

ACTIVE MANAGEMENT AND RESEARCH FOR THE RESTORATION OF THE BAGO AND MARAGLE STATE FORESTS FOLLOWING THE WILDFIRES OF 2019/2020



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This report was commissioned by the South East Regional Forestry Hub with funding from the Australian Government, Department of Agriculture, Fisheries and Forestry

Active management for the restoration of the Bago and Maragle State Forests following the 2019-2020 wildfires.

Summary

This report highlights the case for active forest management and research to further improve the recovery and ongoing resilience of fire-killed areas of the Bago and Maragle State Forests in south-eastern NSW. The report includes a plan for research to support active management of the recovering forests, specifically to investigate fire recovery and fuel management options. The 2019/20 wildfires impacted over 5 million hectares of NSW including over 50,000 hectares of highly productive alpine ash forests fire-killed within the Bago and Maragle State Forests.

Active management of these fire-damaged forests could address several objectives including increasing the resilience of these forests to ongoing climate change with the attendant risk of more fire. Active management that continues the salvage of fire killed trees would assist in maintaining public access to the forest through the removal of hazardous trees and generate income for forest restoration activities.

Potential whole-of-forest restoration actions also encompass fuel reduction in adjacent drier forests, the monitoring and mitigation of weed infestations within Bago-Maragle, and the maintenance of road and foot access tracks.

Four years on from the fires has seen restoration activities such as track clearing, signage and infrastructure rebuilding mostly completed, so the time is right to review forest management and to test forest resilience treatments that can bring immediate benefits and guide active management options.

Overall, research trials of active forest management would allow for comparison of the baseline of fire-killed mature tree stands with no intervention, with various forms of forest management including partial and complete removal of dead trees, to test impacts on forest regeneration, biodiversity indicators and resilience to future fires.

Restoration of the Bago-Maragle forests could extend to active management in the surrounding forests and plantations where future fire may originate. There is an opportunity for increased support for cultural burning to protect sites of cultural value and to evaluate and demonstrate these approaches for immediate fire risk mitigation and for increasing forest resilience over the longer term in a changing climate.

Background

Pentarch Forestry and NSW Forestry Corporation are operating in the Bago-Maragle State Forests (BaMSFs), significant and important production forests in NSW that were badly damaged in the 2019/20 bushfires. Out of 103,001 ha of the BaMSFs, Alpine Ash (*Eucalyptus delegatensis*) accounts for about 67,768 ha where 52,070 ha or about 77% were killed by the

2019/20 fires. Most of the fire impacted forests are in the north and west of the Bago State Forest where the fire burnt through adjacent plantation areas into the native forest. As the fire progressed south and east in the BaMSFs the severity of the fire decreased as it burnt into the night, and the pattern of burning became patchier. The severity of the fire subsequently increased as it burnt into the National Park areas east the BaMSFs (Figure 1).

The Bago and Maragle State Forests

The Bago Plateau in southern NSW, comprises the Bago State Forest (31,681 ha), Maragle State Forest (12,332 ha), and a portion of Kosciuszko National Park. The majority of the Bago-Maragle State Forests (BMSF) exceeds 1,000 m in elevation and encompasses the Snowy Mountains, South Eastern Highlands, and Tumut River incised valleys (Kambouris *et al.* 2013). The BMSF are characterized by a cool and moist sub-alpine climate with temperature range from -0.5 to 8.2 °C in July and from 10.6 to 26 °C in January. Most areas in the BMSF receive an annual precipitation of approximately 1,400 mm. The eucalypt forests are productive and dominated by varying strands of alpine ash, mountain gum (*E. dalrympleana*), and snow gum (Tickle *et al.* 2001). The alpine ash area constitutes approximately 36% of BMSF. Commercial harvesting has occurred since the 1850s, while the selective cutting of single alpine ash trees has been continuous since the early 1900s (Hatich 1997). The study area has had several large fire disturbances in the past century, with the most extensive occurring in 1926 (Lindsay 1939, FCNSW 1986) and the most recent, the Black Summer Fires, in 2019 and 2020. The diverse disturbance histories and ongoing forest management create an ideal study area to investigate how prior and ongoing disturbances impact alpine ash regeneration.

Regeneration ecology of alpine ash

E. delegatensis usually regenerates from seed following infrequent high intensity fire and mortality of seed-bearing trees. The ash-type eucalypts store seed for not more than 2 years in capsules held in the lower portion of the green crown and the number of viable seeds varies with the extent of previous flowering. Following a fire, seeds released from the canopy require winter cold to stratify *E. delegatensis* seed before it will germinate. Generally, ash-type species regenerate profusely after stand replacing fires, often with seedling densities more than 15,000 stems ha^{-1} at the age of four, followed by self-thinning mortality of smaller stems that peaks at about the age of 16 years. Recurring fires at less than 10 to 20-year return intervals, combined with warmer winters can further severely limit the seed source for recovery of these forests following future fires. It is for this reason that minimizing the risk of short interval fires is a central aim of active forest management.

