# ADVANCES IN FOREST FIRE RESEARCH

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# Manipulating fire regimes in sensitive ecosystems to adapt to climate change

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**Abstract**

Fire regimes in Australian temperate forests have changed with the area burnt by bushfires having increased due to changing climate extremes every decade for the past 40 years. The Australian Capital Territory (ACT) has been heavily impacted with year-since-last-fire in forests being the shortest of all Australian jurisdictions due to large, intense bushfires during the droughts of 2003 and 2020.

The forested landscapes of the ACT are predominantly mountainous and scattered throughout are species and communities which are likely to be disadvantaged by an increase in the frequency of high intensity fire. Examples include alpine bogs, Alpine Ash (*Eucalyptus delegatensis*) and Mountain Plum Pine (*Podocarpus laurencei*). Many of these systems were severely burnt in 2003 and 2020.

Protection of these species and communities from bushfires is a high priority for conservation, but suppression operations are difficult due to inaccessibility and the danger to firefighters. A potential solution is to use prescribed burning to manipulate fire regimes to reduce risk. In this paper, we describe an approach designed to reduce bushfire risk while optimising land management workloads and total area burnt.

The approach has two key components: 1) development of a method for managing landscape bushfire risk in time; and 2) utilisation of landscape flammability mapping to design burn infrastructure to meet ecological objectives.

Bushfire risk planning is focused on space, but risk also changes in time with the effects of drought on fuel moisture accumulating and drying over multiple years. This time-scale offers an opportunity to intervene to reduce bushfire risk in fire sensitive ecosystems and influence fire regimes in favour of those ecosystems using prescribed burning. To do this, bushfire planners need to identify ecosystems at risk and develop burns which are to be implemented contingent on agreed climatic triggers.

Landscape flammability in mountainous landscapes in southeastern Australia during the autumn prescribed burning season is driven by solar radiation with north faces being drier and much more likely to burn than south faces. This imposes a critical constraint on prescribed burn planning. We conducted an assessment of the feasibility of designing burns to protect alpine bogs, Mountain Plum Pine and Alpine Ash. There appears to be some potential for reducing fuels around alpine bogs and good potential for emhancing protection of Mountain Plum Pine. On the other hand Alpine Ash stands largely occur on southern slopes and do not appear to be easily amenable to fire regime manipulation.

## 1. Changed Forest Fire Regimes

Fire regimes in Australian temperate forests have changed with the area burnt by bushfires having increased due to changing climate extremes every decade for the past 40 years (Canadell et al. 2021). The Australian Capital Territory (ACT) has been heavily impacted with year-since-last-fire in forests being the shortest of all Australian jurisdictions due to large, intense bushfires during the droughts of 2003 and 2020.

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(Hawkins et al. 2021). Examples include alpine bogs, Alpine Ash (*Eucalyptus delegatensis*) and Mountain Plum Pine (*Podocarpus laurencei*). Alpine bogs are a product of the anaerobic decomposition of vegetation due to saturation in water. Fire is a fundamentally rare event and the ecological impacts of fires on bogs are overwhelmingly negative (DEWHA, 2009). Alpine Ash is a serotinuous species which is killed by high intensity fires and takes >10 years to mature (Doherty et al. 2017). High intensity fires at a frequency of <10 years present a threat to Alpine Ash populations which may be unable to produce seed. Mountain Plum Pine is a slow growing Gondwanan relic which occurs in high rocky mountain tops and is killed by fire of moderate intensity and greater (Tolsma et al. 2004). Discontinuous fuels on rocky mountain tops provide some protection from fire for this species but high intensity bushfires cause mortality (Figure 1). All of these systems were severely burnt in 2003 and 2020.

## 2. Limitations of Fire Suppression Operations

Protection of these species and communities from bushfires is a high priority for conservation (Hawkins et al. 2021), but suppression operations are difficult due to inaccessibility and the danger to firefighters. Even if suppression operations are technically feasible, for example by deploying helicopter-borne Remote Area Fire Teams (Cooper, 2020) resources must be prioritised to protection of human life and property. During the large fire events which are of most concern for conservation management, conservation-focussed suppression will almost certainly be restricted to small areas of the highest priority.

