FIRE, TREES AND CLIMATE CHANGE

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Introduction

The Black Saturday fires that occurred on 7 February 2009 in Victoria conjure images of destruction, damage and death. These fires, like those of Ash Wednesday in 1983, and more recently in Sydney, South Australia, Western Australia and Canberra, are seen as devastating and catastrophic to the natural environment, human life and property. They are also reminders that southern Australia has a long history of major fires that regularly punctuate the historical record of the past 150 or more years. The fossil record indicates an even longer record of major and frequent fires (Gill and Groves 1981).

Parts of southern Australia are among the most fire prone places on earth – only parts of Mediterranean Europe, and the southern parts of the USA are rivals for frequency and intensity of fires. Bushfires are not destructive in the natural environment. They are part of the normal ecological cycle to which native plants and animals have adapted. There are individual plants and animals that die during a fire, but populations and communities continue. Communities that are known and loved by many Australians are often dependent on fire and without fire their future survival is jeopardised.

There were reports that the recent fires were the worst ever and that everything had been killed and that there would be little, if any, natural recovery. Even the soil was said to have been destroyed. There was also the now usual kneejerk reaction against native vegetation, particularly in peri-urban areas. As a consequence there have been questions about the role of vegetation in peri-urban parts of Australian cities, especially as climate change is likely to result in more extreme fire weather and more fire prone days (Moore, 2009).

The action of fire on plants and their ecology

At a time of climate change when the weather patterns in many parts of Australia (in terms of rainfall, higher temperatures, higher wind speeds and wind direction) have already changed, it is essential to recognise what fire does to plants. There are a number of components to understanding the effects of fire on plants, including intensity of the fire (often measured as temperature), the duration of the fire and the frequency of how often fires occur.

Some plants are burnt where there is a high temperature, irreversible oxidation of plant materials. If the intensity and duration of the burning are high enough, then the plant part or plant as a whole may be killed. Other plants are singed, which is essentially superficial burning and those parts of the plant or the whole plant have prospects of recovery. Finally, plants may also be scorched by the blasts of hot air from the strong winds associated with bushfires.

The effects on plants of burning, singeing and scorching are quite different, and plants respond variously to the effects of fire depending on the adaptations they possess to fire and stress in general. Adaptations may be structural, physiological or ecological and some of the adaptations of eucalypts to fire (Table 1) serve as fine examples of the typical adaptations of the components of the Australian flora more generally to fire (Gill and Groves 1981). The possession of some, or all, of these adaptations is also an indicator of likely species survival of fire. Consequently different species must be managed in different ways after the fire.

From an ecological perspective, fire removes competition and allows high levels of light to reach the forest floor. Many, and often large, mushrooms and "toadstools" appear which are often the fruiting structures of the mycorrhizal fungi associated with tree, shrub and grass roots. Usually soils are not killed by fire but enriched with nutrients. Signs of recovery are often in evidence 10 days after fire if there has been rain. Many people are up-lifted, given hope and impressed with the speed of recovery.

In the smooth-barked eucalypt communities, such as mountain ash (*Eucalyptus regnans*) forests, the effects of fire are swift, sure and predictable. Individual trees are very sensitive to fire and almost all that are burnt are killed (Moore 1995). However, within weeks of the fire, the fruits and foliage on the trees at the time of the fire are shed, providing both a nurturing mulch (or ash bed) and a rich seed source for the regeneration that follows.

Table 1. Some common adaptations of eucalypt species to fire that can affect their survival and recovery from bushfire (from Moore1995)

Common Eucalypt Adaptions To Fire
• Thick bark. • Sclerophyllous leaves. • Epicormic buds. • Lignotubers. • Woody fruits. • Fibrous/stringy bark. • Volatile oils in leaves. • Seedling regeneration after fire.

In mixed eucalypt forests, such as those of messmate (*E obliqua*) and peppermint (*E radiata* and *E dives*), regeneration occurs not only from seed, but many individual trees survive the fire, and epicormic shoots and lignotuberous shoots emerge as the communities commence a new cycle of growth within months. Lignotubers, probably better known as mallee roots or as basal burls in the northern hemisphere, are found in many Australian species and provide a rapid and sound replacement of a tree.