The case for active forest management

Standing dead trees near roads and walking tracks pose risks to public health and the maintenance of forest access. Access for survey of permanent sample plots and to ground truth regeneration is becoming riskier because the fire killed trees are collapsing. Large areas of fire-killed forest comprise century old stands with trees exceeding 50 m height and more than 1 m in diameter at 1.3m height. Access to this fire killed area of the forest is becoming dangerous and is a key motivation in adopting remote/drone survey methods for monitoring regeneration.

Continued safe access to the forest for tourism will require careful consideration as fire killed trees continue to collapse in the coming years.

A forest resilience plan should investigate the removal and utilisation of a portion of these trees for use in long-lived wood products through sustained timber supply to local mills. This may result in long-term carbon sequestration in timber products, rather than the release of carbon from decaying dead trees over time. A unique opportunity exists for an adaptive management approach, to maintain forest access for all uses and to improve resilience to future fires.

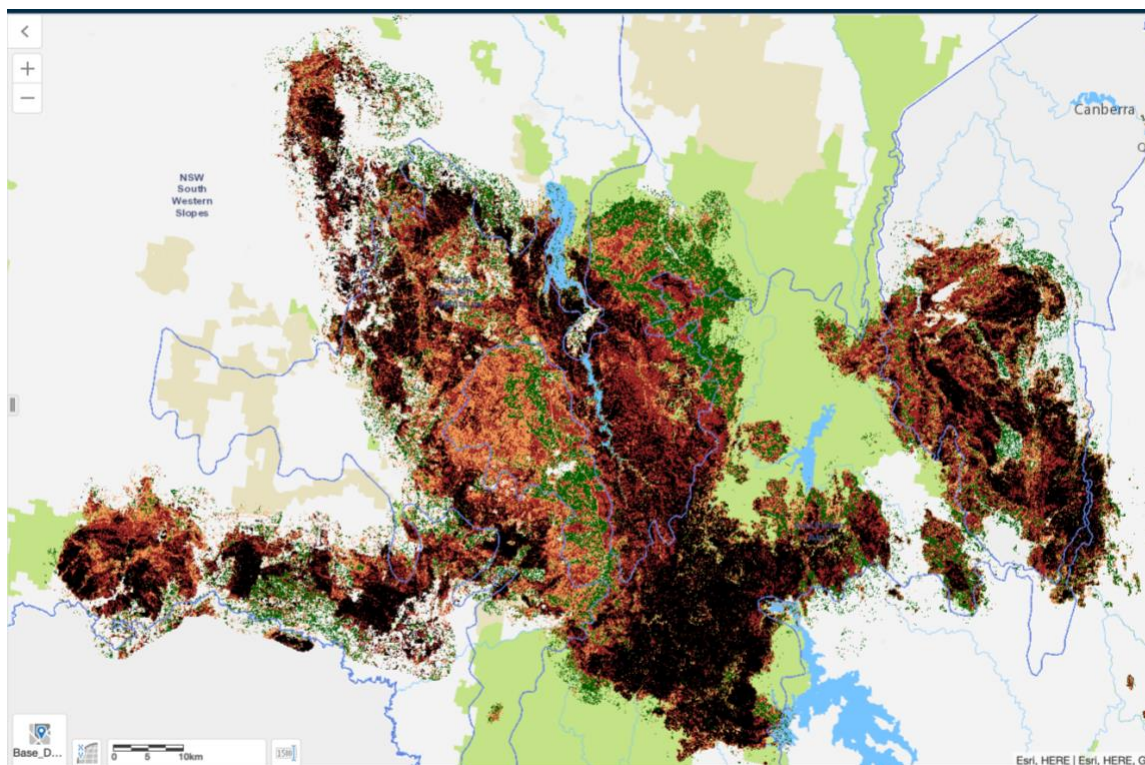
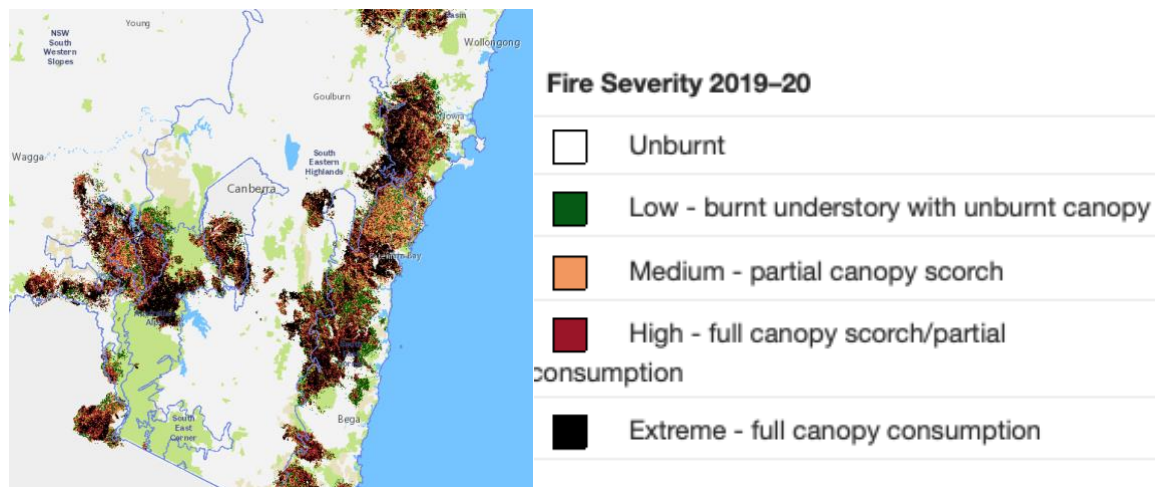


