Thinning Combined With Biomass Energy Production Impacts Fire-Adapted Forests in Western United States and May Increase Greenhouse Gas Emissions

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Introduction

Many municipalities, electric companies, and small energy producers are replacing fossil fuel energy production with biomass energy in response to global concerns about greenhouse gas emissions and the negative impacts of climate change (eg, US Energy Policy Act of 2005). Biomass is often touted as "renewable" energy and therefore receiving of various financial incentives and credits because when trees and shrubs grow back they are able to sequester the carbon that was emitted during combustion of energy (Evans and Finkral, 2009).

Unfortunately, after quick and often large-scale implementation of biomass energy production in Europe and parts of the United States, this approach can result in higher greenhouse gas emissions compared to combustion of fossil fuels, especially within the first few decades of use (Manomet Center for Conservation Sciences, 2010; Schulze et al., 2012; NRDC, 2015). If we are to truly reduce our greenhouse gas emissions from fossil fuels, as the best science indicates that we must do quickly and substantially, than thinning and biomass energy production need to be ecologically appropriate and carbon neutral to receive consideration as a climate saving strategy.

Thinning forests to reduce fire occurrence or intensity and using vegetation byproducts of thinning in energy production is gaining traction in the western United States due to concerns about wildfires (eg, Southern Oregon Forest Restoration Collaborative, 2013; Governor Edmund Brown, 2015). Proponents argue that fires are increasing in intensity and/or area burned and that widespread thinning is needed to reduce fire effects and emissions from forest fires. The byproducts (trees and shrubs, Fig. 1) are used as fuel in biomass energy production. It is believed that biomass burning results in lower greenhouse gas emissions than the use of fossil fuels for energy production. This abundant energy source is seen as a "win-win" because it is sourced as a byproduct of fire risk reduction from thinning activities. According to the Western Governor's Association (2006), 4.3 million hectares are available for "hazard fuel reduction" from western forests, yielding 270 million dry tons of biomass.

We examine common assumptions associated with thinning and biomass energy production by summarizing the relevant literature regarding whether: (1) thinning lowers fire intensity, fire occurrence, and carbon dioxide emissions compared to wildfire emissions and (2) biomass is clean, renewable energy with lower greenhouse gas emissions than fossil fuels. Our intent is to help inform managers about whether fuel reduction approaches are ecologically sound and carbon neutral. We caution that based on numerous published studies, improper accounting of carbon and biomass lifecycles could lead to large-scale clearing of forests (Mellillo et al., 2009; Wise et al., 2009) at a time when enhanced forest growth and reduced deforestation and forest degradation are needed to combat climate change (NY Declaration on Forests, 2014). Finally, we provide 11 principles to help mitigate some of the impacts of widespread thinning and biomass utilization.



Fig. 1 Thinning for fire risk reduction and proposed as biomass fuels in the Ashland, Oregon watershed, southwest Oregon (photo: D. Odion).

In this article, we examine two core assumptions commonly used to promote thinning for fire risk reduction and for utilizing the biomass in fuel consumption: (1) thinning is effective in lowering fire intensity and occurrence and therefore results in reduced carbon dioxide emissions compared to wildfires believed to be increasing in western forests and (2) biomass produced from thinning is clean, renewable energy compared with fossil fuels.

Core Assumption: Wildfires Are Increasing, Thinning Lowers Fire Intensity and Occurrence, and Biomass Is Carbon Neutral

These core assumptions are often packaged together in fuel- and fire risk reduction projects. Here, we unpackage them and examine whether they are ecologically appropriate and carbon neutral for western forests based on the best available science.

Fires Are Not Increasing in Much of the West Compared to Historical Baselines

The fire regime in most of the fire-adapted low- to mid-elevation mixed-conifer and ponderosa pine (*Pinus ponderosa*) forests of the western United States is what fire ecologists describe as "mixed severity": patches of unburned, low, moderate, and severe (>75% dominant overstory tree kill) fire effects on vegetation (Halofsky et al., 2011; Odion et al., 2014; DellaSala and Hanson, 2015). Despite assumptions that fires are unprecedented in the West, due to a build up of fuels caused by decades of fire suppression, severe fires, the biggest concern of managers and a component of large mixed-severity fires, have changed little from over the past several decades (Odion and Hanson, 2008; Hanson et al., 2009; Odion et al., 2014; Baker, 2015; **Fig. 2A**). Notably, there is currently a deficit of area burned (all severities) throughout most of the western United States (Odion et al., 2014) when compared to longer timelines (eg, **Fig. 2B**). It is quite possible that fire regime shifts could occur due to climate change in places (Littell et al., 2009); however, the fire deficit is so large currently that it would take decades for fires to approach historical levels. Thus, at least for the next several decades, the current fire deficit, and not a surplus as commonly claimed, stands (see DellaSala and Hanson, 2015).

