



SPECIAL LIFTOUT No. 65

Spring 2003
Vol. 26 No.3

‘WHOEVER OWNS THE FUEL OWNS THE FIRE’ – FIRE MANAGEMENT FOR FOREST GROWERS



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CSIRO maintains a philosophy that fire management must be based on a sound understanding of fire behaviour and its impact. CSIRO has focused much of its research over many years towards gaining a better understanding of fire behaviour and how this knowledge can be applied to provide safe and efficient bushfire management for a range of objectives.

This liftout provides background information on bushfire and its role in shaping the Australian landscape. It outlines the key elements of fire behaviour as they apply to fire management and discusses management actions that can be taken by forest growers to protect their forest assets.

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The quote ‘Whoever owns the fuel owns the fire’ is attributable to Phil Cheney.

The ideas and words in this liftout are the authors and do not necessarily reflect the views of any other group or individual.

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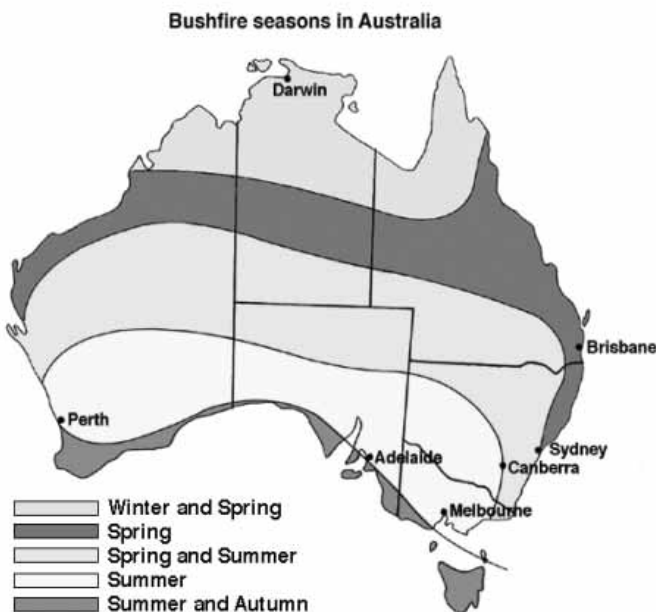


Fire as a natural phenomenon

Fire is a natural phenomenon in the Australian landscape. It is impossible to say at this stage of our knowledge whether the major elements of the Australian fauna are adapted to the eucalypt forests or whether both are adapted (co-adapted) to an environment in which intense wildfires are the norm. Fire is an environmental factor that both affects and is affected by vegetation, but it can by no means be seen in a simple light as the major determining factor of vegetation in any given area. This is because there is a complex interaction between aspect, slope, climate, geology, fire behaviour and vegetation that does not permit simple cause and effect explanations.

There seems little doubt that Australia's sclerophyll vegetation has been associated with fire for 10,000 to 15,000 years (Singh *et al.* 1981) and that fire has been an environmental factor for 100,000 years (Kemp 1981). As the temperate rainforests contracted in the late Tertiary, they were replaced by *Eucalyptus* and *Acacia* (Crocker and Wood, 1947), genera which are widespread today. Associated with this change in vegetation was the radiation of Australia's unique marsupials (Stirton *et al.* 1968). Accordingly, the fauna may have evolved in a complex, interrelated system of increasingly dry climate, fire, and a vegetation that enhances and is enhanced by fire.

BUSHFIRES IN AUSTRALIA



Australia suffers frequent wildfire disasters that have a profound impact on communities.

The climate and vegetation combine to ensure that during almost every summer there is a threat of a bushfire disaster somewhere in the country.

Figure 1: Regions affected and degrees of fire risk in Australia.

A complete fire history of Australia is not available and hence it is difficult to assess how human intervention (pre and post European), has affected fire regimes (seasonality, frequency and intensity). Unravelling the nature of the disturbance to the environment before the advent of closer settlement and exploitation 200 or so years ago is a significant challenge. While the large tracts of forest remaining today provide us with information on the plant species present, and much of the fauna, our knowledge of disturbance processes centuries ago is far from clear (Gill and Catling 2001). Aboriginal people, firesticks in hand, had a presence in some forests at least (Jones 1969, Hallam 1975). Fires occurring as a result of their presence seem inevitable either as accidents or as deliberate management acts. Some forests had open understoreys (Ashton 1981a, b), a condition that could be created by frequent fires (Catling 1991) but also by long periods without fire (Catling and Burt 1995). In other places, forest understoreys were dense (Ashton 1981a,b), a condition that can be explained by the appropriate combination of fire events and their characteristics.