Epicormic buds are dormant buds that are found just under the bark of many eucalypts, and like the dormant buds found in oaks and elms amongst many other species, provide for a very rapid canopy replacement. Initially however, they are often weakly attached and so if they occur low down on the trunk they have to be managed to ensure that they do not get too long and too heavy. As time goes by, each growing season a new tree grows over the old wood and so a proper and strong branch attachment develops.

In the past after fires, bulldozers often piled ferns and tree ferns into great heaps on the assumption that they were fire sensitive and had been killed. In fact, the opposite is the case, and the growth habit of the rough tree ferns (*Cyathea australis*), and to a lesser extent the smooth tree fern (*Dicksonia antarctica*) and many of the ground fern species (*Polystichum sp., Blechnum sp.*) is such that they are unlikely to burn and as a consequence are fire resistant. The fibrous leaf bases hold a great deal of moisture and are slow to burn (Moore 1995). These characteristics provide protection for the growing apices and so ferns suffer little damage. They have been defoliated, but soon produce new fronds and show a full recovery.

Many of the mountain and peri-urban landscapes burnt in recent fires were renowned for their conifer collections. It is often assumed that conifers are very fire sensitive and as a consequence many trees are felled in the days immediately after the fires. While most pine and cypress species are sensitive, not all conifers are killed by fires, and some are renowned for their longevity and fire resistance. The thick bark of the redwoods renders them fire resistant, and some of the deciduous conifers also cope well with fire. Often these trees are removed after fire unnecessarily, causing major impacts on the landscapes they once dominated.

For other exotic plants, whether they are killed or survive fire depends upon the nature of their injury, their growth habit and adaptations. Many rhododendrons burnt in the fire were killed, but those that were scorched by hot wind blasts, while looking rather sorry suffered little more than defoliation and soon produced new leaves and shoots.

For other plants, although the stems and foliage were killed in the fires, the root systems remained alive and suckers soon emerged. Regeneration from the rootstocks is not only useful, but provides a rapid means of re-establishing valuable vegetation. However, caution must be exercised because for grafted specimens, such as many exotics, the rootstocks may not only be the wrong variety, but in some cases are different species that are not wanted in the garden. This scenario is amply demonstrated in the recovery of rhododendrons, roses, wattles and olives amongst other species.

For bulbous and cormous plants the fire has no real effect on their subsequent growth, apart from providing a boost in nutrient and light levels and the removal of competition. Indeed, following the fires, the displays of such plants, including native orchids in the following May through to September is often spectacular. For certain of the rhizomatous species, the effects are similar and fire has little impact upon subsequent growth.

Assessing the effects of fire on urban vegetation

In the days immediately after a fire it is essential to identify those plants that have survived and those which have succumbed to fire. The cleaning up exercise after a fire is usually conducted by emergency services officers who have little arboricultural knowledge, but who are often proficient with chainsaws. Importantly, the cleanup is conducted at the expense of the State as no charge is made to individuals for the work done as part of the mopping up, including pruning or removing trees. Trees that are left and which subsequently die have to be felled at the property owner's expense, which can readily mount to tens of thousands of dollars in a large garden containing many trees. However, it was interesting that after the Victorian Black Saturday fires of 2009 many more arborists were involved in assessing tree condition after the fire and in particular along roadsides and in public open spaces than had happened after previous fire events. This is a development in post-fire management that is to be applauded.

It is essential that ecological and environmental values inform any mopping up operations that follow bushfire. Where possible, mopping up should be avoided as it can degrade the environment through compaction of soil, the elimination of microhabitats and disturbance to natural regeneration processes. However, where it may be necessary it should be managed under the direction of experts who have detailed ecological and plant knowledge for sustainable environmental outcomes rather than as an engineering based "clean up". Too often mopping up destroys healthy plants that would readily recover from fire, alters edaphic conditions through compaction and changed soil contours and drainage, and eliminates the microhabitats that facilitate the diverse regeneration that follows fires. It is often no more than a form of approved environmental vandalism!

