DEFINITION

*Forest thinning* refers to removing trees in a forest stand to allow space for other trees and plants to grow (Punches 2004). Thinning is a silvicultural treatment used for commercial forest management and wildfire mitigation. Thinning projects are often performed as a part of larger forest land and resource management plans (USFS 2018). *Mechanical thinning* is the process of removing trees in overgrown forests to reduce the risks of extreme wildfires (Westover 2021). It is also frequently referred to as *mechanical treatment*, a more general term for any mechanized forest treatment, including mechanized cutting and hand thinning. Thinning can be done with chainsaws, crosscut saws, hand tools, bulldozers, and woodchippers (Westover 2021). As a nature-based solution, the primary goal of forest thinning is to reduce fuel and fuel connectivity to reduce high-intensity crown fires (Banerjee 2020). Thinning that is not followed by prescribed fire is not always an effective tool to combat wildfire spread, so it is essential to use them together as much as possible (Kittler 2022).

TECHNICAL APPROACH

1. **Create a plan or prescription:** Thinning projects vary greatly depending on location and forest composition; a forester should be involved in the planning and implementation of a project. When considering the number of trees to remove from a certain area, it is essential to determine what the region looked like historically. For example, south-facing slopes will have less vegetation, while drainages will have more. Treatments that focus on the removal of smaller trees as opposed to larger trees are typically more effective in reducing crown fires due to the reduction of ladder fuels (Hunter et al. 2007).

2. **Select equipment:** When conducting a thinning project, land managers can use hand tools, machines, or a mix of both (CAL FIRE 2021).

   - **Hand thinning:** Commonly used tools include chainsaws, Pulaskis, and McLeods. These tools allow crews to cut and drag the thinned debris and vegetation to the roadside or into a slash pile (CAL FIRE 2021). Hand thinning can be effective for trees less than 16 in. in diameter, on steeper slopes, or in sensitive areas (USFS).

   - **Machine thinning:** When conducting mechanical thinning, agencies typically use skid steers with various attachments such as brush rakes, grapple attachments, or masticating attachments to remove trees and other fuel from the forest (CAL FIRE 2021). Mechanical thinning is typically more cost-effective and can be very useful in the removal of large trees, but it is prohibited on slopes greater than 30% and in sensitive areas (USFS). Another form of forest machine thinning...
is *mastication*, which is a method of using heavy machinery to grind up fuels (Northern Colorado Fireshed Collaborative 2023).

3. **Remaining slash**: After conducting either hand or machine thinning, there are multiple ways to handle the *remaining slash*, which is the residual woody debris (Murray et al. 2022). Many considerations go into deciding which method to use, including costs, capacity, and invasive species management (DeGomez 2014).

   - **Mastication**: Mastication uses machinery to break down slash and spread it across the forest floor (Northern Colorado Fireshed Collaborative 2023). Excavators with masticator attachments can create breaks in fuel to provide fire breaks and safety for firefighters (CAL FIRE 2021).

   - **Chipping**: Chipping of slash is a method often used for thinning projects to change the shape of the slash to reduce the risk of large wildfires (CAL FIRE). Chipping is appropriate to reduce catastrophic fire danger but can lead to the death of low-level plants if the chips are dried out (Glitzenstein 2009).

   - **Piles**: Slash is often collected and moved into piles by machine or hand (Figure 1). These piles are dried out for a few years and then burned (USFS).

   - **Commercial sales**: Often, agencies will perform commercial thinning, which combines wildfire mitigation work with generating funds (Figure 2). The most significant barrier to thinning projects is often the cost, which can be covered with commercial sales of woody products (Chang et al. 2022; Johnston et al. 2021).

**Figure 12.1 Slash piles created after thinning for fuel reduction**

*Photo courtesy Oregon State University*
• **Prescribed burn**: Prescribed burns are typically used after a thinning project to further reduce hazardous fuels (CAL FIRE 2021).

4. **Monitoring**: Monitoring is a crucial final step of a thinning project to determine if the project was effective and should be repeated in similar forest types or the same site in the next 20 or 30 years, depending on the forest’s needs. Monitoring also builds public confidence in fuel treatment projects (Hunter et al. 2007).

**OPERATIONS AND MAINTENANCE**

Thinning (and associated prescribed burning) will need to be repeated over time to maintain effectiveness. The number of years between thinning treatments will differ based on the type and age of a forest.