Figure 1. Map showing fire severity and total wildfire footprint of (top) all southeastern NSW), and (bottom) several fires that joined to burn through around 600,000 hectares (Dunns Road fire, the East Ournie Creek fire and the Green Valley fire) south of the Snowy Mountains. The Bago and Maragle State Forests are just west of the centre of the fire-impacted area.

Status of the forest 2024

Field inspection of the Bago Forest in February 2022, October 2023, March 2024 and September 2024 confirmed strong wheatfield regeneration of *E. delegatensis*. The field regeneration of *E. delegatensis* shows that a viable seed crop was present in the canopies of 2020 fire-killed trees that established in abundance later in 2020. Current observations by NSW Forest staff suggest that 2024 will be a strong flowering year and plans are in place to commence seed harvesting from mature stands with an aim to collect over 800 kg of seed. In Bago 150 kg seed from < 1200 m stands and 350 kg seed from > 1200m stands is planned.

Following the 2020 fires the regeneration from seed has resulted in overstorey tree stocking rates ranging from 6,800 to 38,000 stems per hectare, and sapling heights generally between two to four metres with some 8m saplings. Where *E. delegatensis* occurs in mixed stands the recovering forests is comprised of surviving re-sprouter species, fire-killed *E. delegatensis* and saplings of all forest dominants, regenerating from seed. The regeneration in these burnt mixed species stands was not as advanced as in pure *E. delegatensis* areas due to competition with surviving mature trees.

Younger stands of fire killed *E. delegatensis* created by Australian Group Selection trial logging of forests over the last 15 to 20 years were reported to have more patchy regeneration, although this will require confirmation from field investigation. Where the fire burnt through just-logged areas surrounded by circa 40 years+ mature *E. delegatensis* stands, the sapling regeneration was also dense and wheatfield-like as for fire-killed mature stands.

Salvage logging

Three years of salvage logging has been applied since the 2020 fires, and it has focussed on the pure *E. delegatensis* areas burnt at high severity. Ninety percent of the Bago Forest has not been salvage harvested since 2020 with about 200,000 tonnes recovered to date. A further 1,000,000 tonnes of accessible standing dead tree timber is estimated. (Note: NSW State Forests operations to remove large dead trees from roadsides (road-lining) started in mid-2024, and tree removals are underway; data from these tree removals are not included in this report). Several of the areas salvaged since 2020 (not road-lining operations) were inspected in October 2023 with the following observations. The harvest loading and haulage points viewed needed re-planting to re-establish *E. delegatensis* saplings that had been removed by machinery operations. The areas viewed were not in range of live mature trees that could serve as a seed source. Areas salvaged more distant from the log landing were less intensely impacted. One salvage harvest landing that we inspected had been replanted with *E. delegatensis* seedlings that had subsequently been impacted by horse trampling indicating that enrichment planting of harvest areas may require protection measures.

NSW State Forests has commenced a drone field survey of the regeneration status of the fire impacted areas of the forest. The drone flights are planned to cover the range of environments and fire severity and the imagery captured is later interrogated to yield a regeneration assessment. This technique overcomes the difficulties of traversing the thick regeneration and allows a more intensive sampling of the forest status post fire.