Forest stature and structures vary widely with forests from 10m tall to over 80m tall. Understorey structures reported by early European observers have been an important part of the debate over what fire regimes existed when Aboriginal people were the only human inhabitants of Australia (Benson and Redpath 1997). Mature trees with sparse understoreys were reported to be common, but dense thickets have been reported as well. Rather than debate the proportions of forest with particular structural attributes, it is sufficient to say that both existed.

Fire management

Fire management encompasses all those activities that involve the use of fire and the suppression of wildfires. These activities include the provision of access and firebreaks, communications, risk assessment and threat analysis, burning for fuel management, species regeneration and habitat management, wildfire suppression and rehabilitation after wildfires. Fire management is the legal responsibility of state agencies who manage government land and individuals or corporations who manage private land. For specific activities such as fire suppression and fuel management, volunteer bushfire brigades have been formed throughout the rural and peri-urban areas and are co-ordinated by a state fire authority.

Fundamentals of fire behaviour

Fire behaviour is everything a fire does. It covers the way a fire ignites, builds up or grows, its rate of spread, the characteristics of the flame front and all other phenomena associated with the moving fire front. Most of the research effort in fire behaviour has focused on the prediction of fire rate of spread, the dimension of the flames and the likelihood of firebrands being thrown ahead of the fire to start new fires. It has not been possible to apply traditional physical theory to the prediction of fire spread. Prediction of fire behaviour at any specific point in space or time usually has a wide error margin because it is difficult to predict the fuel that will be consumed and the direction and speed of the wind that will affect the combustion process at that point.

As fire builds up from ignition, however, it does reach a quasi-steady rate of spread that can be correlated to some mean value or characteristics of the fuel and the mean wind speed measured at a standard location. The error in prediction is reduced by selecting a suitable period of time



(often 30 minutes or more) to encompass the inherent variation in wind and fuel. The key factors that influence how fire spreads are the fuel characteristics, the moisture content of the dead fuel, the slope of the ground, the wind speed and its orientation to the fire. Mostly, predictions are made for the fastest spreading part of the fire called the head fire.

Fuel

The fuel that influences fire spread is the fuel that actually burns, or the available fuel. It is determined by the stratification of moisture within the fuel bed and by the intensity of the fire. The available fuel is predicted from the previous weather conditions. After recent rain only the top layer of the litter bed will burn, but after prolonged drought even a low-intensity fire will consume all the fuel on the forest floor.

Fuel characteristics that influence the rate of fire spread relate primarily to the ignition speed of the fuel particle and the length of the flame. These include:

- The fineness of the fuel particle (the finer the particle, the faster it will ignite);
- The height of the fuel bed (the higher the fuel bed, the longer the flames);
- The compaction of the fuel bed determines whether the fire first burns across the top of the fuel bed and then down into lower layers, or whether the fuel is mostly consumed at the same time. There is an optimum compaction that yields the maximum rate of spread:
 - if the fuel is too compact the fire will spread slowly; or,
 - if the fuel is too widely spaced the flames from one fuel particle cannot easily heat and ignite the next fuel particle;
- The fraction of live to dead material. Green material generally has a moisture level greater than 120%ODW (oven dry weight) and must be dried out by fire before it will burn. Thus green material can act as both a damper to fire spread or it can contribute to the length of flame particularly if it is fine and elevated above the surface fuel. After prolonged drought the live moisture content can reduce to 80% and require less heat for ignition;
- The total amount of fuel consumed; and,
- The continuity of the fuel bed.

These factors are difficult to describe numerically. To overcome this, fuels have been grouped into specific fuel types with similar characteristics (e.g. grassland, scrubland [heath] and forest fuel) and a number of conventions have been adopted. It is generally accepted that the available fuels <6mm diameter (termed 'fine fuel') contribute most to the dimensions of the flame front, and thereby contribute to the heat flux that ignites new fuel. Fuel larger than this diameter either does not burn or burns slowly, well behind the leading edge of the fire.

Weather

The important weather variables that are used for the prediction of fire spread are those that determine the moisture content of the dead fuel, the amount of available fuel and those that provide the dynamic force to drive the fire forward. These are:

- **Rainfall.** The amount and duration of rain not only determines the immediate moisture content of the fine fuel, but also, over a longer period, determines the amount of available fuel.
Fires can burn severely in dry forest earlier in the season before grassland has fully cured and is capable of supporting

a moving fire (e.g. Linton fire Victoria, December 1998).

A conflagration grass fire can occur after a short drought period of 6-8 weeks, which completely cures all grasses, usually after a wet spring that has provided abundant grass growth. Under these conditions the tall wet forests and montane forests are usually too moist to support a severe fire. After a period of prolonged drought, fuels in all forests become available including tall wet forests and forests in montane areas. Effective natural barriers in a normal fire season, such as swamps riverine areas and shallow lakes, dry out and fires become extremely difficult to suppress even under mild weather conditions. During these seasons, grasslands are usually heavily grazed and grass fires spread relatively slowly and are easy to suppress.