The Chance That a Thinned Site Will Encounter a Fire When Fuels Are Lowest Is Slim

The chance that thinning will influence fire behavior is based on a number of improbable factors that, in turn, affect emissions, including:

1. Probability of a thinned site encountering a fire when fuels are lowest (<20 years) is only 5–8% based on computer simulations (Rhodes and Baker, 2008). Additionally, there is just a 2% chance that a thinned site will encounter a severe fire. Therefore, costly fuel treatments would need to be applied repeatedly over very large areas in order to keep fuels at low levels and even so thinned sites would have a very low probability of co-occurrence with fire. Repeating fuel treatments increases net carbon dioxide emissions over the life of a project.
2. Thinned sites must encounter a fire during "average" weather conditions when fire intensity is likely to remain low enough to be mitigated by fuel treatments. Large fires in dry forests are mostly driven by severe weather and less so by fuel densities (Littell et al., 2009; Odion et al., 2014; Baker, 2015). During severe fire-weather, even thinned sites burn (Thompson et al., 2007) as large fires are mostly driven by extreme fire-weather, which may increase in frequency in places due to climate change (Littell et al., 2009). Solving for fire risks without reducing greenhouse gas emissions is therefore treating the symptom rather than the cause.

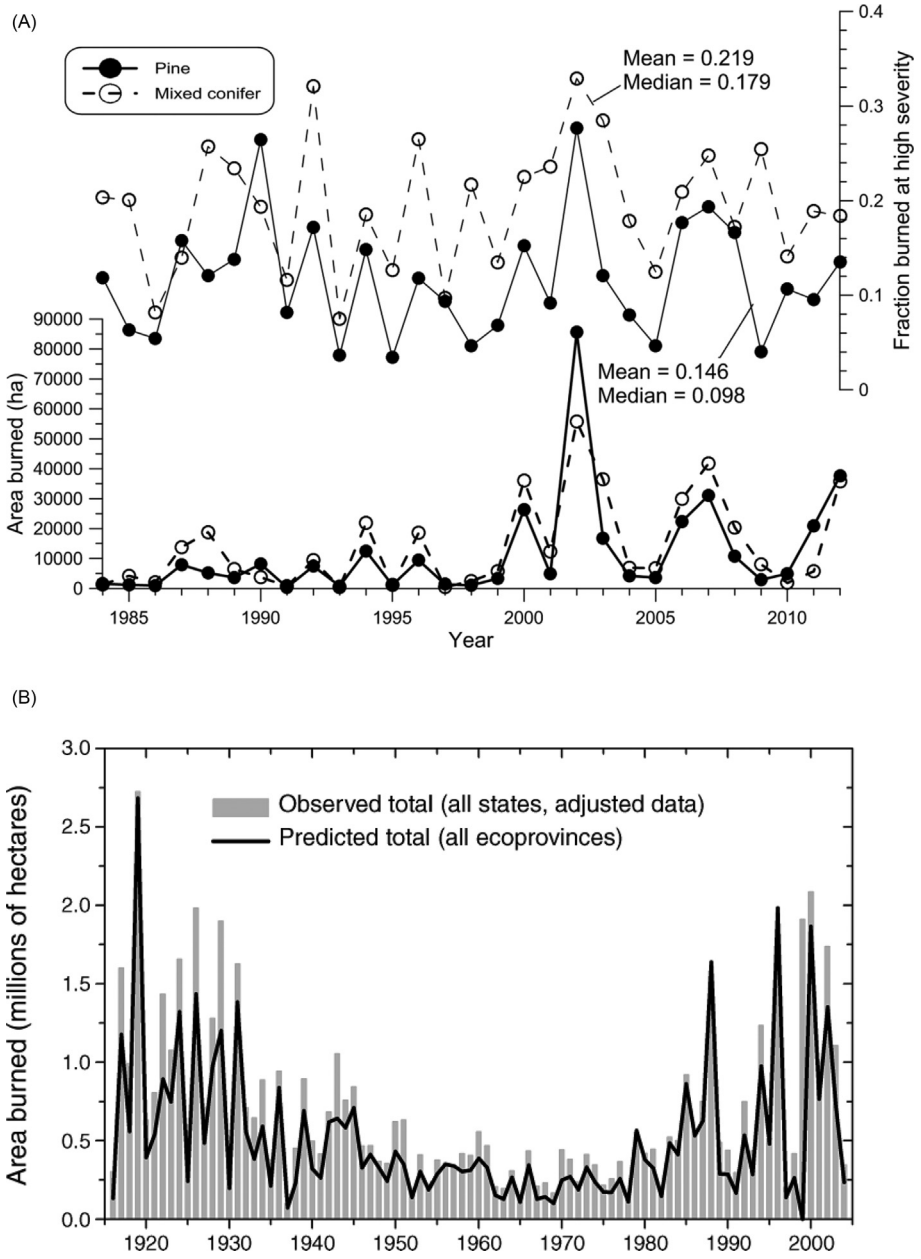


Fig. 2 (A) Area burned in pine and dry mixed-conifer forests of the western United States at high severity (bottom) and fraction burned at high severity (top) from 1984 to 2012. (B) Observed and reconstructed area-burned from early 1916 to 2004 for 16 ecoprovinces in the western United States. Note the U shaped pattern in area burned with historical highs, followed by a mid century dip, and then recent decadal increases. (A) Reproduced from Baker, W. (2015). Are high-severity fires burning at much higher rates recently than historically in dry-forest landscapes of the western USA? *PLoS One* **10**, e0136147. http://dx.doi.org/10.1371/ journal.pone.0136147. (B) Reproduced from Littell, J. S., McKenzie, D., Peterson, D. L. and Westerling, A. L. (2009). Climate and wildfire area burned in western U.S. ecoprovinces, 1916–2003. *Ecological Applications* **19**, 1003–1021.