In relation to the mopping up of vegetation after previous fires, following a more thorough examination of the trees that are left standing and those that are felled, a rough rule of thirds seemed to apply to the vegetation of fire damaged trees:

- About a third of the trees left standing were dead, or so badly damaged that they should be felled.
- About a third of the trees felled were alive and would have survived as useful trees after the fire.
- About a third of all the trees affected by the fire were incorrectly identified as dead or alive.
- About two thirds of the trees were correctly assessed and therefore were well managed.

This general rule suggested that many of the decisions made after fires concerning trees are little more than guesses with a two in three chance of getting things right. However, the outcomes of these decisions can have a profound effect on subsequent fire recovery. A dead tree left standing may cost thousands of dollars to remove after the mopping up period, and trees that add great value to streets, gardens and landscapes and which have significant environmental value are removed in error.

The assessment of tree condition after fire can be difficult, but a number of simple criteria can be used to assess plant condition (Table 2). In woody species it is important to determine whether the cambium has been damaged by fire. This can be done on young tissue simply by pealing back the bark and looking for the bright green or light to pale brown cambial layer depending on the species. Dark brown layers normally indicate that the plant is dead or dying. Another symptom worth looking for is the lifting of the bark from the cambium or the development of substantial cracks in the bark which indicate that the cambium has "stewed" in the heat and that bark and wood have separated.

In older parts of the plant, especially for thick barked species, it might be necessary to tap the bark to see if it has lifted from the cambium or to remove a small section of the bark to allow cambial inspection. If the cambium is dead, that part of the plant or the whole plant needs to be removed. In ferns the soft and usually moist fiddleheads in the crown are a sure sign that all is well and that recovery is imminent. Making a correct diagnosis of plant condition after fire can save a great deal of money, time and effort in restoring a landscape.

In assessing tree condition after fire a diagnostic accuracy in excess of 95% is certainly achievable with species that are common and where there is a history of management post-fire. After the 2009 fires several hundred specimens of native pine, *Callitris preisii,* were assessed on the Horsham Golf Course. There is little information on the post fire recovery for the species and so the criteria listed in Table 2 were used to determine whether the trees were dead or alive. The presence of a whitish resin at the base of the trunk proved to be a good indicator of death or survival. If resin occurred around the entire base the tree was assessed as dead, and if resin was present for less than 40% of the circumference then there was a chance of survival. Subsequent investigation of the specimens revealed that when resin was present around the entire circumference 100% of the trees were dead and when 40% of the circumference was free from resin there was an 80% chance that the trees were still alive six months after the original assessment.

Table 2. Criteria that are useful in determining likely plant survival after fire (Extended from Moore 1995)

Criteria for Assessing Plant Condition
• Cracked and lifting bark. • Bark separated from the cambium and sapwood. • Dead cambium (discoloured/dark brown tissue under bark). • Ringbarked major branches or trunk. • Ringbarked trunk at soil or mulch surface. • Dead or seriously damaged roots. • Presence of dormant buds. • Presence of epicormic buds. • Presence of lignotubers. • Capacity for suckering. • Possession of bulbs, corms and rhizomes. • Possession of thick insulating bark. • Possession of woody, fire resistant fruits. • Protected meristems (such as apical buds protected by fruits or fiddleheads protected in the crowns of ferns). • Presence of resins oozing from cracks in the bark at base of trunk.

It is also worth noting that the adaptations described earlier for eucalypts (Table 1) are also possessed by many other species, both native and exotic. For example, some specimens of the lilly pilly (*Acmena smithii*) can possess a lignotuber; some species of elms possess epicormic buds; many species of shrubs and trees have thick bark; sclerophyllous leaves are possessed by many native and exotic species; and, of course, many species possess woody, fire resistant fruits. In evaluating the chances of survival of these species, it is worth considering their adaptations and the likelihood of their survival.