- **Temperature and the relative humidity.** These weather variables determine the moisture content of the dead fuel. These follow a diurnal cycle so that fuels may be moist at night and driest in the late afternoon.
- **Wind.** The wind speed is the dynamic variable that drives the fires forward. This can change in strength and direction extremely rapidly and both forest and grass fires respond almost immediately to this change.
Other weather variables that affect fire behaviour include solar radiation, atmospheric stability and upper wind strength.

Topography

Depending on its position in the topography, the fuel and the fire react at different rates to changes in weather variables. The terrain can have a dramatic effect on the speed and direction of the wind near the ground. The hills and associated valleys provide important channels that establish a local wind direction.

Generally, wind blowing across mountain ridges is lifted along the surface to the gaps and crests. It will increase in speed as it crosses the ridge, so that ridge top winds tend to be somewhat stronger than winds in free air of the same level. Ridges at right angles to the wind direction create considerable turbulence and often produce a strong eddy on the lee side, so that the wind near the ground is blowing in the opposite direction to the prevailing wind.

Under strong winds it is extraordinarily difficult to predict the direction and strength of winds in the valley and lee slopes of rugged terrain. The two features of the topography that most influence fire behaviour are aspect and slope:

- **Aspect:** Early in the fire season the terrain's aspect has a strong influence on the moisture content of forest fuel. On southerly and easterly aspects, fuel dries slower than fuel on northerly and westerly aspects that are more directly exposed to solar radiation. In mild fire seasons southerly aspects may remain moist and fires burn slowly throughout the summer. However, after a period of moderate drought and by early summer, fuel on all aspects becomes uniformly dry so that the main influence on fire behaviour is the orientation of the aspect to the prevailing wind.
- **Slope:** The slope of the ground, when aligned with the prevailing wind direction, has a strong influence on fire behaviour. The rate of spread of a fire up a slope of 10 degrees will be double the rate of spread of the fire on level ground. The rate of spread of the fire up a slope of 20 degrees will be four times the rate of spread of the fire on level ground. Although the effects of the slope and wind



interact to determine the direction of fire spread, the magnitude of this effect depends on the strength of the wind. Under light wind the slope of the ground will determine the direction of fire spread but a strong winds can overcome the effect of slope and dominate the direction of fire spread driving fire across quite steep slopes.

Scales of fire behaviour

In addition to the rate of spread of fire there are two commonly used scales that are used to qualify fire weather and fire behaviour. These are the McArthur fire danger rating systems for forests and grasslands and the Byram fire intensity scale. These scales are important for fire managers to appreciate the range of fire weather that can occur and the range of a bushfire behaviour that is possible, particularly under extreme weather conditions. It is useful for forest managers to understand these systems as one means of assessing the risks to their own forests.

Fire danger

The McArthur fire danger rating systems combine a measure of seasonal drought with the weather variables of temperature, relative humidity, and the wind speed to provide a numerical index of the difficulty of suppressing a fire in a standard fuel type. The fire danger rating systems have been used throughout Australia for more than 40 years and have provided the basis for setting levels of preparedness, such as the manning of lookout towers, placing fire fighting resources on standby and providing public warnings. The fire danger rating systems are used to derive the maximum daily fire danger in either forest or grasslands, and during summer these warnings are displayed on the roadside fire danger signs throughout rural areas. The difficulty of suppression associated with each fire danger class is given in Tables 1 and 2.

Table 1: Grassland Fire Danger Rating and difficulty of suppression in an average pasture carrying 4t/ha.

Fire danger rating	Fire danger index	Difficulty of suppression
Low	1 - 2.5	Low. Head fires stopped by roads and tracks.
Moderate	2.5 - 7.5	Moderate. Head fire easily attacked with water.
High	7.5 - 20	High. Head fire attacked generally successful with water.
Very high	20 - 50	Very high. Head fire attack may succeed in favourable circumstances. Back-burning close to the head may be necessary.
Extreme	50 - 200	Direct attack on the head will fail. Back burns from a road for wide fire line will be difficult to hold because of blown embers. Systematic attack from the rear up along the flanks of the fire is usually successful.

Table 2. Forest Fire Danger Rating and difficulty of suppression on level ground in a dry eucalypt forests carrying 12.5 t/ha.

