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Potential for forest thinning to reduce risk and increase resilience to wildfire in Australian temperate Eucalyptus forests

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1 **Potential for forest thinning to reduce risk and increase resilience to wildfire**  
2 **in Australian temperate *Eucalyptus* forests**

3 *Short title: Forest thinning to reduce wildfire risks*

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11 *Abstract*

12 Unprecedented wildfires in south-eastern Australia in 2019-20 focused attention on forest  
13 management to reduce their risks and impacts. These fires mostly burnt dry eucalypt forests.  
14 In this short review, we found evidence from international studies that thinning combined  
15 with fuel reduction can reduce wildfire risks and impacts in dry forests compared to no treat-  
16 ment or thinning alone. In Australia studies so far demonstrate mixed outcomes, indicating  
17 that more landscape-scale experiments are required to better assess the use of thinning in dry  
18 *Eucalyptus* forests to reduce fire risks in a rapidly changing climate.

19 *Keywords:* prescribed burning, forest resilience, wildfire fuels, fuel hazard; Indigenous burn-  
20 ing practices.

21 *Introduction*

22 In south-eastern Australia in the summer of 2019-20 megafires of unprecedented scale af-  
23 fected more than seven million ha of *Eucalyptus* forests and woodlands [1], reflecting the in-  
24 creased risk of wildfires since the 1970s under a changing climate [2] with hotter, drier and  
25 more extreme fire weather (see [3, 4]). Projections indicate these conditions are likely to  
26 worsen under future climate change, particularly in south-eastern Australia, and the economic  
27 cost of wildfires is predicted to double by 2050 [2]. The impact of recent events prompted a  
28 national inquiry and ongoing debate about Australia's preparedness for wildfires, including  
29 appropriate land management and other actions to reduce wildfire risks and future fire im-  
30 pacts, and to build resilience to enable more rapid forest recovery [5].

31 Prescribed burning is the main form of land management to reduce fire risk in Australia [6].  
32 The efficacy of this practice continues to be debated, with some arguing for wider applica-  
33 tion, while others suggest wider use may present higher risks and ecological impacts. Austral-  
34 ian and international evidence indicates that strategic fuel reduction treatments can reduce lo-  
35 calized wildfire spread and severity but effectiveness declines with time since fire and as fire  
36 weather conditions become more extreme [7, 8]. The proportion of land with fuels reduced  
37 through prescribed burning has increased in south-eastern Australia over the last decade, but  
38 annual areas burnt are still well below the average annual area treated from 1970-1990. This  
39 is due to the shorter windows of appropriate weather to burn safely, increased operational  
40 costs, reduced availability of land management staff and concerns for negative impacts on hu-  
41 man health and agricultural products from prescribed burn smoke [9, 10]\*. Urban expansion  
42 into forested areas has also made prescribed burning more complex, with many fires in the

43 summer of 2019-20 burning in forest-urban interfaces where implementing regular burning is  
44 very challenging socially and ecologically [5, 11, 12].

45 Mechanical thinning of forest was recognised by the recent Royal Commission into Natural  
46 National Disaster Arrangements as one of a suite of practices for reducing wildfire hazard  
47 [5]. The Royal Commission report highlighted an example of regrowth clearing and stand  
48 thinning treatments that restored an open, grassy forest stand structure with fuel treatments  
49 that prevented shrub re-encroachment and reduced fire hazard on private property adjoining a  
50 national park in southern NSW [5].

51 Thinning has been used for commercial timber production objectives in plantations, and in  
52 some native forests, to reduce tree density and concentrate growth on the remaining trees so  
53 they reach a valuable size more quickly. Commercial thinning usually involves removal of  
54 less valuable species and stems with poor form, and giving adequate space for future crop  
55 trees [13]. However, the effects vary with forest types and financial benefits from increased  
56 log size may not justify the costs. Debate over future access to native forests for timber pro-  
57 duction [14] has also been a disincentive to practice thinning for commercial forestry, be-  
58 cause potential future benefits may not be realised if thinned areas are subsequently included  
59 in conservation reserves.