3. Done incorrectly thinning can actually increase the chance of a severe fire if forest canopies are opened too much due to increased understory vegetation growth rates, increased surface fuels (eg, slash piles), increased desiccation, and greater wind penetrance affecting fire spread (Brown et al., 2000). Thinning also decreases carbon storage in a forest especially when forests are thinned repeatedly as the carbon emitted by thinning is never recouped because forests accumulate carbon slowly (decades–centuries) but release it quickly when logged (Mitchell et al., 2009, 2012; Hudiburg et al., 2009, 2011; Ryan et al., 2010; Campbell et al., 2012).

Forest Fires Are Not Currently Large Emitters of Carbon

Contrary to what many believe, individual fires do not emit large quantities of carbon dioxide to the atmosphere (Campbell et al., 2007; Mitchell, 2015). For all fire severities, most of the vegetation combustion consists of fine fuels, litter and duff, rather than large trees. Even severe fires that kill most of the trees in an area emit only 5–30% of stored carbon as carbon dioxide (Campbell et al., 2012). Thus, most of the carbon in the burned forest is simply transferred (stored) from live vegetation to dead trees. Lightly to moderately burned areas also continue to sequester carbon for decades to centuries while new vegetation in severely burned patches also sequesters carbon. Unless forest fires increase greatly in frequency or severity, they will have little overall impact on carbon dioxide emissions. High-severity fire on average also only accounts for about 12–14% of the total burn area in large fires (Law and Waring, 2015). Notably, the difference between forest biomass combusted in high-severity crown fire and low-severity fire is small because even in high-severity fire, $<5\%$ of total stem mass is combusted (Campbell et al., 2007; Meigs et al., 2009).