## 3. Prescribed Burning in the Australian Capital Territory

The ACT Parks and Conservation Service conducts a prescribed burning program which is evaluated annually using Normalised Burn Ratio (Leavesley et al. 2021). Analysis of the interaction between the Orroral fire in the ACT in 2020 found that burns which were <2 years old halted the spread of the bushfire, reducing its final extent. In addition, a burn which was four years old significantly reduced the severity of the bushfire. Burns which were seven years old were discernible in the landscape but appeared to have a limited effect on bushfire behaviour. The study concluded that the interaction between the burning program and the Orroral fire was positive for conservation and catchment values.

## 4. Concerns about Prescribed Burning

A criticism of prescribed burning is that in many ecosystems the leverage is low (Price et al. 2015). The leverage number represents the likelihood that a prescribed burn will intersect with a bushfire before fuel accumulates to the point that fire behaviour is affected. For example, in southern Australian forests, the leverage has been calculated to be 0.33 which means that to reduce the annual average area burnt in bushfires from 5 percent to 2.5 percent requires the annual area of prescribed burning to be 7 percent – an overall increase in total area burnt.

But this generalised analysis does not take into account conservation land management objectives or fire response traits of focal species. Species which are tolerant of low or moderate intensity fire but sensitive to high intensity fire can be advantaged by high frequency application of low intensity prescribed burning and this is well documented in ecosystems such as the northern Australian savannahs (Evans and Russell-Smith, 2020).

Similarly, where a species or ecosystem is identified to have exceptional conservation value, managers may make a judgement that a trade-off which advantages a high value ecosystem or species is justified, despite disadvantaging other effected species. To our knowledge, such trade-offs are relatively rare in southern Australian forests where the conservation policy focus is on ensuring that prescribed burning is applied at intervals determined to be consistent with the fire response traits of all of the species in a particular ecosystem or known to be present in a burn block. We suggest, that in the face of changed fire regimes, a greater focus on conservation priorities and a renewed consideration of trade-offs is warranted.

## 5. How can we adapt?

High-frequency, broad-scale application of low intensity prescribed burning to southern Australian forests is likely to change ecosystems and is difficult and costly to achieve. Can we be more judicious in the use of fire but still reduce the risk to high value species and communities? We think this could be achieved by prescribing burns at times when landscape bushfire risk is elevated and in places most likely to manipulate the conservation outcome positively, should a bushfire subsequently occur.

Our approach has two key components: 1) development of a method for managing landscape bushfire risk in time; and 2) utilisation of landscape flammability mapping to design a burn program to meet ecological objectives.

## 6. Managing bushfire risk in time

Best practice landscape bushfire risk planning is usually focused on space (eg Gazzard et al. 2020; Penman et al. 2020), but risk also changes in time with the effects of drought on fuel moisture accumulating and drying over multiple years (Nolan et al. 2016). This time-scale offers an opportunity to intervene to reduce bushfire risk to high value conservation assets by conducting burns aimed at manipulating fire regimes in the prescribed burning season, between summer fire seasons, at times when landscape dryness is elevated and the likelihood of large, intense landscape-scale bushfires is consequently also elevated. If applied successfully, the approach would increase the leverage of a burning program because the likelihood of intersection between burns and bushfires is greater. It is worth noting, that operational experience suggests that the risk of prescribed burn escape in the burning season, is not significantly affected by elevated landscape dryness during the burning season.

To be effective in southeastern Australia the approach requires a sound understanding of landscape fuel moisture dynamics and a robust predictive capability for landscape dryness in the coming fire season which exceeds present capability (Vinodkumar *et al*. 2021). The triggering metric would be needed in advance of the peak burning season in March and April, at least seven months before the usual commencement of the fire season on 1 November.

The next stage of the work would be to test some candidate prescriptions in a fire regime simulation. The main aim of the work would be to define a set of parameters which were effective and operationally achievable. If an effective prescription was identified, the results of the simulation would be critical in developing options for stakeholder consideration and ultimately for obtaining a social licence to implement the work.