60 Australia's recent history of intense widespread wildfires, coupled with past land clearing and  
61 other forms of disturbance, have resulted in extensive areas of densely stocked regrowth for-  
62 ests that are stressed and in poor health. Ecological thinning of these forests has been tested  
63 for conservation objectives and to improve stand health and resilience to drought, insects  
64 pests and disease in several forest types across Australia – including jarrah [15], river red  
65 gum [16, 17], box-ironbark [18] and cypress pine [19].

66 Thinning of forest to reduce fire risks and impacts is extensively practiced in the US [e.g. 20]  
67 and is actively promoted in other countries, but is not being widely applied in Australia. Here  
68 we briefly describe and discuss the rationale for thinning to reduce wildfire risks, the out-  
69 comes of thinning combined with other forms of fuel treatments, and the benefits and trade-  
70 offs of thinning in the Australian context.

### 71 *The rationale for thinning to reduce wildfire risks*

72 Thinning to reduce wildfire risk aims to modify forest structure to reduce the probability of  
73 wildfires reaching the canopy, reduce flame height and rate of wildfire spread, and reduce

74 severity of wildfire impacts [21]. Reduced stand density can result in lower consumption of  
75 overstory vegetation during wildfires [22] and they reduce the probability of trees dying in  
76 intense wildfires because trees reach a larger size and develop thicker bark more quickly.

77 However, thinning alone results in a short-term increase in fine and near surface fuels. A re-  
78 cent review of 56 US studies [23] found that thinning followed by prescribed burning reduced  
79 subsequent wildfire severity, tree mortality, and crown scorch, but thinning alone (without  
80 active fuel treatments) had less effect, or none at all, compared to untreated sites. A study car-  
81 ried out in Spain also found that thinning plus prescribed burning was the most effective  
82 treatment for reducing active crown wildfire and decreasing the rate of fire spread and flame  
83 height [24]. However, thinning alone can lead to increased rates of wildfire spread under high  
84 winds, negatively impacting fire suppression outcomes [22].

85 For long lasting benefits, thinning and surface fuel treatments need to be repeated regularly  
86 because tree crowns expand over time to fill available space, the understorey regenerates and  
87 surface fuel loads increase over time. A simulation study in 3000 forest plots in the US indi-  
88 cated that treatment effectiveness is limited to between 10 years and up to 30 years [25]\*.  
89 Scale of treatment is also an important factor in determining potential benefits [23].

#### 90 *Australian thinning studies*

91 Research in Australia has focussed on assessment of thinning and burning treatments on fuel  
92 hazard (including the extent and duration of increased hazard), simulation of the effects of  
93 thinning on wildfire behaviour and analysis of thinned areas burnt in wildfires. Mechanical  
94 thinning plus burning was found to be most effective for reducing fuel hazard in long unburnt  
95 *Eucalyptus sieberi* forests in the state of Victoria, with major reduction in dead trees, surface  
96 and elevated fuels [26]. In thinned-only treatments, where only commercially valuable wood  
97 was removed, harvest residues and bark left on the ground led to a short-term increase in sur-  
98 face and near-surface fuel loads and high overall fuel hazard. A study in higher altitude *E.*  
99 *delegatensis* forests found decreased surface fuel hazard eight years after thinning but no sig-  
100 nificant effect on the loads of coarse woody fuels [27]. Simulation of wildfire behaviour un-  
101 der severe to extreme weather conditions predicted that eight years after thinning fireline in-  
102 tensity would decrease by 30% and rate of spread and spotting distance by 20% in thinned  
103 forest compared with un-thinned forest [27].

104 In other studies, higher fuel hazard was measured immediately after thinning, for example in  
105 an ecological thinning trial in *E. camaldulensis* forests in NSW, but fuel hazard had declined

106 to pre-treatment levels three years after thinning [16]. A study across 12 sites in low elevation  
107 mixed species forest in eastern Victoria [28]\* found that fine fuel from thinning slash had  
108 largely decomposed by 4 years after thinning, and overall fuel hazard was lower at thinned  
109 sites than adjacent un-thinned sites, primarily due to the reduction of elevated fuel (bark and  
110 shrubs).