Since the 2020 fires a Bago State Forest Masterplan has been developed to address the restoration of five key tourist areas within the forest. This plan will need to consider public safety with respect to fire killed trees along access roads and areas of tourist activity including campgrounds, walking trails, and cycling routes.

Plan for forest recovery research

The proposed research should encompass previously harvested and burnt and unburnt areas to describe the pattern of change in forest regeneration and bushfire fuels over time since fire, with and without active management intervention. Active management trials could be established opportunistically in unburnt forest, recently harvested unburnt forest and in fire-impacted areas with and without salvage harvesting (Bago and Maragle State Forests). An example of a sampling design based on ground survey for sites and GIS records of harvest and fire, is shown in Figure 2 further below.

Research recommended to support the restoration of the Bago and Maragle State Forests:

- Over a range of forest management interventions establish research trials to assess forest recovery encompassing biomass, fuels, forest structure and biodiversity indicators.
- Compare the baseline of fire-killed mature tree stands with no intervention, with various forms of forest management including partial and complete removal of dead trees, to test impacts on forest regeneration, biodiversity indicators and resilience to future fires. This objective would address whether the removal of fire killed trees and associated disturbance to forest floor up to a decade after wildfire impacts forest recovery.
- Address impact of forest regeneration and restoration treatments on fuel hazard and fire risk parameters such as vegetation flammability and under canopy wind speed.
- Assess carbon flow and wood supply from different management options.
- Test active forest management options including mosaic burning in mixed-species forests surrounding the alpine ash stands.
- Work with traditional owners and support cultural burning to protect cultural sites in the Bago and Maragle State Forests and in mixed-species forests surrounding the alpine ash stands – and evaluate and demonstrate these approaches for immediate fire risk mitigation for increasing forest resilience over the longer term in a changing climate.
- Identify and map areas that have not regenerated adequately since the 2020 fires for subsequent planting rehabilitation.
- Identify and map areas infested with weeds, mainly blackberry, for subsequent treatment and ongoing weed suppression.

Currently, knowledge of how prior disturbances affect forest regeneration after mega-fires and the vulnerability of these forests to the next fire is poorly developed (Swanson *et al.* 2011, Lindenmayer *et al.* 2019, Bowd *et al.* 2021). The major fire in 2019/20 and logging activities in burnt (defined as salvage logging in this study) and unburnt areas in the Bago and Maragle State Forests provide an opportunity to study the effects of different disturbance regimes on alpine ash forest recovery, and to adapt results in an active forest management plan.

An example for addressing the research recommended is given here with the objective to measure stand features in forests recovering from different forms of disturbance (see details in Table 4), and to investigate relationships between regeneration attributes (seedling density, tree height, and DBH of seedlings) and stand (canopy openness, CWD, and understorey density) and disturbance features (fire severity and logging intensity).