## 7. Working with flammability gradients

A critical constraint on the autumn prescribed burning program in southeastern Australian mountain forests is the pattern of landscape flammability (Nyman et al. 2018). In autumn, the landscape transitions from mostly dry enough to burn, to mostly too wet (Nyman 2019). Flammability is driven by solar radiation and during the transition, the north faces are drier and much more likely to burn than south faces.

Prescribed burn planning for high value conservation assets must work within the landscape flammability constraints. Direct manipulation of fire regimes can only occur in the flammable parts of the landscape. Where Alpine Ash stands occurred on northern slopes, fuel could be reduced by low intensity prescribed burning to reduce the risk posed by high intensity bushfire the following summer. Similarly, prescribed burning could be deployed to enhance the topographic protection that Mountain Plum Pine derives from its rocky mountaintop habitat by removing connecting fuels. Alpine bogs present a greater challenge because they cannot be directly fuel-reduced. Nonetheless it may be possible to identify landscapes in which adjacent systems are flammable and which can be burnt to create a protection zone.

Our analyses show that burning to create a protection zone surrounding and directly adjacent the largest alpine bog in the ACT, Ginini Wetland, is not appear likely to be possible due to the large extent of non-flammable terrain adjacent, however an extended area encompassing other ecosystems, might be possible (Figure 2). The second largest alpine bog, Snowy Flat appears to be better situated for creation of a protection zone which is directly adjacent (Figure 3). Mountain Plum Pine habitat on mountain tops appears to be generally amenable (Figure 4) with an important caveat that operational experience at that altitude is limited. Alpine Ash stands are almost exclusively located on southern slopes and cannot be burnt under prescribed burning conditions (Figure 5). Further thought and planning would be required to manipulate the fire regimes of that community.

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***Figure 1- Two aerial views of the summit of Mt Murray (1845m) in Namadgi National Park, Australian Capital Territory: green points indicate Mountain Plum Pine records, blue indicates alpine bog and black/white indicates the ACT/NSW border. a) acquired in 2017; and b) acquired in 2020 following the Orroral fire.***

