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Fire Management in Pine Plantations

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The Sensitivity of Radiata Pine to Fire

Radiata Pine *(Pinus radiata)* is very fire sensitive and trees may be killed by even moderate intensity fire[1]. Mortality can be caused by combustion of the tree crown (candling or crown fire), or heating and desiccation of the tree canopies, as the flame front passes under tree (crown scorch), and of the living tissue under the bark near the base of the tree (butt damage).

Tree death from scorch will usually result if:

- More than two-thirds of the green crown is scorched; or
- The leading growth tip of the tree is scorched (even though much of the lower crown may remain green).

Low intensity fires in litter and pruning slash (<500 kW m^{-1}) cause little butt damage in trees more than 16 years old. However, heavier slash from thinning operations close to the tree or smouldering logs against the tree will usually cause quite severe butt damage. Old log and branch material from thinning operations often burns completely under summer conditions and can cause quite a high level of localised scorch, butt damage and tree death from a relatively low-intensity fire.

Fire Protection Strategies for Pine Plantations

The fire protection strategy for a pine plantation is aimed at reducing the impacts of fire by adopting measures that minimise the occurrence and impact of fires. This includes hazard reduction in adjacent native vegetation together with fast detection and rapid initial attack of wildfires to ensure that they are suppressed while small. This approach has been generally successful around Australia with only relatively small proportions of the plantations destroyed over time.

Development of the fire protection strategy takes account of the fire statistics for the area, assessment of risk, the cost and effectiveness of each fire prevention measure and plantation management strategies. The strategies for reducing the number of fires in and around plantations include:

- Monitoring of ignition causes and adaptive management of these;
- Public education and positive neighbour relations;
- Control of burning activities in and around the plantation;
- Control of public access and patrolling in an around the plantation;
- Effective maintenance of forest machinery and monitoring of mandatory fire suppression equipment on forest operations sites; and
- Restricting harvesting and machine operations on days of extreme fire danger.

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[1] Fire intensity refers to the amount of energy measured in kilowatts (kW) released from every meter (m) of fireline at any point in time. Fires intensity is a function of rate of spread and the amount of fuel being consumed by the flame front. A low intensity fire is considered to have an intensity of less than 500 kW/m, a moderate intensity fire has an intensity of less than 1000 kW/m, and extreme and very extreme fires have intensities of 4,000 kW/m and 10,000 kW/m respectively. Difficulty of control and likelihood of damage increases as fire intensity does.

The strategy for reducing fire damage is based on two principles:

- Provide maximum access (with safety) for fire suppression resources within and around the plantation; and
- Provide fire protection works and facilities at strategic locations to minimise the area burnt by any fire and to maximise the chance of suppression success on intense fires at pre-determined control lines.

Plantation Fire Losses

The history of fires in pine plantations around Australia is that most fires are contained without significant loss of plantation assets. For example, between 1974 and 1994 Victoria recorded 308 fires which burnt about 5% (5,540 ha) of its 106,000 ha of state-owned pine plantations, giving an average fire size of 18 ha (CFA/DCNR/VPC, 1994).

Most losses have resulted from fires that have burnt into plantations from adjoining native forest or grassland under severe fire weather conditions, rather than from fires that commenced in pine plantations. In Victoria fire statistics indicate that only 25% of plantation fires originate outside plantations, but these fires are responsible for 90% of the area burnt (CFA/DCNR/VPC, 1994).

Most of the significant plantation fires around Australia have destroyed less than 2000 ha of plantation. The 2003 fire in the ACT destroyed the second largest area of softwood plantation on record, which makes it somewhat of an unusual fire event. The biggest losses of pine plantations from fire occurred during 1983, including 21,000 ha in South Australia, 6,457 ha in New South Wales and 2,339 ha in Victoria.

ACT plantation losses:

Specific information on the total number of fires affecting plantations in the ACT is not available. However, in most years there are a number of small fires within the plantations which are usually contained rapidly, with only minor losses of plantation assets. Most of these fires burn very small areas (commonly <0.01 ha).