111 The implications for wildfire risk of woody debris such as larger branches and tree boles left  
112 on the forest floor following thinning are less well understood. On the one hand thinning  
113 usually results in greater amounts of woody debris [25], making it more difficult to com-  
114 pletely extinguish wildfires after the fire front has passed through. On the other hand, a wind  
115 tunnel simulation found the presence of logs halved the rate of spread of heading fires com-  
116 pared to when no logs were present [29].

117 A recent study [30] of area burnt in the 2009 Black Saturday fires in Victoria found no differ-  
118 ence between thinned and unthinned areas in crowns burnt in two ages of *E. regnans* forests,  
119 but significantly lower probability of fire impact in thinned younger-aged mixed species  
120 stands (at a stage when forests are most vulnerable). In Eastern Victoria, in an experiment set  
121 up in 2018 and burnt in the 2019-20 wildfires, forests that were thinned with fuels reduced  
122 using prescribed fire did not burn in the wildfire but adjacent thinned only stands did burn  
123 [31]. This was because the two-year period between thinning and the wildfire was not long  
124 enough for residues left after thinning to collapse and decompose.

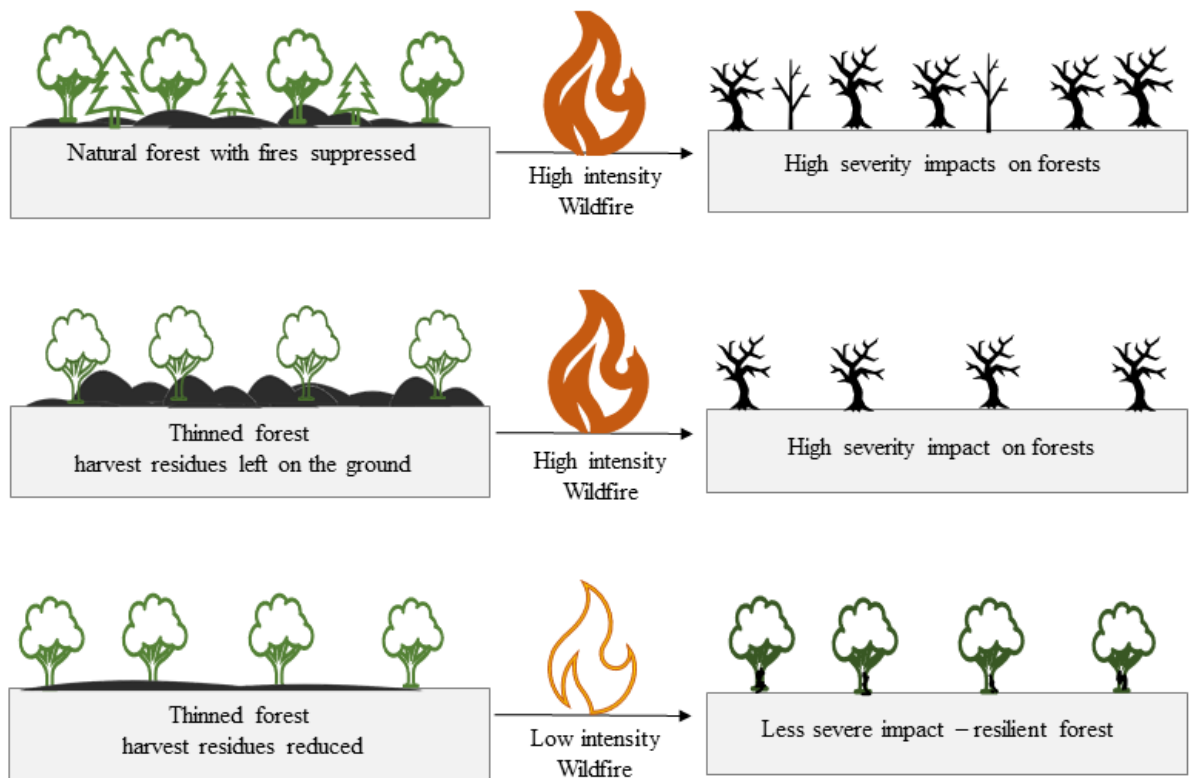
### 125 *Reducing forest vulnerability and increasing resilience to wildfires*