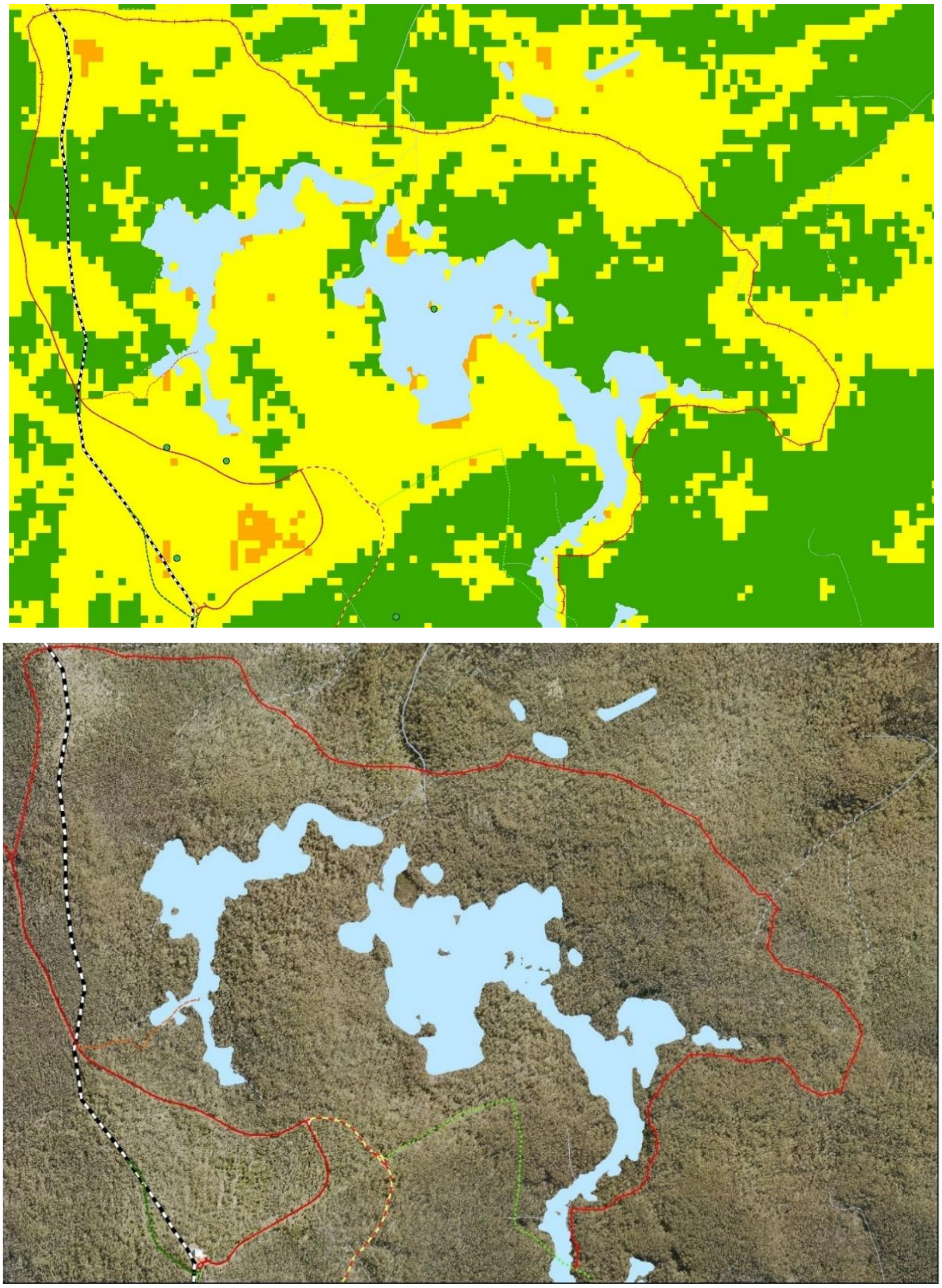

***Figure 2- Ginini Wetland, the biggest alpine bog in Namadgi National Park, Australian Capital Territory. Ginini Wetland does not appear to be well situated for creation of a fuel reduced protection zone because a high proportion of the adjacent landscape is predicted to be non-flammable: Blue indicates alpine bog, black/white indicates the ACT/NSW border and other lines indicate roads and tracks required for containment. Top: Flammability mapping: yellow and orange indicates land which is flammable under prescribed burning conditions; green indicates land which is not flammable; and Bottom: aerial image acquired in 2017.***