Fire danger rating	Fire danger index	Difficulty of suppression
Low	1 - 5	Low. Fire easily suppressed with hand tools.
Moderate	5 - 12	Moderate. Fire usually suppressed with hand tools and easily suppressed with bulldozers. Generally the upper limit for prescribed burning.
High	12 - 24	Fires generally controlled with bulldozers working along the flanks to pinch the head out under favourable conditions. Back burning ¹ may fail due to spotting.
Very high	24 - 50	Initial attacked generally fails but may succeed if fires are below potential rate of spread on favourable lee-slopes. Back burning will fail due to spotting. Burning-out ² should be avoided.
Extreme	50 - 100+	Fire suppression virtually impossible on any part of the fire due to the potential for extreme and sudden changes of fire behaviour. Any fire suppression actions such as burning out will only increase fire behaviour and the area burnt.

1. Back burning is setting fire downwind of the head fire in order to create a break wide enough to stop the head fire.
2. Burning out is setting fire to consume unburned fuel inside the control line.

The Bureau of Meteorology forecasts for the maximum fire danger for the day form the basis for planning fire suppression. However, the weather variables of temperature, relative humidity and wind speed usually follow a diurnal pattern, so on a day of forecast extreme fire danger the actual hourly fire danger may be low in the early morning and rise to extreme as the temperature and the wind speed increase. Similarly, the fire danger may rise by one or two fire danger classes in a very short time if the wind speed suddenly increases.

The standard fuel types for forests and grasslands are common and widespread so the fire danger rating system provides a good guide for planning and suppression preparedness. Suppression difficulty depends, however, very much on the type and structure of the fuel and the intensity of the fire in a particular fuel type.

Suppression strategies

The fundamental requirement for extinguishing a forest fire is that the fire must be totally surrounded by a trail that completely separates the fire from unburnt fuel and is constructed down to the mineral earth. The entire fine fuel within the control line must be burnt out and smouldering



logs and trees within 50m of the line extinguished. This basic requirement has not changed since people successfully started suppressing forest fires. It is labour-intensive and any failure to fulfil this requirement will mean that the fire will escape from control if very high to extreme weather subsequently occurs.

Water is very effective in suppressing the flames, but a waterline cannot be relied upon because the quantities of water required may not be readily available, and smouldering fuels will reignite as the water dries out. Fires that are suppressed by water, be it from ground or air tankers, must be followed up with a bare-earth fire line around the fire and mopped up within the fire perimeter to ensure that embers will not be blown out and breach the fire line.

The most effective fire fighting will be enhanced if there is good access and preparedness to ensure that fire fighters get to the fire without delay. Fire trails should be maintained and cleared prior to the fire season so that valuable time is not lost opening up overgrown or abandoned roads and repairing unsafe bridges.

The primary objective of an initial attack is to control fire at minimum size in minimum time. If this is not possible because of the remote location of the fire or the nature of the terrain, then the primary objective must be to control fire in minimum time before the next period of dangerous fire weather occurs. This decision will determine whether the fire fighting strategy is direct or indirect.

- **Direct fire fighting**

This is primarily deployed during an initial attack when the objective is to contain the fire in minimum size. The flames are either suppressed directly or a fire line is constructed parallel and close to the fire edge.

- **Indirect fire fighting**

Indirect fire fighting involves constructing a fire line, or using an established road as the control line, located at some distance from fire. The same principles that apply to direct fire fighting apply to indirect fire fighting: the fire must be surrounded by a bare-earth trail or road, and the fuels between the trail and fire burnt out and mopped up before the next period of dangerous fire weather re-occurs.

Forest fire fighting is tough arduous work that is most effective if it is carried out by trained experienced fire-fighters who are physically fit. During summer it is essential that response time is rapid and fire fighters are able to take every opportunity to attack the fire under mild conditions that reduce the intensity of the fire.

Fuel management

Of the variables affecting fire behaviour, fuel is the only one over which managers can take direct action. The aim of fuel management is to alter of the structure of the fuel bed and the load of the available fuel to make fire fighting safer and easier as well as reducing the risk to forest assets. The cheapest and most ecologically sound way to do this in forest fuels is by prescribed burning. Grazing or other forms of biomass removal may be useful in grassland situations.

Prescribed burning is defined as burning under specified environmental conditions and within a predetermined area to achieve some predetermined objective. The objective may include habitat management for native fauna, species regeneration, maintenance of specific eco-types or hazard reduction.

Hazard reduction burning will reduce the total load of fine fuel and is also effective in reducing the height and

flammability of elevated fine fuels such as shrubs and suspended dead material. Burning is the only practical way of reducing the fibrous bark on trees, which is the prime source of firebrands that causes spotting. Hazard reduction reduces fire behaviour by:

- Reducing the speed of growth of the fire from its ignition point;
- Reducing the height of flames and rate of spread;
- Reducing the spotting potential by reducing the number of firebrands and the distance they are carried downwind; and,
- Reducing the total heat output or intensity of the fire.