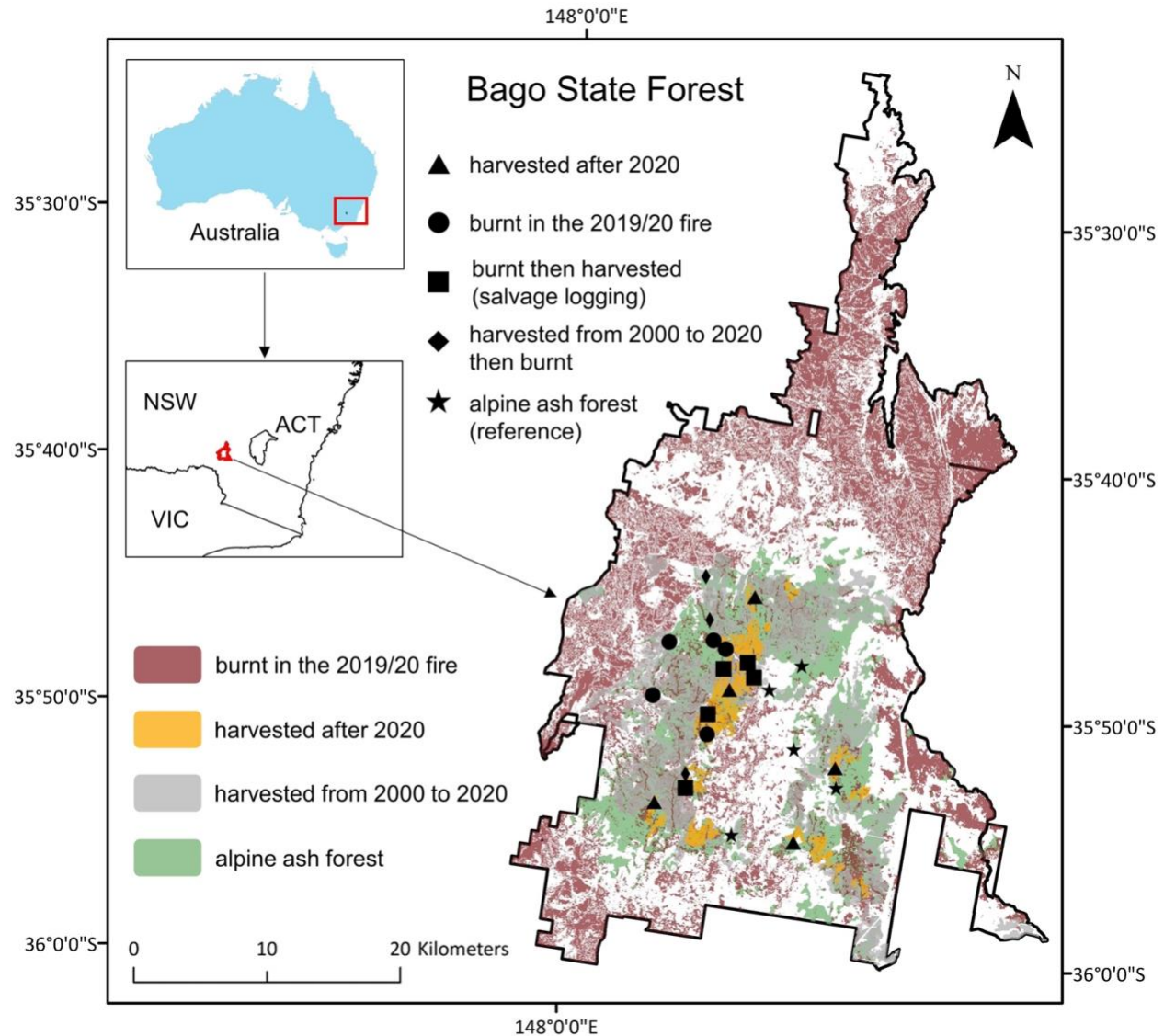


Figure 2. Identified research and monitoring plot locations in alpine ash forests within the Bago and Maragle State Forests – sites for a well-replicated sampling of forest not burnt and not harvested, not burnt and harvested, burnt and not harvested, burnt and harvested – with further details given in the “Experimental Design” section below and in Tables 2-6.

Fire impacted forests should be chosen to cover the range of age classes burnt through by the fire to determine interactions between stage of forest development at the time of the fire, and subsequent regeneration following the fire. The proposed project is best framed to build on

vegetation recovery surveys and biodiversity monitoring currently underway by NSW SF. Outputs of the experiment will assist to inform decisions regarding active management for forest resilience.

The occurrence of failed *E. delegatensis* regeneration and of heavy weed infestations will be identified from discussions with NSW SF research and operations staff – and current research questions can be modified to address trials of ways to address these problems.

Dean Freeman, a Wiradjuri man from the Brungle Aboriginal Reserve, at the Northern Foothills of the Kosciuszko National Park, advised on the need to include the ongoing protection and maintenance of traditional owner cultural sites in the Bago and Maragle forests. The application of cultural burning to protect sites of significance is required and is best achieved through integration with existing fire management and response plans. Dean commented that the ACT's integrated fire management model allowed cultural burning to slot straight in and be recognized and acted on. A similar approach is desirable in an active management plan for the Bago and Maragle State Forests. The application of cultural burning within the *E. delegatensis* forests would offer an opportunity to evaluate and demonstrate these approaches for immediate fire risk mitigation for increasing forest resilience over the longer term in a changing climate. This aspect could be built into the network of research sites suggested in Tables 1-6.

Experimental Design

To ensure good spatial replication of the experimental treatments (5 treatments), five blocks that are geographically separate are proposed, with 3 plots at each site and 3 subplots. A summary of this design, the total number of plots and a broad indication of what would be measured at plot or subplot scale is:

5 treatments x 5 blocks x 3 plots x 3 subplots

= 75 plots (20 m x 20 m (400 m²) for stand structure, biomass, carbon and fuel, observations).

= 225 subplots (2-4 m radius (12.5-50.3 m²) for regeneration/seedling count).

Table 1 below sets out the suggested forest treatments that allow for research on the theme of recovery with and without salvage harvest.

Table 1. Summary of proposed burn and harvest treatments in *E. delegatensis* dominated forests within the 2019/2020 wildfire impacted Bago and Maragle forests.