Fire Risks Do Not Necessarily Increase as Time Between Fire Increases

Different forest types have different fuel relationships. For instance, mixed evergreen forests of the Klamath–Siskiyou region (southwest Oregon, northern California) do not show the same fire and fuels relationships as low elevation ponderosa pine forests that they are often lumped with in proposing fuel reduction projects. As the time since fire increases in these forests, fuel densities and fire severity do not increase, with the exception of tree plantations where trees are unnaturally dense and fires burn intensely through densely stocked stands (Odion et al., 2004). Presumably this is because as forests mature, they begin to shade out more flammable understory vegetation, naturally lowering fire intensity. Finally, fuel reduction models have been criticized because they have had a tendency to over-predict effects of thinning on fire intensity and they lack empirical testing (Cruz and Alexander, 2010; Alexander and Curz, 2013; Cruz et al., 2014). Relying too much on thinning to reduce fire intensity therefore is creating a false sense of security that fires will burn in low intensity in what are predominately mixed-severity, climate influenced systems.

Core Assumption: Biofuel Burning Produces Clean, Renewable Energy Compared to Fossil Fuels

> . . . clearing or cutting forests for energy, either to burn trees directly in power plants or to replace forests with bioenergy crops, has the net effect of releasing otherwise sequestered carbon into the atmosphere, just like the extraction and burning of fossil fuels. That creates a carbon debt, may reduce ongoing carbon uptake by the forest, and as a result may increase net greenhouse gas emissions for an extended time period and thereby undercut greenhouse gas reductions needed over the next several decades.
>
> Fargione et al. (2008)

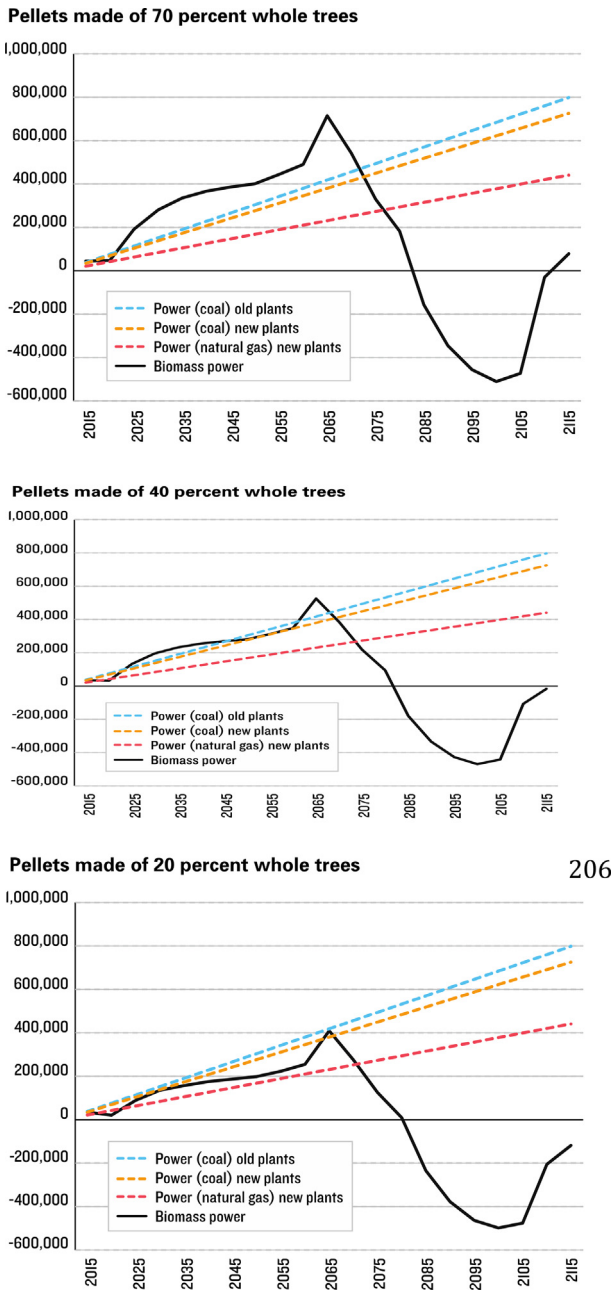
Burning Woody Biomass for Fuel Emits More Carbon Dioxide than Coal

Biomass is often considered a clean, renewable fuel because, under ideal conditions and over long time frames, carbon emitted during combustion for energy is re-sequestered once trees regrow. Because wood byproducts from lumber mills and other manufacturing are plentiful and would decompose anyway, there are situations where energy production from biomass at lumber mills can be carbon neutral. The amount of carbon dioxide released from woody biomass combustion per unit of energy produced, however, is often comparable to coal and much larger than that of oil and natural gas due to inefficiencies in burning wood compared to more energy dense fossil fuels (Haberl et al., 2012; **Fig. 3**). Additionally, it takes decades to recoup carbon removed from a forest for biomass production as some estimates indicate this source of energy would actually release more carbon dioxide emissions compared to coal and natural gas. Biomass emissions would especially accumulate from projects that include short-rotation timber harvests and repeat thinning to keep fuels at low levels due to multiple ways carbon is emitted (**Fig. 3**).

