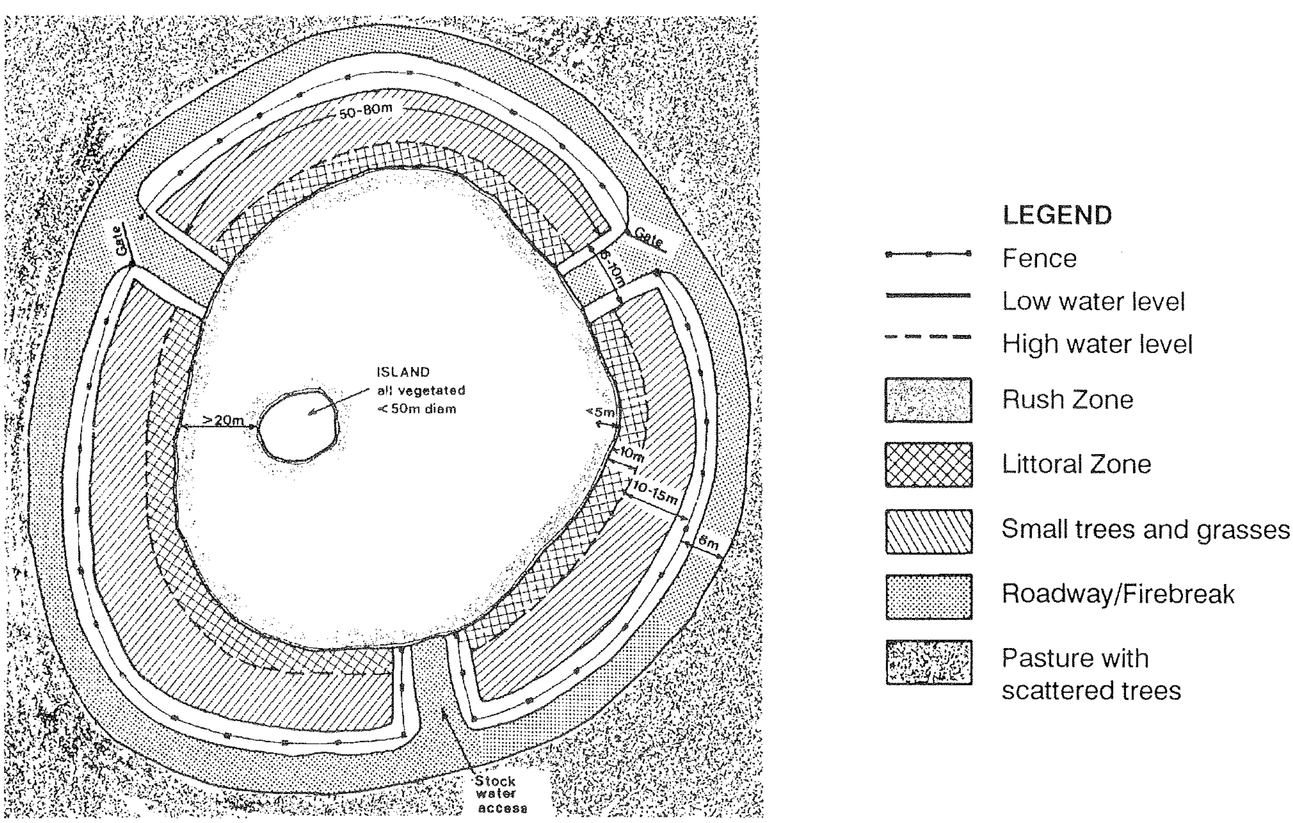


Fig 11b. Plan view of recommended Wetland

Note also that such a plan may look at fire protection per se but it does also provide an enhanced capability for a wetland to "protect itself" from destruction by wildfire. There is always some flexibility in the development of wetlands landscapes in that their location must also be related to the location of those values being protected from fire as well as to those attributes which affect wildfire behaviour (refer discussions in previous text).

3 RECOMMENDATION AND CONCLUSIONS

Tree selection, distribution and management for fire protection is complex. By examining and understanding these variables and their relationships the following recommendations and conclusions have been developed to help with land management planning decisions.