Forest Burn and Harvest Treatment	Black summer wildfire	Harvest from 2000 to 2020	Harvest after 2020
Not Burnt 2020, Not Harvested since 2020	×	×	×
Not Burnt 2020, Harvested since 2020	×	×	√
Burnt 2020, Not Harvested since 1957-1979	√	×	×
Burnt 2020, Harvested from 2000 to 2020	√	√	×
Burnt 2020, Harvested after 2020 (salvage logging)	√	×	√

Site details and measurements

A study is proposed to test five combinations (or treatments in an experimental context) of 2020 fire and harvest timing (Table 1), with measurements at five sites per treatment. Example photos of four treatments surveyed to date are shown in Figure 3. The locations of the sites are suggested by considering the representativeness and accessibility of the sites within not harvested, harvested and not burnt and burnt areas (Figure 3). The sites vary in size and shape. Each site consists of three plots (400 m²) and each plot consists of three subplots (12-50 m²). Litter is sampled at the plot level with a circular fuel ring of 0.1 m² and dried and weighed at the laboratory. The following measurements will be recorded for each subplot: coordinates; number of stems by DBH class; measure all coarse woody debris (CWD); dominant tree bark thickness, DBH, and height (tree height and height to green canopy); average tree height in each subplot; understorey height and width; species richness; elevation; slope; aspect; orthophotographs from a 1-m height; and fuel hazard (based on the Overall Fuel Hazard Assessment Guide) (Hines *et al.* 2010). At the plot level, photographs from the north, south, east, west, upward, and downward directions will be taken to assess the vegetation cover and landscape openness. In addition to the subplot measurements, the point-centred quarter method will be applied in not burnt and not harvested plots to estimate the seedling density, and the result will be compared with the subplot-level data. Specifically, the distance from the nearest tree in each quarter to the centre point, and the tree height and DBH of the alpine ash tree nearest to the centre point, will be measured. The plots are of sufficient size to expand measurements to include camera traps for wildlife survey.

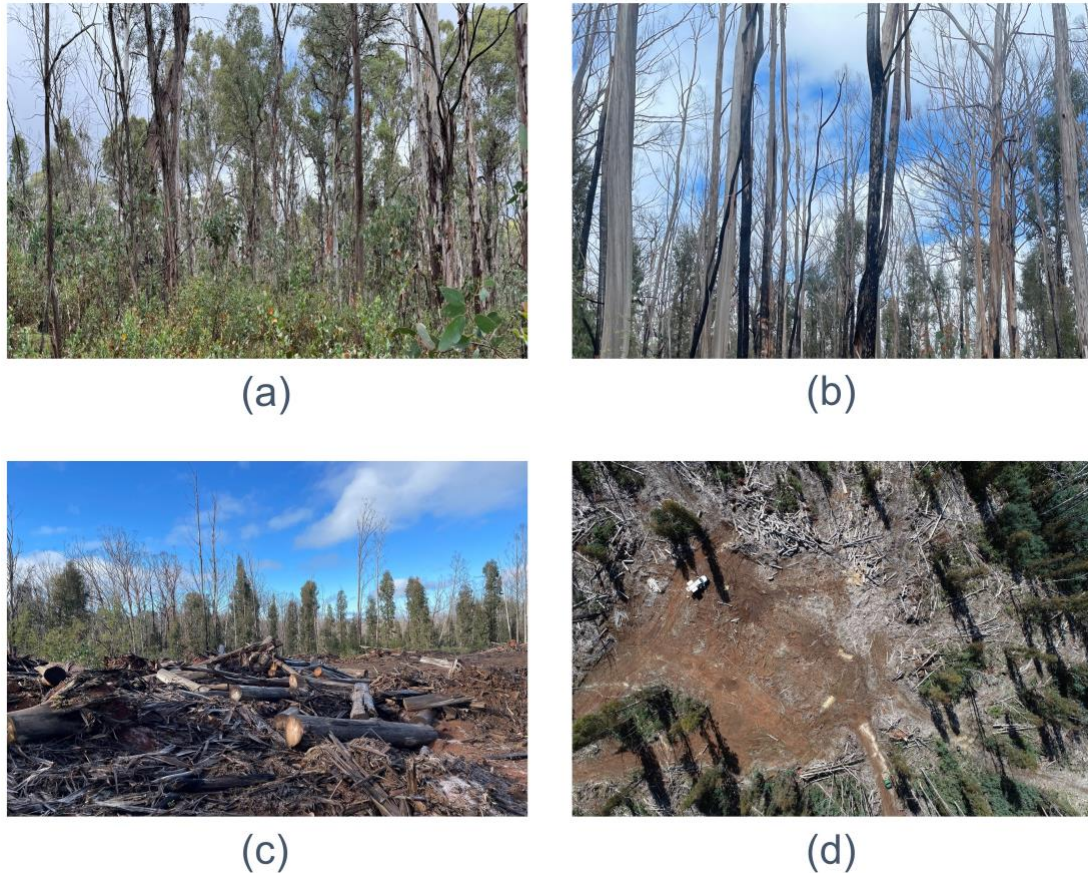


Figure 3. Examples of different treatments: (a) Not Burnt and Not Harvested; (b) Burnt and Not Harvested; (c) Burnt and Harvested (salvage logging) and (d) Not Burnt and Harvested (photo taken from a drone).