Even if the trees are allowed to grow back (if they are not perpetually thinned), the timeframe for re-sequestering the original quantity of carbon conflicts with current policy imperatives requiring drastic cuts in emissions over the near term. In tree plantations, thinning can accelerate tree growth and increase carbon sequestration, potentially lowering emissions some, but this still may not be carbon neutral depending on how much carbon is removed (Mitchell et al., 2009; Law and Harmon, 2011; Hudiburg et al., 2011; Schulze et al., 2012; Hudiburg et al., 2013; **Fig. 3**). A thorough carbon accounting must be done for each particular situation and for the full life cycle (**Fig. 4**). In sum, the large demand of many biomass energy plants for "feedstock" and the economics of woody debris removal often lead to whole trees, rather than just woody debris, being removed, chipped, or turned into pellets for combustion that emits more carbon than fossil fuels.

Principles for Minimizing Impacts of Forest Thinning and Biomass Energy

The best way to store carbon in a forest long term is to protect older high-biomass forests on public lands and increase the interval between timber harvests on private lands (Krankina et al., 2012, 2014). For instance, compared to tree plantations, older forests store 3–10 times more carbon than young forests (Law et al., 2001; Hudiburg et al., 2009) and old forests continue to sequester at high rates as they mature (Luyssaert et al., 2008). If timber harvest rotation intervals were lengthened by 50 years, carbon stores would increase by 15% (Law et al., 2013).



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Fig. 3 Cumulative emissions ($MgCO_2e/MW$) from pellets made of various percentages of whole trees. For the first few decades, wood burning creates a pulse of emissions that rival coal and natural gas production. Reprinted from Natural Resources Defense Council (NRDC). (2015). Issue brief. 2015. Think wood pellets are green? Think again. IB:15-05-A. www.nrdc.org.

Nonetheless, because there is extensive interest in biomass-thinning projects, in spite of concerns that they may be ecologically inappropriate and often carbon negative, we close with 11 principles for mitigating effects of thinning and biomass on ecosystems and carbon budgets based on recommendations modified from conservation groups and concerned scientists. (Modified (edited) from Principles for sustainable biomass. Adopted by Environmental Working Group, Environmental Defense Fund, Friends of the Earth, Geos Institute, Greenpeace USA, National Wildlife Federation, Natural Resources Defense Council, Southern Alliance for Clean Energy, Southern Environmental Law Center, Union of Concerned Scientists, The Wilderness Society, and WWF. May 17 2010 scientist letter to Speaker of the House Nancy Pelosi and Senate Majority Leader Harry Reid (letter includes several signatories of the National Academy of Science).)