3.1 PREFERRED SPECIES

Bringing together all the technical points discussed earlier, some of the more common tree species suited to general site conditions in the Latrobe Valley with desirable characteristics are listed below. They are those which have high foliage moisture contents, firm bark, low oil content and have clean boles (self pruning) (7,8,18).

The species list does not attempt to address matters such as availability or cost of seedlings, or the suitability of specific species to particular sites. These are matters which are more properly addressed at the particular time and place of a specific planting proposal.

INTRODUCED TREES THAT ARE HARD TO BURN INCLUDE:

BOTANICAL NAME	COMMON NAME
Acer campestre	Common Maple
Acer negundo	Box-Elder Maple
Acer platanoides	Norway Maple
Acer pseudoplatanus	Sycamore
Aesculus hippocastanum	Horse Chestnut
Alnus jorullensis	Evergreen Alder
Calodendron capense	Cape Chestnut
Castanea dentata	American Chestnut
Castanea sativa	Sweet Chestnut
Celtis occidentalis	Hackberry
Ceratonia siliqua	Carob
Cercis siliquastrum	Judas Tree
Cinnamomum camphora	Camphor Laurel
Cornus capitata	Evergreen Dogwood
Corynocarpus laevigatus	New Zealand Laurel
Elaeagnus angustifolia	Russian Olive
Fagus sylvatica	Common Beech
Fraxinus spp.	Ash
Gleditsia triacanthos	Honey Locust
Griselinia littoralis	New Zealand Broadleaf
Liriodendron tulipifera	Tulip Tree
Olea europaea	Olive
Pittosporum eugenioides	Tarata
Platanus orientalis	Plane
Populus spp.	Poplar

Prunus laurocerasus	Cherry Laurel
Prunus lusitanica	Portugal Laurel
Quercus canariensis	Algean Oak
Quercus cerris	Turkey Oak
Quercus ilex	Holm Oak
Quercus palustris	Pine Oak
Quercus robur	English Oak
Quercus rubra	Red Oak
Robinia pseudoacacia	Black Locust
Salix babylonica	Weeping Willow
Schinus molle	Pepper Tree
Sorbus aucuparia	Rowan
Tamarix aphylla	Athel
Tamarix articulata	Athel
Tilia vulgaris	Linden
Ulmus spp.	Elms

NATIVE TREES THAT ARE HARD TO BURN INCLUDE:

BOTANICAL NAME	COMMON NAME
Acacia dealbata	Silver Wattle
Acacia decurrens	Early Black Wattle
Acacia elata	Cedar Wattle
Acacia falciformis	Hickory Wattle
Acacia iteaphylla	Gawler Range Wattle
Acacia mearnsii	Black Wattle
Acacia melanoxylon	Blackwood
Acacia pendula	Weeping Myall
Acacia pravissima	Ovens Wattle
Acacia terminalis	Sunshine Wattle
Acmena smithii	Lilly-Pilly
Angophora costata	Apple Jack
Araucaria bidwilli	Bunya Pine
Brachychiton populneus	Kurrajong
Casuarina cristata	Belah
Casuarina cunninghamiana	River She-oak
Casuarina glauca	Swamp She-oak
Casuarina stricta	She-oak
Eucalyptus camaldulensis	River Red Gum
Eucalyptus maculata	Spotted Gum
Eucalyptus tereticornis	Forest Red Gum
Ficus macrophylla	Moreton Bay Fig
Grevillea barklyana	Gully Grevillea
Grevillea robusta	Silky Oak
Lagunaria patersonii	Pyramid Tree
Melia azedarach	White Cedar
Pittosporum undulatum	Sweet Pittosporum

3.2 USE OF SHRUBS AND GROUND COVER PLANTS

In special circumstances, it may not be possible to utilise preferred tree species in re-vegetation or landscaping projects. This may arise from unusual site conditions (i.e. slope, drainage or soil condition). In order to assist in soil erosion prevention measures, a list of low flammability ground and shrub species is provided.