Within the ACT there have been five recorded serious fire events in plantations. The 1939 fire destroyed 1100 hectares of the Uriarra plantation. This fire started west of the Goodradigbee River on 10 January and by the evening of 13 January one tongue of the fire had reached Two Sticks Road near Mt Coree. On 14th January under extreme fire weather the fire burnt across the Uriarra plantation (completely destroying it) and was halted at the Murrumbidgee River. However around noon a spot fire from this fire occurred near Huntly and swept towards Mt Stromlo but was contained about 3 km from Mt Stromlo (Luke and Macarthur, 1978 and ESB website).

In February 1952, a fire burnt about 3000 hectares between the Murrumbidgee River and Woden Valley including 316 hectares of pine plantation at Mt Stromlo. The burnt area was allowed to regenerate with natural regeneration, indicating that the burnt stand carried relatively advanced age class with sufficient seed to provide a reliable and dispersed stocking. The suspected cause of this was a “sleeper” lightning strike from the previous day.

A re-establishment slash burn at Pierces Creek in autumn of 1991 escaped its control lines about three days after the burning operation, and burnt 400 hectares of plantation. This fire led to a review of establishment practices, with a decrease in the use of burning in a bid to avoid further plantation losses. This is the only known instance of a fire caused by site preparation activities in ACT plantations.

In 2001, deliberate ignition at two sites (Huntly and Coppins Crossing Road) resulted in a fire that burnt about 1,200 hectares between Huntly and the Royal Australian Mint at Deakin. The area burnt included 500 hectares of ACT Forests' managed land in Stromlo, of which 342 hectares was standing pine plantation. The value of the standing timber destroyed by the fire was $1.472 million. Some clear felled plantation areas containing heaped and broad acre logging slash in the Blewitts plantation and Greenhills West plantation were also burnt.

In January 2003, about 10,500 hectares of plantation was destroyed by fire in less than 24 hours. This included all of the Pierces Creek and Uriarra plantations and most of the Stromlo plantation, with only some areas of the 2002 replanting surviving the fire. In addition most of Miowera and all of Ingledene plantations were destroyed. The value of the standing timber destroyed by the fire was $56.142 million. This loss followed the pattern of most other major Australian and ACT plantation fires, where large, intense and uncontrollable fires started outside the plantations and then swept through the plantation in a relatively short period of time.

It is important however to keep the 2003 loss in perspective, both in terms of Australian plantation losses and the pre-2003 experience in the ACT. Before 2003, a total of about 2500 hectares of plantation has been destroyed over an 80 year period, which is an average loss of about 30 hectares a year.

Fuels in Pine Plantations

In considering fuels in forests it is important to distinguish between fine fuels and heavy fuels. The fine fuels (<6mm) which includes dead fallen material, such as leaves, bark, twigs and branchlets, ignite and burn readily and are responsible for the spread of the fire. Living materials (<6mm) are also available fine fuels, but other than in drought situations they are not as critical to the development of a fire because of the moisture content in the living fuels. Heavy fuels, which includes all the living and dead woody branch and stem material, generally burn only once the fine fuels are ignited and combustion is usually slow and often incomplete in a fire event. Another significant aspect to consider is the distribution of the fuels. Compacted surface fuels burn less intensely than an equivalent quantity of fuels that are vertically distributed through shrubs or branches.

The fuels available for burning in pine plantations vary greatly with the stages of growth and silvicultural treatment. Fuel loads are not routinely measured in pine plantations because the research evidence shows that for about 50-75% of the rotation fine fuels are in equilibrium. However, some information about fuel loads is available from published research papers.

Forrest and Ovington (1969) found the build up in **radiata pine foliage** (fine fuels) within the trees is slow up to age 5, after which there is a rapid increase until an

equilibrium value of 10 t/ha is reached between ages 7-10 years. From a fire behaviour point of view there is a relatively constant weight of foliage in the crowns following canopy closure, which generally occurs between ages 7 to 10 years depending on the site quality and stocking rate.