Prescribed burning is not intended to stop forest fires, but it does reduce their intensity and this makes fire suppression safer and more efficient. Prescribed burning does not provide a panacea nor does it work in isolation. It must be used in conjunction with an efficient fire fighting force. It should also be undertaken by skilled personnel and with clear objectives.

The effect of reducing fuel and on the efficiency of direct suppression by hand crews is illustrated in Figure 2.

FOREST FIRE DANGER RATING

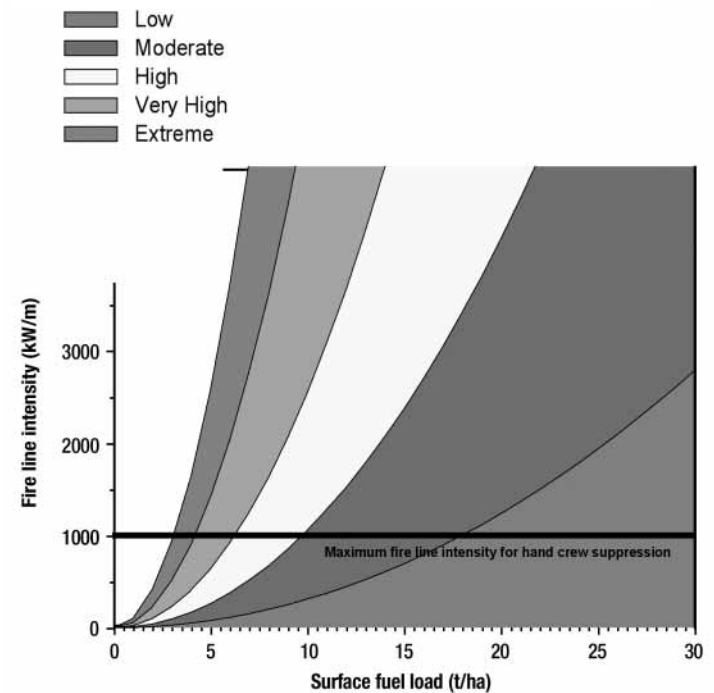


Figure 2: Surface fuel loading and fire line intensity at different forest fire danger rating classes. Black reference line is the maximum intensity hand crews can suppress.

Hand crews can suppress a fire up to a maximum intensity of 1000 kilowatts per metre. If the fuel load > 15 t/ha (which is typical of dry eucalypt forests between 8-15 years since the last fire), this intensity will be exceeded under low to moderate fire danger conditions. If the fuels are reduced to 10 t/ha, fires will not develop an intensity of 1000 kW/m until the fire danger gets into the moderate to high range.

This means that the range of weather conditions that fire fighting with hand tools is effective is increased and more time is available to bring the fire under control. If the fuels are reduced further to a less than 7.5 t/ha, then suppression with hand tools is effective under weather conditions of very high fire danger. Under extreme conditions, provided there is sufficient



fuel to carry fire, fire suppression by any means is virtually impossible because the strong dry winds associated with conditions will cause burning embers to breach any fire line.

A similar relationship between fire intensity, forest fire danger and the effectiveness of direct suppression with air tankers or bulldozers is shown in Figure 3.

FOREST FIRE DANGER RATING

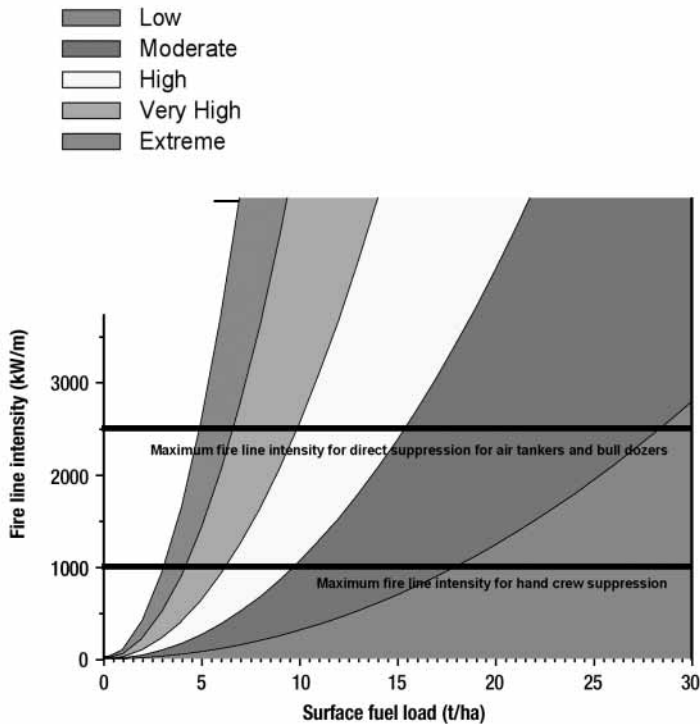


Figure 3: Surface fuel loading and fire line intensity at different forest fire danger rating classes. The top black reference line is the maximum fire line intensity for effectiveness of direct suppression with air tankers and bulldozers.