These shrubs or ground cover plants should be spaced to provide the least fire hazard. It is essential such plants are not planted close to tree species, in order to avoid the ladder-like passage of fire to tree crowns. It is important to keep clumps small and discrete, with easy access and maintenance of fuel loads beneath and surrounding them.

GROUND COVER PLANTS THAT ARE HARD TO BURN INCLUDE:

BOTANICAL NAME	COMMON NAME
Agapanthus	
Ajuga reptans	Bugle
Atriplex spp.	Saltbush
Coprosma "kirkii"	
Delosperma "alba"	
Drosanthemum floribundum	
Gazania spp.	Gazanias
Hedera spp	Clinging types of ivy
Helianthemem spp	Sunrises
Kennedia spp	Coral Peas
Lampranthus multiradiatus	Noonflower
Maireana spp.	Blue Bushes
Myoporum parvifolium	Creeping Myoporum
Portulacaria spp	Jade Plants
Rhagodia spp	Saltbush
Rosmarinus officinalis prostratus	Rosemary (prostrate form)
Santolina spp	Lavender Cotton
Sedum spp	Stonecrops
Verbena peruviana	Verbena
Vinca spp	Periwinkles

INTRODUCED SHRUBS THAT ARE HARD TO BURN INCLUDE:

BOTANICAL NAME	COMMON NAME
Coprosma repens	Mirror Bush
Cornus capitata	Evergreen Dogwood
Laurus nobilis	Laurel
Ligustrum spp	Privet
Photinia glabra	Red-leaf Photinia
Photinia serrulata	Chinese Hawthorn
Ilex aquilifolium	Holly

NATIVE SHRUBS THAT ARE HARD TO BURN INCLUDE:

BOTANICAL NAME	COMMON NAME
Acacia baileyana	Cootamundra Wattle
Acacia cyclops	West Australian Coastal Wattle
Acacia glandulicarpa	Hairy Pod Wattle
Acacia howittii	Sticky Wattle
Acacia iteaphylla	Flinders Range Wattle

Acacia ligulata	Small Cooba
Acacia prominens	Golden Rain Wattle
Acacia vestita	Hairy Wattle
Atriplex nummularia	Old Man Saltbush
Agonis juniperina	Juniper Myrtle
Fugosia patersonii	Native Hibiscus
Grevillea rosmarinifolia	Rosemary Grevillea
Hakea salicifolia	Willow Hakea
Hakea suaveolens	Sweet Hakea
Heterodendrum oleifolium	Cattlebush
Melaleuca lanceolata	Moonah
Myoporum insulare	Boobialla

3.3 IMPLICATIONS FOR LAND MANAGEMENT ACTIVITIES INCLUDING LANDSCAPE DESIGN

The attitudes of the bulk of Victorians to fires in their landscapes suggest that they see fire as something to be fought when danger threatens rather than anticipated when danger was not so obvious (11,22,23). Similar attitudes have been reflected in other States such as South Australia (24). When severe fires do occur, the initial enthusiasm usually demonstrated during the suppression effort later tends to wane as the memory of the fire recedes - the continued concern in assuring fire prevention is left to be borne largely by the controlling authorities and some land management agencies. Such apathy for fire protection exists despite our history of repeated, destructive, costly and lethal rural wildfires in an environment which is notorious for its high inflammability.

Successful fire prevention depends on utilising education, enforcement and engineering in logical, well planned combinations designed to counteract those fires that cause the most damage within the protection area (10). Secondly fire prevention forms an integral part of any land management strategy and must be married with all the other constraints such as land use, flora fauna and soil conservation, demographic factors, finance etc. In those areas that are known to be particularly fire hazardous, fire protection must be given greater weighting in this integrated land management approach than would be the case in areas that are less fire hazardous. The one principle that the fire protection manager must never forget however is that the purpose of the fire organisation (and the fire budget) is to minimise the damage from fire to the parent organisation (10).