Williams (1976) measured fuels in un-thinned 12 year old radiata pine plantations and found that the total fine fuel (on the ground and within the trees) is 22.6 t/ha, made up of the following components:

Category of Fine Fuel	**Weight (t/ha)**
Ground fuels	5.6
Living needles	7.7
Dead needles in crowns	2.4
Living branchwood	4.3
Dead branchwood	2.6
Total	**22.6**

He concluded that the fine fuels constitute only 16% of the total fuels in the plantation (150 t/ha). This information indicates that even if all the ground fuels and the dead needles in the crowns were removed the 12 year old plantation would still have 14.6 t/ha of available fine fuels in a wildfire. Green needles are generally retained for 3 years on pine trees which means that mean annual growth of needles is 2.6 t/ha. These stands have an average of 85 t/ha of stem wood and 13.4 t/ha of coarse branch wood, which means that in a thinning operation (which removes approx 1/3rd of standing trees) approximately 18-25 t/ha of dry fine and coarse fuels would be added to the site after the merchantable stem wood is removed.

Woodman (1982) measured fuel quantities at ground level in plantations from 10-30+ years and found that the fuel is composed of litter (whole and partly decomposed needles) and duff (needles in an advanced state of decomposition). **The results indicated that from 15 years the total ground fine fuels in a plantation is in equilibrium at about 10 t/ha.** This is generally consistent with the 8 t/ha level of fine fuels that native forest managers try to achieve in areas where fire protection is a priority.

In terms of total biomass (hence total fuel) in a pine plantation, once the stand reaches canopy closure (7-10 years) most of the biomass is added in the stem or boles of the trees, increasing from about 100 t/ha to 400 t/ha. The branch biomass increases slowly from about 20 t/ha to about 40 t/ha and the foliage biomass remains relatively constant, only reducing in times of drought when needle shed occurs.

Impact of Harvesting Operations

Thinning causes dramatic changes in fuel distribution. While in the long-term these changes may be beneficial in terms of fire behaviour, the hazard increases in the short-term because of increased ground fuel quantities, increased exposure of dead fuels to the drying effects of the wind and sun, and greater penetration of the wind into the stand during a fire. Williams (1978) found that **first thinning in 12 year old stands added about 7.5 t/ha of fine fuels and 12-18 t/ha of heavy fuels**.

Woodman (1982) studied the impact of a **second thinning** operation (50% reduction in stems/ha) at age 18 years and found that **about 18 t/ha of fuels were added to the ground fuels of which about 1.9 t/h was living and dead needles**.

Woodman (1980) studied the relationships between slash age and retention of elevated needle fuel and found that about 50% of the needle fuel can be expected to fall from the slash within one year of thinning and 80% within 3 years by which time the slash is no longer a substantial hazard.

When a pine plantation is clearfelled at about 30 years of age, it is not uncommon on good site quality areas to remove up to 350-400 t/ha of merchantable log products (sawlogs and pulpwood), depending on the productivity of the stand and the quality of the trees. Once this material is removed there would be an estimated 50 t/ha of branch material and foliage left on the site.

In situations where there is no market for pulpwood and the quality of the unthinned trees is poor, it is possible that up to 250 t/ha of branch and bole material may be left on the site after clearfelling. However, more realistically the quantity of branch and bole material in such circumstances would be in the order of 140 t/ha (Bartlett – personal observation). For example the debris remaining in ACT Forests Blewitt's plantation following sawlog only harvesting in 2001 was estimated to be 95 t/ha of log material, 35 t/ha of branches and 10 t/ha of suspended needles. This stand had an average Mean Annual Increment of 14 m^3/ha/an and was clearfelled at 27 years of age and had had one commercial thinning operation conducted previously.

Fire Behaviour in Plantations

Plantation fires will either behave as surface fires or crown fires. They usually start as surface fires and, if conditions are suitable, rise to the canopy after moving 25-50 metres within the plantation. Surface fires generally occur when fire danger is low to moderate and burn the grass, surface litter and understorey fuels. Crown fires occur when the fire spreads from surface fuels to burn foliage and crown fuels resulting in greatly increased flame heights, fire intensity and a 2-3 times increase in the rate of spread of the fire. Under most circumstances crowning is restricted to the head fire or to areas of mass spotting and the junction zones of fires. Mature plantations are less prone to crown fires than in younger aged plantations although most stands are susceptible under extreme fire danger conditions.