126 Vulnerability of forests to increasing disturbance such as wildfire is a function of exposure to  
127 the risk and sensitivity of the ecosystem to the disturbance. Resilience can be considered in  
128 multiple ways and depends on the nature of the disturbance [32]. Forest management can aim  
129 to resist the impacts through fire suppression or protection mechanisms, or increase resilience  
130 and the capacity in forests to recover from severe wildfires [4]. Over time, as climate change  
131 pressures on forests increase, managers might shift their strategy from a focus on fire sup-  
132 pression to supporting a change in forest composition and structure that promotes resilience  
133 and capacity to recover from disturbance. Forests are social-ecological systems and assessing  
134 resilience requires a sound understanding the interactions between human and ecological  
135 components of the system and the costs and benefits of different management actions that  
136 aim to improve resilience [32, 33].

137 Linking human and natural ecosystem components is also consistent with the world view of  
138 Australian Indigenous people, the Traditional Owners [34]. Thinning can be used as part of  
139 forest management to remove small trees and shrubs and restore forest structures similar to  
140 those under management by Traditional Owners. For example in parts of the US, more than a  
141 century of wildfire suppression and exclusion of Indigenous people has resulted in dry forests  
142 that are more vulnerable to, and have reduced capacity to recover from, severe wildfires [34].  
143 Mechanical thinning together with Indigenous burning practices are being used in forest res-  
144 toration programs [35]. Thinning can be done in most seasons and, together with mulching,  
145 can facilitate finer-scale and more variable burning used in cultural fire. This type of manage-  
146 ment needs to be integrated into appropriate self-governance or collaborative governance ar-  
147 rangements that reflect the ontologies, world views and objectives of Traditional Owners  
148 [36].

149 Dry forest types with similar short fire-return intervals to those in the US, make up over 80%  
150 of Australian *Eucalyptus* forests [33]. Long-term exclusion of wildfire in these forests is un-  
151 likely and exclusion can have significant negative ecological impacts, creating forests more  
152 vulnerable to impacts of large-scale disturbances. Appropriate thinning can more rapidly in-  
153 crease average tree size, increase resistance to impacts of wildfire and improve resilience and  
154 capacity of forests to recover from fires and maintain their important ecological functions  
155 (Figure 1). When a wildfire occurs in even-aged, unthinned forest it burns with high intensity,  
156 leading to high impacts (top panel). Thinned forests without active fuels treatment are also  
157 susceptible to high intensity wildfires in the short term, until fuels decompose (middle panel).  
158 Thinned even-aged forests where residues are removed through prescribed fire or mechanical  
159 treatment will potentially have lower severity of crown damage and recover more rapidly af-  
160 ter intense wildfires (bottom panel).

161 Thinning and burning is not suitable for other forest vegetation types (for example rainfor-  
162 ests) and may increase their vulnerability to wildfire. Use of thinning therefore needs to be  
163 carefully planned to be consistent with the ecological attributes and values of different forest  
164 types. Strategic planning is needed to identify those parts of the landscape where it can be  
165 used operationally and where the benefits are likely to be greatest, in particular where it  
166 might allow more effective suppression of fires burning in milder weather and reduce major  
167 damage under extreme conditions [23].



168

169 *Figure 1. Illustration of how thinning, thinning and removal of harvested residues can reduce*  
 170 *fire severity and increase forests resilience to wildfires.*

171 *A paradigm shift in Australian forest management*

172 Increasing the resilience of forest landscapes threatened by increasing fire risks due to cli-

173 mate change requires a paradigm shift in forest management in Australia [37, 38]\*. In the

174 past, and prior to the development of more sustainable forestry practices, accessible native

175 forests were exploited for timber or cleared for agriculture. Timber removals from native for-

176 ests became more heavily regulated from the 1960s. Over the last few decades the volume of

177 timber removed has declined to about one third of that in the 1990s [39]. Social expectations

178 from forests are changing faster than the institutional capacity for change in forest manage-

179 ment organisations, with the pace of climate change intensifying this phenomenon [4]. This

180 requires extensive dialogue among all actors to decide on appropriate ways forward in a time

181 of high uncertainty about future environmental conditions. Following large-scale wildfires in  
182 the US new types of partnerships have formed (e.g. <https://restoringtherockies.org/about/>) to  
183 find common ground between parties with very diverse views on forests on the best ways to  
184 reduce wildfire risks and increase forest resilience in the face of climate change. Similarly, in  
185 southern Australia the scale and impact of the megafires of 2019-20 has challenged *status*  
186 *quo* approaches to wildfire risk mitigation in the coming years. New dialogue is needed on  
187 the best way forward.