Fire control authorities recognise that no fire suppression system has yet been developed in the world which can halt the forward spread of high intensity fire burning in continuous heavy fuels under the influence of extreme fire weather (25).

Bushfire suppression in high fuel loads is very dangerous work and the combination of extreme fire weather and heavy fuel loads is the major cause of fire fighter fatalities.

Vegetation provides the biggest proportion of fuel for rural wildfire. Obviously the most manageable aid to reducing the fire risk is the manipulation of vegetation to keep fuel loads to a level and of a spatial arrangement and type that makes it unlikely for an intense conflagration to occur. It is also essential, particularly in the environs of the Open Cut Coal Mines, that we avoid enhancing the risk of a fire moving from ground level into tree canopies producing crown fires which are the most difficult to control and have the added potential to spot fire well ahead of the original front. The crowning potential of trees is indicated in the dichotomous key (next page) developed by FAHNESTOCK (1970)(26).

CROWNING POTENTIAL KEY	RATING +
A. Foliage present, trees living or dead - B	
B. Foliage living - C	
C. Leaves deciduous, or if evergreen, usually soft, pliant and moist; never oily, waxy or resinous	0
CC. Leaves evergreen, not as preceding - D	
D. Foliage resinous, waxy or oily - E	
E. Crowns dense - F	
F. Ladder fuels plentiful - G	
G. Canopy closure > 75%	9
GG. Canopy closure less than 75%	7
FF. Ladder fuels sparse or absent - H	
H. Canopy closure > 75%	7
HH. Canopy closure less than 75%	5
EE. Crowns open - I	
I. Ladder fuels plentiful	4
II. Ladder fuels sparse or absent	2
DD. Foliage not resinous, waxy or oily - J	
J. Crowns dense - K	
K. Ladder fuels plentiful - L	
L. Canopy closure > 75%	7
LL. Canopy closure less than 75%	7
KK. Ladder fuels sparse or absent - M	
M. Canopy closure > 75%	5
MM. Canopy closure less than 75%	3
JJ. Crowns open - N	
N. Ladder fuels plentiful	3
NN. Ladder fuels sparse or absent	1
BB. Foliage dead - O	
O. Crowns dense - P	
P. Ladder fuels plentiful - Q	
Q. Canopy closure > 75%	10
QQ. Canopy closure less than 75%	9
PP. Ladder fuels sparse or absent - R	
R. Canopy closure > 75%	8
RR. Canopy closure less than 75%	4
OO. Crowns open - S	
S. Ladder fuels plentiful	6
SS. Ladder sparse or absent	2
AA. Foliage absent, trees dead - T	
T. Average distance between trees 33 feet or less - U	
U. Ladder fuels plentiful - V	
V. Trees with shaggy bark and/or abundant tinder	10
VV. Trees without shaggy bark and/or abundant tinder	8
UU. Ladder fuels sparse or absent - W	
W. Trees with shaggy bark and/or abundant tinder	10
WW. Trees without shaggy bark and/or abundant tinder	5
TT. Average distance between trees > 33 feet	2

+ The Key produces a rating between 0 and 10; these output numbers indicate the order of likelihood of a crown fire.

Although there are both limitations and strengths with this key it does serve to indicate how tree characteristics, spacing and surrounding (other) vegetation do interact to affect the fire crowning potential of a forest or plantation. (It should be comforting to note that experienced fire people can judge relative crowning potential from overall appearance of the stand without the need to break it down in the seven steps outlined in the key (10)).

Spaced trees are safe trees; whatever species of tree is planted, the aim of landscaping should be an open, park like effect (28). A maximum 35% tree cover greatly reduces the probability of fires spreading laterally from crown to crown (20). Some trees which are not inherently fire retardant can be made relatively so by careful maintenance and ground clearance beneath them.