The primary factor determining the difference in fire behaviour between fuels under eucalypt and pine forests is the extent of the gap between surface fuel and the aerial fuels in the tree crowns. Pine trees generally retain their branches even after they no longer contribute to the live green crown and, unless pruned, these maintain a continuum between ground and crown fuels. In the past, trees in pine plantations were pruned to provide a barrier between ground and aerial fuels to lessen the chance of crown fire initiation. However, the high cost of pruning and the lack of a market premium for pruned logs mean that most plantation owners now only implement pruning in strategic fire protection zones. There is also a growing recognition that pruning, even to heights of 10 metres, will not eliminate the potential for crown fires on days of extreme fire danger.

Spotting distances of fires within pine plantations are considerably lower than of fires burning within eucalypt forests (generally only 10-20% of the eucalypt distance). The longest spotting distance recorded from a plantation fire in Australia is 2 km (1958 Wandilo fire), however under most circumstances spotting activity is generally within 200 metres of the head fire.

The rate of spread of most plantation fires is in the order of 0.5 – 2.0 km/hr, although the 1979 Caroline fire (SA) burnt at 4.0 km/hr while the 1983 Mt Muirhead fire (SA) burnt at more than 12 km/hr. The 2001 Stromlo fire burnt at a rate of spread of 2.5 km/hr within the plantation and it is estimated that the January 2003 fire burnt through the Stromlo plantation at a rate of spread of 6.0 km/hr.

Fire Protection and Fuel Management Strategies in Plantations

In addition to maintaining an active fire detection and fire suppression capability, plantation owners generally implement a range of fire protection strategies within their plantation estates. Unlike the situation in native forests, fuel management is not the predominant strategy due to the difficulties of treating fine fuels within plantations. The most common fire protection strategies within plantations include the following:

Access

Plantations are generally well roaded, compared to native forests, in order to facilitate removal of harvested produce and to assist with rapid fire suppression. While the location and density of the road network varies according to the terrain, most plantation managers aim to ensure that about 95% of their plantation estate is within 400 metres of a road. Access networks should be clearly sign posted, mapped, allow for vehicles to pass and turn, and minimise the use of one-way or dead end trails.

Water Supplies

The use of water under pressure is an important part of fire suppression tactics in plantation fires. This is achieved by running hose lines into the fire from fire tankers located on roads and firebreaks. To achieve this it is important that there is adequate access to water supplies within and around the plantation estate. This is achieved by providing access to permanent watercourses or waterholes supplemented by the establishment of a network of fire dams within the plantation.

Firebreaks

Firebreaks are established to obstruct an approaching fire, to provide access for suppression forces as well as to provide a line from which a suppression tactic can be implemented. This typically involves the establishment of a grid of firebreaks within the plantation, with most emphasis on those aligned parallel to the anticipated direction of fire spread under extreme fire behaviour conditions. Construction and maintenance of firebreaks is expensive and it reduces the productive area of the plantation, but effective firebreaks can assist with minimising damage and losses to plantations during fires.

Firebreaks aligned parallel to severe fire weather can be useful for flank attack. A flank of a severe fire has been held by a break of 10 metres. Firebreaks perpendicular to severe fire weather will probably be ineffective against severe fires (eg Tuggeranong Parkway during the 2001 Stromlo fire) unless strengthened by significant adjacent fuel reduction treatment. Firebreaks of up to 100 metres width have proved no more effective than narrower breaks and in some respects may exacerbate the difficulty of control by allowing the wind to penetrate the plantation and thereby increase fire behaviour within the plantation. At the 1979 Caroline plantation fire in South Australia, the fire crossed 60 metre wide firebreaks as easily as it crossed 20 metre breaks under extreme fire danger conditions.