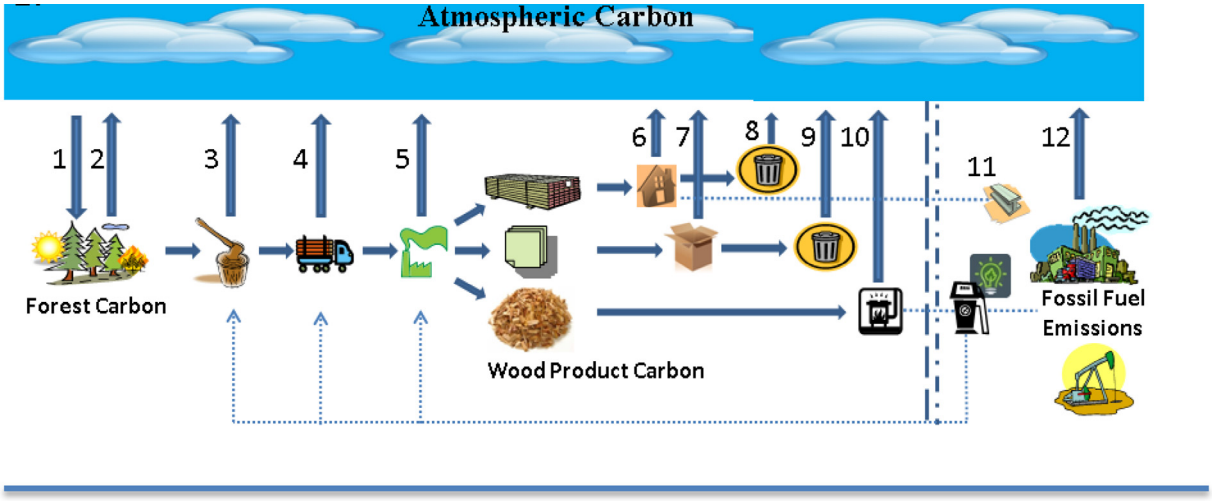


Fig. 4 Carbon uptake (down arrow) and flux (up arrows) from forest thinning and biomass utilization. From Hudiburg, T., Law, B. E., Wirth, C. and Luyssaert, S. (2011). Regional CO2 implications of forest bioenergy production. *Nature Climate Change* **1**, 419–423. http://dx.doi.org/10.1038/NCLIMATE1264.

Require Full Carbon Accounting

Assess net carbon flux from thinning and biofuels using published probabilities of treatment efficacy under "average" versus extreme weather (eg, Rhodes and Baker, 2008). Invest in carbon flux assessments (eg, see LANDCARB http://landcarb.forestry.oregonstate.edu/) and ground verification of fuel models and carbon assessments (accuracy assessment). Independent verification of assessments should be factored into a project's operating costs, much like carbon offset projects.

Assure Sustainability

Production, sourcing, and utilization of biomass must assure the protection of all natural ecosystems (including those on public and private lands), habitat values, and air and water quality and quantity, and must not adversely affect soils or contribute to soil erosion.

Prevent Global Warming and Ocean Acidifying Emissions

Projects must result in lower life cycle, cumulative and net emissions, and ocean acidifying emissions within 20 years and also over the longer term than the energy sources they replace or compete with.

Protect Conservation Land

Biomass must not come from protected or conservation lands including but not limited to any area designated by federal or State governments for conservation purposes such as Wilderness or Wilderness study Areas, old-growth forests, Inventories Roadless Areas, or aquatic buffers except for invasive alien species and for material whose removal is necessary to protect public health and safety (ie, near homes).

Safeguard Special Ecosystems

Biomass must not come from lands identified at the federal or State level as endangered, rare, or threatened; at the global, national, or State level, such as old-growth forests and native grasslands or other seriously diminished ecosystems such as late-successional stands except for material whose removal is required for restoration of characteristic structure, composition, and function of the ecosystem involved if consistent with the other principles herein and with regional and local fire regimes and characteristic vegetation of the area.

Prevent Loss of Natural Ecosystems

Biomass removed from lands converted from forests, grasslands, or other natural systems into plantations or simplified, intensively managed, or cultivated systems shall not qualify for government subsidizes if the conversion occurs after the adoption date of such incentive program.

Protect Threatened and Endangered Species

Biomass harvest must not occur on lands identified at the federal or State level as harboring or potentially harboring any species classified as endangered, rare, or threatened at the global, national, or State level, or is a candidate for such status, except for material whose removal is required for restoration of the species' habitat and protection of the species.

Avoid Toxic and Other Air Pollutants

Biomass energy facilities must not contribute to greater air pollution per unit of energy produced than would result from the energy source they replace or compete with, including, for example, nitrogen oxides (NO_x), volatile organic compounds, and particulate matter, must not increase local community exposure to such pollutants, and must not be afforded special treatment under the Clean Air Act.

Be Energy Efficient

Biomass energy production must meet strong standards for efficiency in the conversion of biomass to useful energy.

Require Sustainable Procurement

Biomass energy producing facilities must develop and implement a biomass source plan that satisfies the above principles and is capable of supplying the facility for its operational life, accounting for competing biomass demand in the sourcing area.

Prioritize Vegetation Reduction Treatments

Vegetation reduction is most likely to influence fire intensity during average weather conditions, within unnaturally overstocked tree plantations, and by removal of small trees. Proponents should factor in the likely occurrence of more extreme fire behavior due to climate change, provide realistic estimates of thinning efficacy, and account for collateral damage to ecosystems.

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