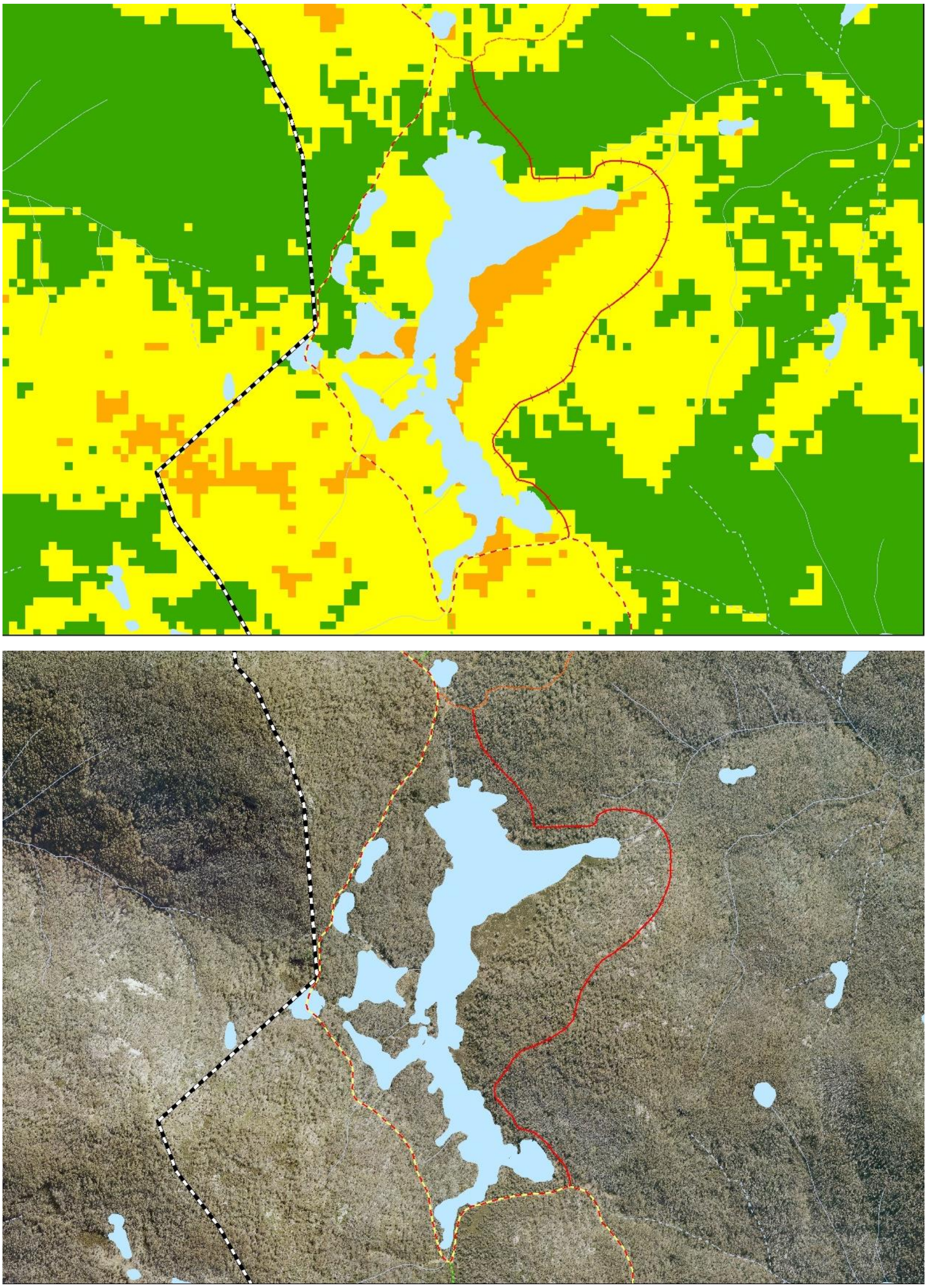

***Figure 3- Snowy Flat, the second biggest alpine bog in Namadgi National Park, Australian Capital Territory. Snowy Flat appears well situated for creation of a fuel reduced protection zone because a high proportion of the boundary appears to be flammable under prescribed burning conditions. Blue indicates alpine bog, black/white indicates the ACT/NSW border and other lines indicate roads and tracks required for containment. Top: Flammability mapping: yellow and orange indicates land which is flammable under prescribed burning conditions; green indicates land which is not flammable; and Bottom: aerial image acquired in 2017.***