External firebreaks are generally recommended to be between 10-15 metres wide and maintained in a low fuel condition with no overhanging branches for a vertical height of 10 metres. The setback distances that existed around the Narrabundah Hill plantation and the roads at the urban interface within the suburb of Duffy ranged from 30 to 100 metres. The evidence from CSIRO suggests that these setback distances were sufficient to prevent direct flame contact with residences, but insufficient to prevent ember attack impacting significantly upon the gardens and residences.

Internal firebreaks are generally recommended to be between 8-10 metres wide cleared of flammable vegetation and aligned on a grid pattern 600-800 metres apart. To further enhance the effectiveness of these firebreaks some plantation managers conduct fuel modification (especially high pruning, and shrub removal) within adjacent stands for a distance of 80-90 metres on the northern and western sides of the firebreak and 30-40 metres on the southern and eastern sides of the firebreak. Fuel modification can include pruning and treatment of ground and slash fuels.

Crown Fire Free Zones

One fire protection practice used by many plantation growers for the past 20 years has been the implementation of "Crown Fire Free" Zones. Crown fire theory is based on the principle that a crown fire can only be maintained if the surface fire has a flame height sufficient to continually ignite the lower foliage of the crown, or ladder fuels (such as scrub and branches) are available to carry fire into the crowns. In the past there have been observations of crown fires not being sustained when they enter an area where the trees have been pruned. However there is other evidence that suggests that this practice merely reduces rather than eliminates the likelihood of crown fires developing within plantations.

These zones are strategically located areas in which the fuels are modified in an effort to prevent the formation or maintenance of a crown fire. These zones have been established near settlements or high value assets and are usually located adjacent to major access roads or firebreaks with the aim of creating a 200 metre wide fuel modified zone. This will often involve a zone of 130 metres on the upwind side of a 20 metre firebreak and a 50 metre zone on the downwind side of the firebreak.

Trees within the zones are thinned out to achieve a final stocking level (150-200 trees per hectare) as early as possible in the rotation and all trees are high pruned to 6 metres to create a clear gap between ground fuels and canopy fuels. The zone is managed to ensure that ground fuels are maintained at a relatively low level, by employing various management strategies including grazing, scrub slashing, weed control and low intensity prescribed burning.

A crown fire free zone had been established in ACT Forests' Narrabundah Hill plantation adjacent to Eucumbene Drive in Duffy. The ground fuels within a significant portion of this zone had been reduced in a low intensity prescribed burn during early 2001. The intensity of the fire on 18th January 2003 was so great that the zone had little or no impact on the maintenance of the crown fire in a considerable part of the zone. There is some evidence that the fire burnt as a ground fire in some parts of the zone where the prescribed burn had been carried out two years ago.

Fuel Reduction Burning in Adjoining Native Forests
Fuel reduction burning of adjacent native forest provides effective perimeter protection for plantations, particularly where these areas are located on the north or western sides of plantations. Treatment of external native forest should extend for a distance of 200-500 metres and is often applied to meet fuel reduction objectives such as fine fuels at less than 8 tonnes per hectare on 90% of the treatment area. Undergrowth vegetation can also be reduced by slashing or mechanical treatment for a minimum width of 20-50 metres on plantation boundaries where the fire risk is low or where burning is difficult.

Fuel Reduction within Plantations
Herbicides are used to control weeds and grass in young plantations to improve the growth and survival of the planted trees and in doing so reduce the distribution and quantity of these fuels within the plantation. Grass fuels can also be controlled by grazing once the young trees reach an age of 4-5 years.

Pruning of branches to a height of 2 metres can be conducted in strategic areas from age 6-8 years once the trees have attained a height of 5 metres. However this operation has some disadvantages including adding 3 t/ha to the surface fuels and allowing wind to penetrate the plantation as well as being expensive (>$1000/ha).

Under very mild conditions, low intensity prescribed burning can be carried out in mid aged to mature plantations to reduce surface fuels and logging slash. However, the "window of opportunity" for successfully conducting burning operations within radiata pine plantations is quite small and to date most Australian growers have only used this technique for experimental or small-scale hazard reduction purposes.