Pre-fire landscape management

In parts of Australia fire is part of the ecology of plant communities and does neither harm nor good; it is simply part of nature's cycle (Gill and Groves 1981). In such places natural fires should be allowed to take their course and in managing such areas, the inevitability of fire must be recognised. If people are to live in these places, as part of peri-urban sprawl, their homes must be properly constructed and appropriate fire prevention plans and techniques implemented which will allow such fires to burn without threatening the property or the lives of people who live within or adjacent to natural forest communities.

In urban areas where the vegetation of streets, parks and gardens are often a mixture of native and exotic plants, bushfires present some interesting challenges. While all plants are flammable given the right conditions, some are fire resistant or retardant (Table 3). Some of the native plants are well-adapted to fire and survive, others may be killed but regenerate readily from seed. Many exotics however, lack adaptations to fire and have to be managed if the landscape is to be re-established properly and quickly.

Table 3. Characteristics of fire retardant tree species (from Moore 2009b)

There are really no non-flammable trees. However, there are low flammability plants which have the following characteristics:
• Green foliage during the fire season. • High leaf moisture and mineral salt content. • Low levels of dead canopy material, especially bark. • Capacity to compete with and suppress grasses and other understorey species. • Capacity to survive droughts and occasional fires.

In planning and managing landscapes from a fire perspective it is important to consider the use of fire resistant and retardant species (Table 4). Fine fuel loads in the vicinity of buildings must be managed through raking, use of low growing species, and by keeping any mulch moist thereby reducing its flammability.

Table 4. A selected and indicative list of some fire resistant and retardant Native and Exotic tree species (modified from Moore 2009b, Cheney 1985, Anon, 1980)

Some Selected Fire Resistant and Retardant Native Species		
Acacia bailyana,	*A howitii*	*A mearnsii,*
A dealbata	*Angophora species*	*Atriplex nummularia*
A vesicaria	*Casuarina species*	*Myoporum species*
Rhagodia baccata	*R nutans*	*Banksia marginata*
Banksia integrifolia	*Hymenosporum flavum*	*Lophostemon confertus*
Eucalyptus bauerana	*E gummifera*	*E leucoxylon*
E cladocalyx	*E blakelyi*	*Agonis flexuosa*
Corymbia maculata	*Melia azedarach*	*Melaleuca armillaris*
Tristaniopsis laurina	*Grevillea rosmarinifolia*	*Brachychiton species*
Syzygium australe	*Elaeocarpus species*	*Pomaderris species*
Bedfordia species	*Ficus macrophylla*	*Lagunaria patersonii*
Pittosporum undulatum	*Solanum aviculare*	*Hakea salicifolia*

Some Selected Fire Resistant and Retardant Exotic Species		
Acer negundo	*Acer campestre*	*Malus species*
Prunus species	*Arbutus species*	*Pyrus calleryana*
Magnolia Grandiflora	*Linden species*	*Quercus canariensis*
Cercis siliquastrum	*Ulmus species*	*Liquidamber styraciflua*
Populus species	*Camellia species*	*Photinia glabra*
Quercus species	*Sorbus aucuparia*	*Delonix regia*
Ligustrum lucidum	*Citrus species*	
Note: Where a genus is listed, there may be many species which are fire retardant, but the most appropriate species within the genus are those that best meet the criteria listed in Table 3.		

However, it should be remembered that vegetation can have many beneficial effects in terms of fire behaviour and fire management (Table 5). These benefits are often forgotten in the immediate aftermath of a fire, and in the frenzy of tree removals after fires the subsequent costs of vegetation removal can be quite significant. After the Black Saturday fires of 2009 one property owner was unable to rebuild because the insurance companies deemed the block of land unstable once all the trees had been removed and the stumps ground. The risk of landslip was simply too high!

Table 5. Benefits provided by trees for a fire management regime

Benefits Provided By Vegetation For Fire Management

- Depending on tree density, trees can reduce wind speeds, slowing the rate of spread of fire and allowing the possibility of better fire control.
- Depending on topography, trees can reduce swirling of the wind and so ease fire defence.
- Depending on topography and wind direction, trees may deflect fires, especially crown fires over the top of buildings.
- Some species smolder rather than burn.
- Canopies can act as spark or ember arresters and so reduce the spread of fire on properties and the fire risk to buildings through ember egress.
- Roots can stabilise and consolidate steep slopes considerably reducing the risk of land slippage.
- Presence of trees before and after fire provide all of the usual ecological services such as shade, humidification of the air, wind speed reduction, reduced erosion and diminished water run off among many others (Moore 2009a, Moore 1997).