Application of prescribed burning

There is a perception among people unfamiliar with forest fire management that prescribed burning is simply lighting fires to burn-off the undergrowth and that this can be carried out with only a basic understanding of fire behaviour. Indeed, where burning-off has been carried out in this way, the results have been less than optimal, sometimes resulting in injury and death (e.g. Kur-Ring Gai National Park 2000). Like any land management operation, prescribed burning requires setting clear priorities and objectives, planning, and the application of technical guidelines to meet those objectives. In general terms, the process of conducting a prescribed burn is as follows:

- Set the objectives and desired outcome for the fire;
- Determine the fire intensity and the associated heat pulse that is required to meet that objective (in forestry and for fuel management this may be determined by an acceptable height of scorch on the overstorey canopy or an acceptable level of heat damage to the cambium of regenerating trees);

- Determine the level of fire behaviour that will produce this heat pulse for the particular fuel type;
- Determine the weather conditions and the ignition pattern that will produce this fire behaviour; and
- Light the fire in a planned way and confine it to a predetermined area.

The key to conducting the operation is a good fire behaviour guide that predicts fire behaviour in the selected fuel type. In Western Australia, the Department of Conservation and Land Management has been conducting prescribed burning to meet fire protection, forestry and ecological objectives in a scientific way since mid-60s. Individual burning guides have been developed through empirical research for all their major fuel types including dry jarrah forest, tall wet Karri forest, conifer plantations and Mallee shrublands.

In the eastern states, prescribed burning is largely carried out using rules of thumb based on McArthur's original burning guide for dry eucalypt forests produced in the 1960s (McArthur 1962). Only one specific new burning guide has been developed and that was for burning under young regeneration of silver top ash in New South Wales State Forests (Cheney et al 1992).

Advances in fuel management

The development of more sophisticated burning guides requires a better understanding of fire behaviour in fuels of different structure and composition. Recent work by CSIRO (Project Vesta [Cheney et al 1998, Gould et al 2001]) – work in progress – has identified the importance of fuel structure in determining fire behaviour and has developed a system for quantifying fuel structure with a numerical index that can be used as a fuel predictor variable to replace fuel load.

Although fuel structure is difficult, if not impossible, to measure reliably and consistently, all natural fuels can be divided into easily recognisable layers. It is the characteristics of these layers that determine the particular fuel type and its characteristic fire behaviour and the difficulty of suppression.

For example, the simplest fuel type is annual grassland like wheat. Only a single layer of relatively uniform compaction exists, with the main factor determining the rate of spread being the continuity of the grass. Although the height of the sward affects the flame height, and thereby the suppression difficulty, it has only a minor effect on the rate of spread.

A perennial grass like *Poa* sp. tussock consists of a compacted layer near the ground, commonly 20cm high composed of the tussock base and accumulated dead material from previous year's growth, and a less compact layer of bright grass stalks and leaders and flower heads above. The upright layer of a grass burns before the compacted lower layer and its continuity is the main factor that determines rate of spread. While the fuel load is mostly made up of the compacted fuels, it does not influence the rate of spread because it burns well behind the leading edge of flame. It does influence the suppression difficulty because more water and effort are required to extinguish the compacted fuel and the smouldering combustion within the tussock.

A dry eucalypt forest with a tall shrub understorey has fuel that can be identified into several layers of different compaction. These are in order of decreasing compaction:



- A compacted surface litter bed of leaves twigs and bark that makes up about 60 percent of the total fuel load;
- A near surface layer above it of the low shrubs containing suspended litter and bark;
- An elevated layer of tall shrubs;
- An intermediate layer of small trees and the fibrous bark of the over story trees; and
- The canopy of the overstory trees.

All of these layers make an important contribution to the fire's behaviour and each layer becomes progressively involved in the fire as the intensity increases. The hazard rating system developed by CSIRO takes into account the height continuity and a fraction of dead flammable material in each layer.

Effectiveness of fuel reduction over time

The period that fuel reduction remains effective to assist suppression depends upon the number of fuel layers involved, the rate of accumulation of fuels and the time that it takes for the key layer to build up to its full potential hazard for the site. This may be a relatively short time for fuels with a simple structure or take many years in more complex fuel types – see Table 3.