Following clearfelling of a plantation, the remaining woody debris can either be burnt or treated by "crusher rolling" as part of site preparation operations for the next plantation crop. In the past, it was common practice to treat this debris by implementing high intensity prescribed burning techniques. However, research demonstrated that this technique resulted in significant deterioration in growth rates of the next crop and that this form of management is unlikely to be sustainable over several rotations. For this reason, high intensity burning has generally been replaced by crusher rolling in most Australian plantations.

Crusher rolling involves drawing a heavy spiked roller over the logging debris with a bulldozer. This process breaks up the fuel, incorporates it partially into the soil profile and thereby retains important organic matter on the site. This technique alters the fuel distribution and decomposition rate but it does not reduce the total quantity of fuel on the site after harvesting.

Age Class Distribution within Plantations

Most Australian pine plantation growers recognise that fuel hazards within the plantation differ with plantation age and are increased following harvesting operations. To minimise the risk of these temporal hazards, plantation owners attempt to manage the spatial distribution of age classes within the overall plantation estate.

Summary

Pine plantations are very different to eucalypt forests in terms of how they are affected by fire and consequently plantation managers use different fire protection strategies to those used in native forests. Most fires that occur within plantations are rapidly suppressed with little loss of plantation or other assets. Conversely, most of the significant plantations losses that have occurred around Australia have been as a result of intense fires that have entered the plantation from adjoining land. Under extreme fire danger conditions it is virtually impossible to stop the forward spread of a wildfire within a pine plantation.

Fine fuels on the ground within plantations reach an equilibrium of 10 t/ha from age 15 years, while the fine fuels in the crowns of the trees also reach an equilibrium of 10 t/ha from age 7 to 10 years. Thinning operations increase the quantity of fuels on the ground by up to 18 t/ha, but only 2-7 t/ha of this is fine fuel and most of these needles are shed from the logging debris within 3 years of harvesting. About 50 t/ha of branch and needle debris is left on the ground when the plantation is clearfelled. This fuel is treated by crusher rolling during re-establishment operations to ensure that organic matter is retained on the site.

Plantation fire protection strategies focus on minimising the occurrence of fires, rapid detection and suppression of fires and the provision of appropriate access roads, firebreaks and water points. Grass fuels are treated by grazing or herbicide application. Pruning of branches in strategic areas provides some fire protection benefits under most circumstances but it is costly to implement. Crown Free Fire Zones, in which the trees are high pruned and widely spaced, have been used in strategic locations in an attempt to minimise the chance of crown fires being sustained in these areas. Fuel reduction burning within pine plantations is only possible at certain stages of the plantation's rotation and under very mild weather conditions.

Internal firebreaks are generally 8-10 metres in width and established on a grid pattern with emphasis on aligning most breaks in the direction of the prevailing worst fire weather. External firebreaks are generally recommended to be 10-15 metres in width. The set back distances between pine plantations and the road adjacent to urban areas in the suburb of Duffy varied from 30 to 100 metres. While this was sufficient to avoid direct flame contact between burning trees and residences it did not preclude the residences being subject to considerable ember attack.

References

Country Fire Authority, Department of Conservation and Natural Resources and Victorian Plantations Corporation (1994) Plantation Firefighting – Training Course Manual

Forrest W G and Ovington J D (1969) Organic matter changes in an age series of Pinus radiata plantations *J. Appl. Ecol.* 7(1) 177-186

Luke R. H. and Macarthur A.G. (1978) Bushfires in Australia

Williams D. F. (1976) Forest Fuels in Unthinned Radiata Pine Stands *Aust. For.* 39(4) 238-244

Williams D. F. (1978) Fuel properties before and after thinning in young radiata pine plantations. Forests Commission Victoria Fire Research Report No 3 (unpublished)

Woodman M[1] (1980) The effects of ageing on fire hazard created by radiata pine slash

Woodman M [1](1982) Fuel properties before and after second thinning in radiata pine

[1] references quoted in Woodman, M., Rawson, R (1982) Fuel Reduction Burning in radiata pine plantations Dept of Conservation and Environment Fire Management Branch Research Report No 14