188 Thinning and active fuel management need to be evaluated in this context of broader consid-  
189 erations around native forest management. An argument might be made to continue native  
190 forest timber extraction but focus this on activities that reduce wildfire risks and maintain op-  
191 erational capacity for forest fire fighting [12]. Currently, the evidence base to support the  
192 wider application of thinning in Australia is limited and most studies have been in small-scale  
193 treatments. A large-scale research program could be designed to quantify the effects of thin-  
194 ning more broadly across landscapes and its influence on wildfire behaviour and forest recov-  
195 ery under different scenarios [30]. Because thinning is potentially expensive to implement,  
196 consideration of novel commercial products could be included to allow for the generation of  
197 new enterprises built on smaller, currently lower value materials removed through thinning.  
198 Investment in new equipment will be needed to thin trees with low environmental impact and  
199 incentives may be needed to establish markets for low-value biomass and improve financial  
200 viability [40]. A wider analysis of costs and benefits is also required. In the US, the benefits  
201 of reduced risk and improved ecosystem health and environmental services are considered to  
202 outweigh the costs and large government investments are being made in these activities [41].  
203 These kinds of cost-benefit analyses, including the potential impacts of thinning and pre-  
204 scribed fire on timber quality and the social and environmental benefits and costs are required  
205 to inform forest policy in Australia.

206 These larger landscape-scale experiments building on traditional ecological knowledge and  
207 integrating connections between people, fire, and ecosystems could inform improved forest  
208 management decisions. Thinning operations for resilience also need to be carefully designed  
209 to be compatible with the ecological requirements of the forest to maintain and enrich biodi-  
210 versity, and be applied in accordance with rigorously enforced codes of forestry practice.

### 211 *Conclusions*

212 Unprecedented wildfires in south-eastern Australia in 2019-20 focused attention on forest  
213 management to reduce their risks and impacts. Maintaining the resilience of forests to in-  
214 creasing disturbances linked to climate change is a complex challenge that needs to carry  
215 with it contemporary social expectations from forests. In this review, we found evidence from  
216 US studies that thinning combined with fuel reduction can reduce wildfire risks and impacts  
217 compared to no treatment or thinning alone. In Australia, studies so far demonstrate mixed  
218 outcomes. Forest thinning may be effective as part of a range of activities to reduce fire risk  
219 and impacts as climate change increases extreme fire weather in forested landscapes. Evi-  
220 dence from the US indicates thinning needs to be applied at scale to be effective. While land-  
221 scape-scale experiments can be designed to assess the use of thinning to reduce fire risks, as-  
222 sessing outcomes will require careful consideration of all the costs and benefits, including im-  
223 plications for individuals, human communities and ecosystems.

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### 227 *Authors contribution*

228 RJK, CW and LV have designed the study, overseen its implementation and contributed to  
229 the development of the manuscript idea. All authors contributed to literature review and

230 writing of the manuscript. All authors have read and agreed to the published version of the  
231 manuscript.

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354 published study for Australian forests with well replicated design and comprehensive assess-  
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358 'pivot point' for our thinking on thinning, fire, climate change and the future. We might even

359 call this a “paradigm shift” so that we clearly identify that we can’t just do what we have  
360 done in the past.

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363 recent, this is one of a few, comprehensive field-based studies investigating the effect of thin-  
364 ning on forest fuels hazards in south-eastern Australian forests over a 15 - year period. Op-  
365 portunistically, authors also assessed the impact of wildfires on thinned and nearby untinned  
366 plots confirming the benefits of thinning for reduced wildfire severity.