Results interpretation and publication plan

The experimental design allows for multiple approaches for statistical comparisons among disturbance history and regeneration, and the following analyses are given here as an example of how comparisons may be made. Beta regressions (Bowd *et al.* 2021) will be used to study disturbance histories and regeneration features using the “betareg” (Cribari-Neto and Zeileis 2010) and the “emmeans” (<https://cran.r-project.org/web/packages/emmeans/emmeans.pdf>) package in R 4.3.3 (R Core Team). In addition to field measurements, data on fire, logging, and the stand age will be determined from GIS layers obtained from SEED NSW Government and DATA VIC via ArcGIS. Raw data processing, transformation (if necessary), and modelling will be completed using JMP Pro 16 (SAS Institute). Joint effects of disturbances (indicated by fire severity and logging intensity) and stand features (understory density, CWD density, and landscape openness) will be analyzed using a nested model because stand features are assumed to be impacted by fire and logging. Linear regression modelling will be employed to investigate the individual effects of different factors on regeneration attributes.

At least two manuscripts will be prepared for submission to peer-review, with target journals including *Forest Ecology and Management* and *Science of the Total Environment*. The

experimental design suggested here is rigorous and well-replicated, and there is a great deal of international interest in the recovery of Australian forests from the 2019/2020 wildfires. The timeframe for manuscript preparation and submission for publication would be 12-18 months following the commencement of field work, with a further 3-6 months required for review and revision. In addition to publication of results a review publication addressing the topic of “Active management of *E. delegatensis* forests in a changing climate” will be prepared and submitted for publication – this paper will evaluate options for active forest management in response to a rapidly changing climate and with more extreme and frequent forest disturbances.

Detailed summary of proposed research sites

Tables 2 – 6 summarize details of five burn and harvest forest treatments that have been identified from GIS databases and ground survey. These forest treatments represent the major classes of disturbance across Bago and Maragle State Forests following the 2020 wildfire and subsequent harvest operations. Within the Bago State Forest, the large old trees were regenerated from 1917 (1,200 ha pure even-aged stands “Regeneration Area south of Pilot Hill”), 1939 and 1954/55. In the Maragle State Forest the large old trees regenerated from extensive fires in 1919. GPS locations for the 25 research sites are available on request. An historical map showing the location of pre-1960s logging/regeneration areas was not found. Block identity (ID) naming rules: N means new; B means burnt; H means harvested; and PM means potential (backup) sites. STS means selective timber system.

Table 2. Not Burnt 2020, Harvested since 2020.

Forest Treatment	Block ID	History of forest operations, age classes and retained large trees
<u>Not</u> Burnt 2020, <u>H</u> arvested since 2020	NH1	Harvested in 1967, and 1977, STS medium; Harvested in 2021, STS heavy. 10 live trees near plot (DBH 50-60 cm); a dead tree in each plot, DBH 30 cm.
	NH2	Harvested in 1972, and 1978, STS medium; Harvested in 2022, STS heavy. 5 live trees near plot (DBH 30-40 cm); 2 dead trees in each plot, DBH 50-60 cm.
	NH3	Harvested in 2001, STS medium; Harvested in 2021, STS heavy.
	NH4	Harvested in 1955/56, STS medium; Harvested in 2005, 2015, 2020, and 2022, STS heavy.
	NH5	Harvested in 1962, 1967, 1987, and 1989, STS medium; Harvested in 2021, STS heavy.

Table 3. Not burnt 2020 and Harvested 1957-1979.