Clearly there are also risks associated with vegetation and bushfires, especially near homes and particularly in the more densely populated peri-urban and urban sections of cites (Table 6). Overhead powerlines have long provided a risk in terms of the possibility of tree trunks and limbs clashing with conductors, but the undergrounding of such services could virtually eliminate such situations. The management of litter and especially that which contributes to the fine fuel load has been a recommended goal of fire management near buildings for more than 40 years. However, it does not necessarily mean the elimination of trees and vegetation.

Hollow trees are great habitat trees and should be preserved where possible but when they occur near buildings in a fire prone place they should be removed as they burn hotter and throw sparks further than intact trees. Trees with all or major portions of their canopies dead must be managed as they not only provide fuel for the fire but present a falling hazard during the fire event, which is not only dangerous to life and limb, but can also make fighting the fire more difficult.

Table 6. Risks associated with fire and vegetation to be considered as part of management plans (Modified and extended from Cheney 1985)

Risks Associated With Fire and Vegetation
• Trees growing near powerlines may clash with conductors and increase fire risk. • Litter from trees can accumulate and so increase fuel load. However, this aspect of trees can usually be managed through proper fire planning such as raking and composting of litter. • Trees with fibrous bark may exhibit firebrand behaviour that can lead to spot fires many kilometres ahead of a fire. • Hollow trees can provide a chimney effect that throw sparks and which can make firefighting difficult and dangerous. • Damaged and dead trees may fall or become dangerous during and immediately after a fire. • Plan for a 20m area around the house that is free from flammable fuels. This may be achieved with lawn, paving, gravel, low flammability plants and/or raking to minimize litter and fuel accumulation. • Replace any stringy barked trees close to the house with smooth barked, evergreen, fire-retardant species. This will reduce the risks of fire brands and embers landing on the house. • Regularly manage fuel reduction through raking and proper garden design and management. • Design for fire and make use of fire retardant species. • Ensure that any house is properly designed to cope with fire and to deal with embers that might attack the property. • Construction materials for housing in fire prone areas must be capable of coping with fires and high temperatures.

A Royal Commission vegetation aftermath from Black Saturday

The Royal Commission into the Victorian Black Saturday fires made a number of recommendations in relation to the future management of bushfires. One of the recommendations deals with control (prescribed, or fuel reduction) burning and advised that the State should adopt a policy that at least 5% of public land be burnt each year (Anon 2010). This effectively means that three times more public land would be burnt than is the current practice. It is anticipated that the State is likely to burn more than this minimum and many people in various communities are advocating burning 10-12% of the public land area.

There are good reasons for supporting the strategic use of control (prescribed, or fuel reduction) burning as one of the tools of fire management, but concern must be expressed over the simplistic approach to its use in fire management. It should be considered as part of an appropriate fire management regime, but it should not be too broadly applied and its place should be at the interface between natural plant communities and human habitation. Any use of prescribed burning should involve a proper cost benefit analysis, which looks at its sustainability over the longer term and not just on its use as a fire management tool. The full environmental costs of its use should be evaluated when considering the benefits that it may have in fire management.

It is concerning that controlled burning, is often presented as a panacea for dealing with fire and that it comes at no environmental cost. Rarely is there any media coverage of the impacts of controlled burning on any of the following:

- The risks and frequency of controlled/prescribed fires escaping, the costs of such escapes, and the legal liabilities associated with such escapes.
- The loss of biodiversity in plant communities that are prescribed burnt.
- The loss of biomass in such communities and the subsequent risks of landslides, erosion, silting of rivers and streams, and the impact on water quality and aquatic habitats.
- The loss of nutrients such as nitrogen among others from ecosystems as a result of such fires.
- The large scale release of the Greenhouse Gas, carbon dioxide, on a regular basis further contributing to climate change, and exacerbating the potential for further extreme bushfire conditions.
- The risks associated with the increased spread of pathogens, such as *Phytophthora cinnamomii* among others that may be due to prescribed burning at frequencies that are too high. Such a risk could be devastating in those parts of Australia such as Victoria, Tasmania and to a lesser extent South Australia where many of the forests are dominated by eucalypt species from the subgenus *Monocalyptus* which seem to be susceptible to such pathogens when fire regimes are altered to high frequency, low intensity fire through imposed prescribed burning management practices.
- The effect of prescribed burning on water catchments and its associated environmental and economic costs, not to mention reduced water yields, which would be compounded by climate change.

It is worth remembering that in 1983 in South Australia, areas that had been prescribed burnt carried crown fire with intensity equal to adjacent areas that had not been managed in this way. The same thing happened in the Black Saturday fires as fires were carried in areas where there had been other major fires in the preceding few years. The idea that prescribed burning will solve all of the problems associated with fire is not only simplistic, but dangerous as it could lead to a widespread sense of false security. The crown fire component of fires is where the most dangerous radiant heat is generated.

Another recommendation of the Royal Commission is that overhead powerlines should be under-grounded (Anon 2010). This has proved to be a contentious recommendation as many believe that it is required in bush fire prone areas of the State but its multi-billion dollar cost has been emphasised. There have been media claims that undergrounding the system would add 20% to electricity bills for the next 20 years.

However, the whole debate over this recommendation has been distorted. Few, if any, of the reduced economic costs captured by undergrounding have been factored into the debate to compensate for the higher installation costs. Among the many from an incomplete list of benefits are the following:

- Lowered pruning and line clearing costs.
- Lower long term infrastructure maintenance costs.
- Fewer pole and vehicle accidents and the associated savings in health and social costs.
- Reduced damage and outages during storm events that are likely to be more common under a climate change regime.
- Reduced cost associated with fires and the mopping up operations that accompany them.
- Improve amenity values of streetscapes and the appreciation of real estate values because of them.
- The higher value of a modern electricity distribution infrastructure which has to be replaced as it ages anyway.

From an urban landscape management perspective, undergrounding electricity supply has advantages that far outweigh costs. Not only are there considerable environmental benefits, but the reduced or discontinued pruning regimes would see far more carbon sequestered in trees left standing. While the media debate has focused only on the installation cost, it likely that these will be fully offset, over time, by the reductions in maintenance and environmental benefits that accrue from undergrounding services. Needless to say undergrounding would be achieved by boring under trees rather than open trenching so that there would be minimal root damage

Conclusion

In much of Australia fire is an ecological factor that requires thoughtful, visionary and professional management. It is disappointing that in parts of Australia such as Victoria, South Australia, New South Wales, Tasmania and some parts of Western Australia which are among the most fire prone regions on the planet, the lessons of fire history and vegetation recovery have not been better learned.

Landscape design and species selection must be integrated with an understanding that fire must be part of management plans. Climate change will see a greater fire risk for much of Australia, with more extreme fire weather days, stronger winds from different directions and higher temperatures. At the same time however, the value of vegetation and trees in particular, especially in urban and peri-urban parts of cities, in reducing urban heat island effects and countering some of the temperature increases associated with climate change will be greater than in the past. An overly simplistic reaction to fires that results in large scale tree removal will not serve our society well in the long term, as the many benefits of a vegetated environment would be placed at risk. Management must be about reducing risk but at the same time securing benefits that contribute to the development of sustainable urban and peri-urban environments.

It is certainly possible to have wonderful urban landscapes with all of the aesthetic, health and ecological benefits that they provide in fire prone Australia (Moore 1997). As always, in dealing with environmental and ecological issues, it is a matter of getting the balance right. A focus on one ecological factor to the exclusion of others is usually a recipe for environmental disaster. Poor decisions in reaction to recent fires could easily lead to a degradation of both natural and created landscapes and a loss of the many ecological services they provide. Such an outcome would not only have significant negative economic impacts, but could prove detrimental to human health and well-being.

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