Table 3: The period that fuel reduction burning will assist suppression activities and the main factors that contribute to difficulty of suppression.

Fuel type	Persistence of reduced fire behaviour (years)	Factors contributing to difficulty of suppression
Annual grass	1 (year of burning)	
Tussock grassland	5	Development of persistent tussock fuel
Tall shrubland	10 – 15	Height of shrubs, accumulation of dead material (ROS, flame height)
Forest, short shrubs, gum bark	10 – 15	Surface fuel, near-surface fuels structure (ROS flame height)
Forest, tall shrubs, stringybark	15 – 25	Near- surface fuel, shrub height and senescence, bark accumulation (ROS, flame height, spotting potential)

Although prescribed burning may persist for a considerable time, most fire management agencies consider that sufficient fuels have accumulated after 5-8 years to warrant re-burning.

What can forest growers do?

Public forest managers have traditionally been key fire managers with an eye on the ecological processes as well as the asset protection elements of fires. Combined with the suppression focus of professional and volunteer fire agencies, this has served Australia well for decades. With

increasing private ownership of forests and reduced timber harvesting from native forests, the dynamics of fire management are shifting. Resources for the management and control of fires are changing. The constant in all this is that whoever owns the fuel, owns the fire.

Private forest owners can reduce the risks to their forests by:

Better understanding of fire behaviour and fire danger rating systems

The key to assessing and understanding the risks due to fire is at least a basic understanding of fire behaviour. This, combined with an understanding of fire danger rating systems, will enable forest owners and managers to assess the risks to their own assets and the impact of fuel management strategies, as well as providing a common language with which to interact with fire management and suppression agencies.

Better preparation for fire

The key actions that private forest growers can take are the management of fuel (both reduction in quantity and in distribution), the provision of ready access through fire trails of adequate size, and support for basic fire fighting (water points, tools, equipment) that dovetails with local fire management agencies.

Interaction with fire management agencies

Better engagement with local fire management agencies to produce fuel reduction outcomes and fire management plans will benefit all parties in the event of bushfire. It is difficult for private forest growers to secure and maintain the resources required for fire management without collaboration with other fire management groups.

Ecological impacts

As with all forest management activities, fire management actions have impacts, both positive and negative, on the environment. Flora and fauna are adapted to fire regimes and changes to these regimes can have an impact on the quantity, quality and distribution of biodiversity. The core of the debate over hazard reduction burning centres on a trade-off that is relatively straightforward to describe, but highly complex in its resolution. On the one hand, hazard reduction burning is an essential tool in the array of methods for mitigating risk to life and property from high intensity bushfires. And yet, on the other, frequent, low intensity hazard reduction fires can fundamentally alter the structure and composition of a range of vegetation types. In a plantation this is less of an issue, but in native forest this trade-off must be recognised and addressed.

Science can describe and predict many of the impacts of this trade-off, but ultimately the objectives will be set by social and political constraints and the policies of management agencies. It is possible to meet fire management objectives that are clearly framed against either protection of life and property, management of biodiversity objectives, or the continuum of trade-offs in between, but science cannot direct decision making in isolation.