Forest Treatment	Block ID	History of forest operations, age classes and retained large trees
Not burnt 2020 & Harvested 1957-1979	NAA1	Harvested in 1972, STS medium. Wet and abundant understorey. 12 large <i>E. delegatensis</i> measured with DBH ranging from 24.2 to 81cm (47 cm on average).
	NAA2	Harvested in 1967, STS medium. Wet and abundant understorey. 12 large <i>E. delegatensis</i> measured with DBH ranging from 23.8 to 82.4 cm (50.2 cm on average)
	NAA3	Harvested in 1966, STS medium. Wet and abundant understorey. 12 large <i>E. delegatensis</i> measured with DBH ranging from 37.1 to 93.1 cm (60.8 cm on average).
	NAA4	Harvested in 1957, STS medium.
	NAA5	Harvested in 1968, and 1997, STS medium.
	PMAA1	Harvested in 1969, STS medium.
	PMAA2	Harvested in 1979, STS medium.
	PMAA3	Harvested in 1974, and 1979, STS medium.
	PMAA4	Harvested in 1974, and 1979, STS medium.

Table 4. Burnt 2020, Not Harvested 1983-2002

Forest Treatment	Block ID	History of forest operations, age classes and retained large trees
<u>B</u> urnt 2020, <u>N</u> ot Harvested 1983-2002	NB1	Harvested in 1991 and 2002, STS medium. 4 dead trees near plot, no live large trees. DBH range of dead trees 30cm.
	NB2	Harvested in 1963, 1990, 2002. 7 dead trees near plot, no live large trees. DBH range of dead trees 30-40 cm.
	NB3	Harvested in 1972, 1991, and 1997, STS medium. 6 dead trees near each plot, no live large trees. DBH 30cm.
	NB4	Harvested in 1981, and 1985, STS medium. 9 dead trees near each plot, no live large trees. DBH 40-50cm. Dead large trees (DBH 80 cm).
	NB5	Harvested in 1970, and 1985, STS medium.
	PMB1	Maragle, Harvested in 1983, STS medium.
	PMB2	Maragle, Harvested in 1979, STS medium.

Table 5. Burnt 2020, Harvested from 2000 to 2020

Forest Treatment	Block ID	History of forest operations, age classes and retained large trees
<u>B</u> urnt 2020, <u>H</u> arvested from 2000 to 2020	NHB1	Harvested in 1961, and 1970, STS medium; Harvested in 2018, STS heavy. Heavy acacia. 9 dead trees near plot, DBH 50-60cm. Average 1 live AA in each plot, DBH 40cm.
	NHB2	Harvested in 1976, STS medium; Harvested in 2018, STS heavy. Black berry exits. 11 dead trees near plot, DBH 40-70cm. Dead large trees (DBH around 80cm) exist. No alpine <i>E. delegatensis</i> . Live snow gum and mountain gum (<i>E. dalrympleana</i>).
	NHB3	Harvested in 1982, 1985, 2004, and 2012, STS medium
	NHB4	Harvested in 1961, 1986, and 2004, STS medium; Harvested in 2014, STS heavy.
	NHB5	Harvested in 1959, 1960, and 1995, STS medium; Harvested in 2017, STS heavy.

Table 6. Burnt 2020, Harvested after 2020 (salvage logging).

Forest Treatment	Block ID	History of forest operations, age classes and retained large trees
Burnt 2020, Harvested after 2020 (salvage logging)	NBH1	Harvested in 1972, and 1993, STS medium; Harvested in 2020, STS heavy. 2 dead trees near each plot, but no alive large trees. DBH 30cm. Dead large trees (DBH 60-70 cm) lying.
	NBH2	Harvested in 1959/60, STS medium; and in 2022, STS heavy 2 dead trees near each plot, no alive large trees. DBH 40cm. Log debris lying (DBH 40-60 cm).
	NBH3	Harvested in 1957, and 1972, STS medium; Harvested in 2022, STS heavy. 2 dead trees near each plot (DBH 40cm), no alive <i>E. delegatensis</i> but there are several alive mountain gums (DBH 40-50 cm).
	NBH4	Harvested in 1981, STS medium; Harvested in 2008, unknown intensity; Harvested in 2020, STS heavy. 2 dead trees near each plot (DBH 40-50 cm), no alive <i>E. delegatensis</i> but there are heavy acacias. One dead-standing tree with DBH > 80 cm.
	NBH5	Harvested in 1981, and 1985, STS medium; Partially thinned and harvested in 2008, unknown intensity; Harvested in 2015 and 2022, STS heavy. 2 dead trees near each plot (DBH 40-50 cm), no alive <i>E. delegatensis</i> . Open stands with heavy <i>E. delegatensis</i> regeneration. One dead-standing tree with DBH around 70 cm.

Acknowledgements

This report was prepared with the assistance of many staff from SF NSW (Tumbarumba, Coffs Harbour, Eden Offices). Dean Freeman from the Brungle Aboriginal Reserve shared his knowledge and perspectives on protection of cultural sites. Shuqiao Zhang (University of Melbourne) researched and prepared the proposed experimental framework and, with Luba Volkova, assisted with field investigation of the forest.

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