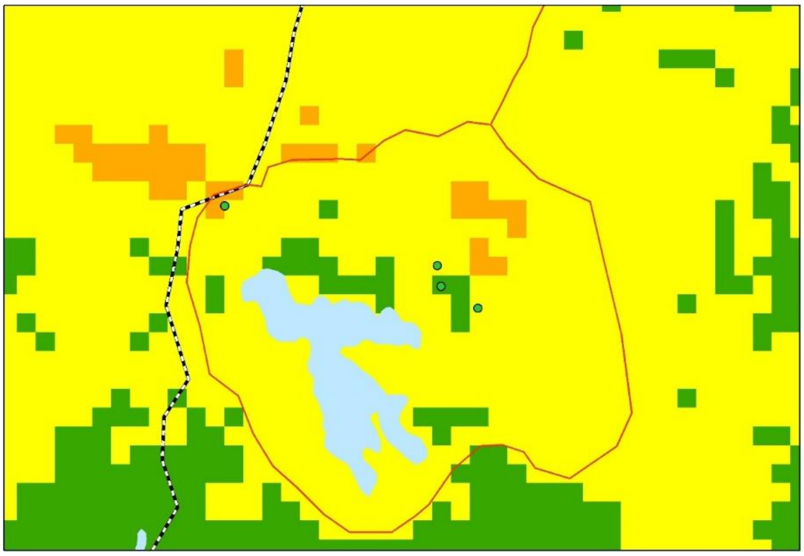

***Figure 4- The summit of Mt Murray (1845m) in Namadgi National Park, Australian Capital Territory. The Mountain Plum Pine habitat appears to be flammable in the prescribed burning season which may support creation of a fuel-reduced protection zone for this species. Green points indicate Mountain Plum Pine records, yellow and orange indicates land which is flammable under prescribed burning conditions; green indicates land which is not flammable, blue indicates alpine bog, red line indicates proposed walking track for containment, and black/white indicates the ACT/NSW border.***

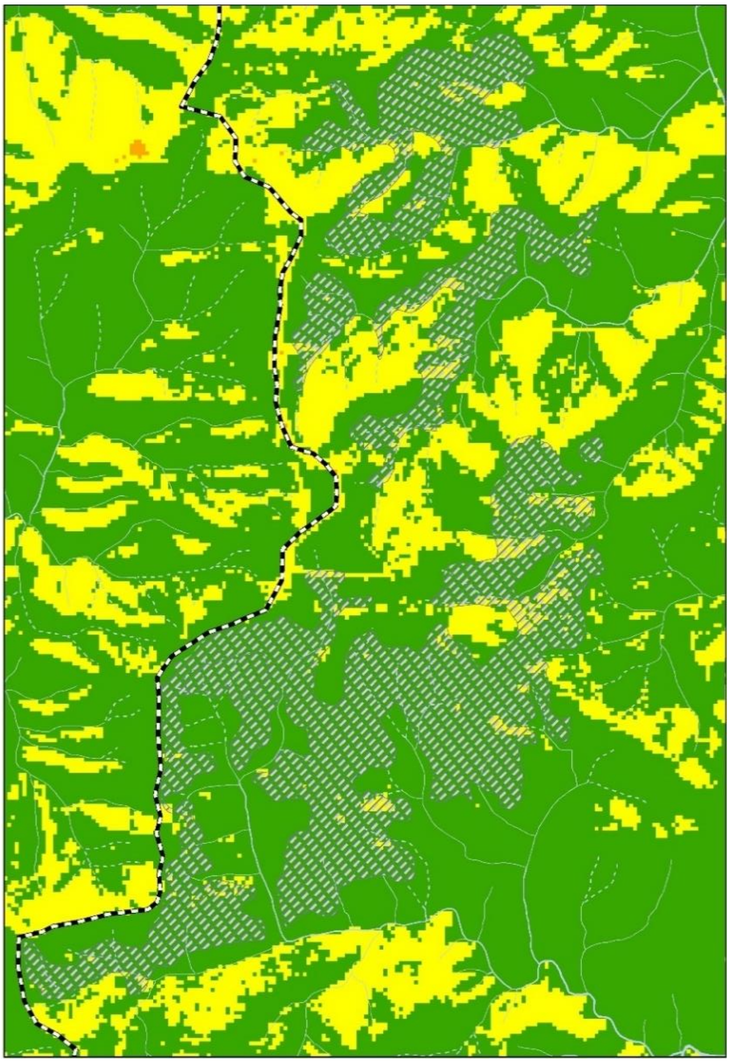

***Figure 5- The distribution of Alpine Ash in Namadgi National Park in the Australian Capital Territory, overlayed on a flammability map. Most Alpine Ash occurs in locations which are not flammable in the prescribed burning season. Grey cross-hatching indicates Alpine Ash, yellow and orange indicates land which is flammable under prescribed burning conditions; green indicates land which is not flammable, black/white indicates the ACT/NSW border.***