Studies have shown that landscapes that are fairly open and grassy with widely spaced, large trees that provide overhead foliage without interfering with visibility at ground level do have high levels of both scenic quality and perceived personal safety (29). Daniel (1989) found this general perception to be irrespective of social or cultural background when based on a purely perceptual aesthetic judgement and was shared by a large majority of individuals (30). Additionally, Ulrich (1986) (27) in his review of European and American research concerning aesthetic, emotional and physiological responses to visual landscapes found the following:

a "high preference views can frequently be described as park-like or savannah-like in appearance"

b "large trees have positive influences on liking, whereas small trees have a mild negative effect"

c "low understorey shrub density and lush grassy or herbaceous ground covers, tend to have strong positive effects on liking"

d " large amounts of downed wood or slash, or a high density shrub understorey has powerful negative effects on preference"

e "the presence of dead trees detracts from liking"

f " aesthetic preferences tend to be significantly higher for managed forest stands than for non-manipulated settings". Ulrich adds to this by saying that the implications from this response are that the highly manipulated stands (characteristic of urban fringe parks and recreation areas) are often more effective as aesthetic amenities than unmanaged, comparatively "wild" forest settings.

Further exemplification of the above is given by such work as done by Brown et al (31) in stands of Ponderosa Pine where it was found that preference was for less dense, less horizontally complex pine stands.

Less dense stands generally have more herbage and fewer small and intermediate sized trees than denser stands with less tree clumping. Preference was also demonstrated for a vertical diversity (i.e. number of tree storeys) that consisted of mature even-aged stands in favour of all-aged stands while, in turn, all-aged stands were preferred to young even-aged stands (see figure 12).

Fig 12.
Example of a Ponderosa Pine stand that measured a very high scenic beauty response (adapted from Brown et al 1984 (31))

All these landscape studies demonstrate a high degree of compatability between the composition of preferred "visual" landscapes and the composition of a low fire risk landscape.

However, any vegetation adds to the fire fuel load and so the choice of vegetation and its arrangement must take into account its proximity to any asset being protected and the prevailing (fire season) weather conditions of the site, as well as the purpose of the vegetation, eg. for shade, aesthetic purposes, erosion control, timber etc. The choice of an appropriate type of tree in terms of height, shape, evergreen/deciduous, growth rate and fire retarding and/or recovery ability is affected by the qualities of the site in which the tree is to grow by such things as soil suitability, adequacy of rainfall/water supply, its frost and drought resistance, any maintenance requirements (eg will it need to be pruned?) and its susceptibility to disease or pests that may already be present or threatening. For example, a tree that has high demands on water supply is not going to reach its normal mature stature and shape on sites where water supply is limited if indeed it survives at all - the same applies for all the site qualities listed above.

Additionally one cannot forget the economic constraints on tree establishment and maintenance. One must not only design planting to achieve the desired goal but it must be correlated with the degree of fire risk (and anticipated costs should the gamble fail) that the parent organisation is prepared to endure. Minimum damage is the anvil on which all fire resource allocation decisions can be tested (10).

When creating any new landscape, particularly in high fire hazard areas, we should in so doing not also create other problems such as high fire risk. No benefit is gained by unnecessarily compromising the fire safety of both firefighters and assets let alone the survival of the created landscape itself.

REFERENCES

1 SECV Latrobe Valley Open Cuts Fire Protection Policy (1984). Unpublished SECV document.

2 SECV Policy for the Protection of SECV Latrobe Valley Assets from Rural Fire (1986). Unpublished SECV document.

3 SECV Rehabilitation Policy for Open Cuts and Overburden Disposal Areas (1986). Unpublished SECV document.

4 ROTHERMEL, R C (1976). Forest Fires and the Chemistry of Forest Fuels; Thermal Uses and Properties of Carbohydrates and Lignins. San Francisco Academic.

5 LUKE, R H & McARTHUR, A G (1978) Bushfires in Australia. CSIRO Division of Forest Research

6 POMPE, A & VINES, R G (1966) The influence of moisture on the combustion of leaves. Aust. For. Vol 30 pp 231 - 241.

7 SIMPFENDORFER, K J (1984). Trees, Farms and Fires. Forests Commission, Victoria.

8 PHILPOT, C W (1970) Influence of mineral content on the pyrolysis of plant materials. For. Sci. Vol 16, pp 461 - 71

9 KING, N K & VINES, R G, (1969). Variation in the Flammability of the leaves of some Australian Forest Species. CSIRO Division of Applied Chemistry.