References

- Ashton, D.H. (1981a). Tall open-forests. In: R.H. Groves (ed.) *Australian Vegetation*. Pp.121-151. Cambridge University Press, Cambridge.
- Ashton, D. H. (1981b). Fire in tall open-forests (wet sclerophyll forests). In: A.M.Gill, R.H. Groves and I.R. Noble (eds) *Fire and the Australian Biota*. Pp. 339-366. Australian Academy of Science, Canberra.
- Benson, J.S. and Redpath, P.A. (1997). The nature of pre-European native vegetation in south-eastern Australia: a critique of Ryan, D.G., Ryan, J.R. and Starr, B.J. (1995) *The Australian Landscape – Observations of Explorers and Early Settlers. Cunninghamia* **5**, 285-328.
- Catling, P.C. (1991). Ecological effects of prescribed burning practices on the mammals of southeastern Australia. In: D. Lunney (ed) *Conservation of Australia's forest fauna*. Pp. 353-363. Royal Zoological Society, Sydney.
- Catling, P.C. and Burt, R.J. (1995). Studies of the ground-dwelling mammals of eucalypt forests in southeastern New South Wales – the effect of habitat variable on distribution and abundance. *Wildlife Research* **22**, 271-288.
- Catling, P.C. and Newsome, A.E. (1981). Responses of the Australian vertebrate fauna to fire: an evolutionary approach. In: A.M. Gill, R.H. Groves and I.R. Noble (eds) *Fire and the Australian Biota* Pp. 273-310. Australian Academy of Science, Canberra.
- Cheney, N.P. (1981). Fire Behaviour. In *Fire and the Australian Biota*. Ed by Gill, A.M., Groves, R.H., Noble, I.R. Australian Academy of Science, Canberra. Pp. 151-156
- Cheney, N.P., Gould, J.S. and McCaw, L. 1998. *Project Vesta: Research initiative into the effects of fuel structure and fuel load on behaviour of wildfires in dry eucalypt forest*. 13th Fire and Meteorology Conference. Lorne Victoria. IAWF. pp 375- 378.
- Cheney, N.P., J.S. Gould and I. Knight. 1992. A prescribed burning guide for young regrowth forests of silvertop ash. *Forestry Commission of NSW*. Paper No. **16**. 92pp
- Clements, F.E. (1920). *Plant Succession: An analysis of the development of vegetation*. Carnegie Institute, Washington, D.C., Publ. No. 290.
- Crocker, R.L., and Wood, J.G. (1947). Some historical influences on the development of the South Australian vegetation communities and their bearing on concepts and classification in ecology. *Trans. Roy. Soc S. Aust.* **71**, 91-136.
- George, C. W., Johnson, G. C., Trethewey, D. and Uchider, J. (1990). Comprehensive status report on the operational retardant evaluations (ORE) study. USDA Intermountain Research Station Missoula Montana. Fire Suppression Research RWU-4402 (unnumbered).
- Gill, A.M. (1975). Fire and the Australian flora: a review. *Australian Forestry* **38**, 4-25.
- Gill, A.M. (1981). Adaptive responses of Australian vascular plant species to fires. In: A.M. Gill, R.H. Groves and I.R. Noble (eds) *Fire and the Australian Biota*. Pp. 243-271. Australian Academy of Science, Canberra.
- Gill, A.M., and Catling, P.C. (2001). Fire Regimes and Biodiversity of Forested Landscapes of Southern Australia. In: *Flammable Australia: the fire regimes and biodiversity of a continent*. Ed. R. Bradstock. Pp. 351-372.
- Gould, J.S., Khanna, P.K., Hutchings, P.T., Cheney, N.P., and Raison, R.J. 2000. *Assessment of the effectiveness and environmental risk of use of retardants to assist in wildfire control in Victoria*. Report prepared for the Department of Natural Resources and Environment, Victoria. 43 pp.
- Gould, J.S. Cheney, N.P. and McCaw, L. 2001. *Project Vesta- Research into the effects of fuel structure and fuel load on behaviour of moderate to high-intensity fires in dry eucalypt forest: Progress Report*. Australasian Bushfire Conference Proceedings. 3-6 July 2001. Christchurch. New Zealand. pp 13-21.
- Hallam, S.J. (1975). *Fire and Hearth. A Study of Aboriginal Usage and European Usurpation in south-western Australia*. Australian Institute of Aboriginal Studies, Australian Aboriginal Studies No. 58.
- Jones, R. (1969). Fire-stick farming. *Australian Natural History*, September 1969.
- Kemp, E.M. (1981). Pre-Quaternary fire in Australia. In: A.M. Gill, R.H. Groves and I.R. Noble (eds) *Fire and the Australian Biota*. Pp. 3-21. Australian Academy of Science, Canberra.
- Loane, I. T. and Gould, J. S. (1986). *Aerial suppression of bushfires: cost-benefit study for Victoria*. CSIRO Division of Forest Research. 213 pp plus Appendices.
- McArthur, A. G. (1962). Control burning in eucalypt forest. *Comm. Aust. For. Timber Bur.* Leaflet 80.
- Noble, I.R. and Slatyer, R.O. (1981). Concepts and models of succession in vascular plant communities subject to recurrent fire. In: A.M.Gill, R.H. Groves and I.R. Noble (eds) *Fire and the Australian Biota*. Pp. 311-335. Australian Academy of Science, Canberra.
- Rawson, R. and Rees, B. (1983). A review of fire bombing operations in Victoria. Report by the Forests Commission Victoria. 16 pp plus Appendices.
- Rees, B. (1983). Retardant distributions from six agricultural aircraft. Fire Management Branch. Dept of Conservation and Environment, Victoria. Research Report No. 18. 15 pp.
- Singh, G., Kershaw, A.P., and Clark, R. (1981). Quaternary vegetation and fire history in Australia. In: A.M. Gill, R.H. Groves and I.R. Noble (eds) *Fire and the Australian Biota*. Pp. 23-54. Australian Academy of Science, Canberra.
- Stirton, R.A., Tedford, R.H., and Woodburne, M.O. (1968). Australian Tertiary deposits containing terrestrial mammals. *Univ. Calif. Publ. Geol.* **77**, 1-30.