10 CHANDLER, C; CHENEY, P; THOMAS, P; TRABAUD, L & WILLIAMS, D. (1983) Fire in Forestry Volumes 1 & 11. J Wiley & Sons

11 GILL, A M; GROVES, R H & NOBLE I R: editors (1981). Fire and the Australian Biota. Australian Academy of Science. Griffin Press.

12 BAKER, R T & SMITH, H G (1902) A research on the Eucalypt, especially in regard to their essential oils. Government Printer, Tech Education Series No 13, SYDNEY

13 DOWNES, R G (1983) Fire, Vegetation and houses: A report prepared for the Garden State Committee.

14 SCHMIDT, W C & WAKIMOTO, R H (1987) Cultural practices that can reduce fire hazards to homes in the interior west. Symposium and workshop on protecting people and homes from wildfire in the interior west. Missoula, Montana, USA

15 GILL, A M & ASHTON, D H (1968) The role of bark type in relative tolerance to fire of three central Victorian Eucalypts. Aust. J of Bot Vol 16 pp 491 - 498.

16 BROWN, J K ; (1970) Ratios of surface area to volume for common fine fuels. For Sci Vol 16 pp 101 - 105

17 MONTGOMERY, K R & CHEO, P C (1971) Effects of leaf thickness on ignitability. For Sci Vol 17 pp 475 - 678

18 Department of Conservation forests and Lands (Victoria).
Tree Growing Notes: Trees and Fire Resistance
Tree Planting for fire protection on farms
Tree Selection for fire prone areas
Tree Maintenance to minimise damage by fire
The versatility of trees in landscape design

19 GILL, A M. (1975) Fire and the Australian flora : a review. Aust For Vol 38. pp 4 - 25

20 DENNIS, F C (1983) Fuelbreak guidelines for forested subdivisions. Colorado State Forest Service 102 - 1083 Colorado State University 16pp.

21 HALL, N; BODEN, R W; CHRISTIAN, C S; CONDON, R W; DALE, F A; HART, A J; LEIGH, J H; MARSHALL, J K; McARTHUR, A G; RUSSELL, V; TURNBULL, J W; (1972) The use of Trees and Shrubs in the dry country of Australia. Dept of Nat Development Forestry and Timber Bureau. Australian Government Publishing Service, Canberra

22 STRETTON, L E B (1939) Report of the Royal Commission to Enquire into the causes and measures taken to prevent the Bushfires of January 1939 and to protect life and property. Government Printer, Melbourne

23 BARBER, E H E (1977) Report of the Board of Enquiry into the Occurrence of Bush and Grass Fires in Victoria. Govt Printer Melbourne

24 HEALEY, D T; JARRETT, F G; McKAY, J M; editors (1985). The economics of bushfires : The South Australian Experience. Oxford Uni Press, Melbourne

25 KOMAREK, E V (1983) Fire-Nature-and Man: in fighting fire with fire....... a symposium on fuel reduction burning in forests. Graduate School of Environmental Science, Monash Uni.

26 FAHNESTOCK, G R (1970) Two keys for appraising forest fire fuels. U S For Serv Res Paper PNW - 99

27 ULRICH, R S (1986) Human responses to vegetation and landscapes. Landscape and Urban Planning Vol 13. pp 29 - 44

28 WEBSTER, J K (1986) The complete Australia Bushfire Book. Nelson

29 personal comment; H W Schroeder, North Central Forest Experiment Station, Illinois, U S A (1989)

30 personal comment; Dr T Daniel, Prof Psychology and Renewable Natural Resources, Uni of Arizona, (Tuscon) U S A (1989)

31 BROWN, T C & DANIEL, T C (1984) Modelling forest scenic beauty : concepts and application to Ponderosa Pine. USDA Forest Service Research Paper RM-256

32 Department of Environment and Planning (1984) Planning in fire prone areas. NSW Government Circular No. 74