**Figure 12.2 Commercial thinning project in Washington**

Photo courtesy US Forest Service—Pacific Northwest Region
FACTORS INFLUENCING SITE SUITABILITY

✓ **Coniferous tree species:** Thinning treatments more effectively reduce catastrophic wildfires in coniferous forests than in broadleaf forests (Moreau et al. 2022).

✓ **Wildfire threat:** The areas defined by the US Department of Agriculture (USDA) and Department of the Interior (DOI) as the highest priority for fuel treatments are the entire Mountain West, West Coast, Southwest, and Southeast (USDA and DOI n.d.).

✓ **Community buy-in:** Because of the potential controversy of thinning projects, it is essential to have community buy-in and engagement to create collaborations and partnerships (Thompson 2021).

✓ **Weather and climate:** Decomposition rates are essential when considering whether to conduct a thinning project, especially when using thinning to reduce severe wildfires (Moreau et al. 2022). Studies have shown the faster decomposition after thinning projects results in lower fire severity (Palmero-Iniesta et al. 2017). Decomposition occurs more quickly in climates with heavier rainfall.

✓ **Areas affected by insects or disease:** Areas affected by dwarf mistletoe and mountain pine beetle are good sites for thinning projects (Hunter et al. 2007).

✓ **Drought-prone:** Because thinning can reduce drought stress, particularly drought-prone areas are good sites for thinning projects (NSF 2018).

✗ **Limited work capacity:** Many federal agencies have limited capacity for thinning projects, so sites without agency investment may be challenging to thin (Hunter et al. 2007).

✗ **Steep slopes:** To conduct effective large-scale thinning projects, machinery is typically the most efficient and often cannot be used on slopes steeper than 30%. For large-scale thinning projects, steep slopes create an extra challenge (USFS, CAL FIRE 2021).
<table>
<thead>
<tr>
<th>Name and Link</th>
<th>Resource Type</th>
<th>Year</th>
<th>Authors/Authoring Organization</th>
<th>Geography</th>
<th>Description</th>
<th>Resource Includes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guidelines for Thinning Ponderosa Pine for Improved Forest Health and Fire Prevention</td>
<td>Guidebook</td>
<td>2014</td>
<td>University of Arizona College of Agriculture &amp; Life Sciences Cooperative Extension</td>
<td>Western United States (anywhere ponderosa pines are managed)</td>
<td>This guide provides information on how to thin a ponderosa forest. This includes stocking rate, basal area, and deciding which trees to mark.</td>
<td>✓ ✓ — ✓</td>
</tr>
<tr>
<td>Fuels Reduction Guide</td>
<td>Guidebook</td>
<td>2021</td>
<td>California Department of Forestry &amp; Fire Protection</td>
<td>California (national applications, but most relevant in the western United States)</td>
<td>This guide provides information on how to conduct a variety of fuel reduction projects.</td>
<td>✓ — ✓ ✓</td>
</tr>
<tr>
<td>A Comprehensive Guide to Fuels Treatment Practices for Ponderosa Pine in the Black Hills, Colorado Front Range, and Southwest</td>
<td>Guidebook</td>
<td>2007</td>
<td>USDA Forest Service (USFS)</td>
<td>Western United States (anywhere Ponderosa pines are managed)</td>
<td>This guide provides recommendations for various fuel treatments within ponderosa pine forests. It includes social, political, economic, and ecological factors regarding fuel treatments.</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Community Wildfire Mitigation Pocket Guide</td>
<td>Guidebook</td>
<td>2021</td>
<td>Coalitions &amp; Collaboratives</td>
<td>National</td>
<td>This guide provides information for community managers on many different wildfire mitigation practices, including forest thinning.</td>
<td>✓ ✓ ✓ —</td>
</tr>
<tr>
<td>Name and Link</td>
<td>Resource Type</td>
<td>Year</td>
<td>Authors/Authoring Organization</td>
<td>Geography</td>
<td>Description</td>
<td>Design/Construction Guidance?</td>
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<tr>
<td>National Priorities for Broad-Scale Fuels Management</td>
<td>Map</td>
<td>n.d.</td>
<td>USDA and DOI</td>
<td>Continental United States</td>
<td>These maps show priority areas for fuel management efforts throughout the continental US.</td>
<td>—</td>
</tr>
<tr>
<td>Forest Vegetation Simulator (FVS)</td>
<td>Software</td>
<td>1973</td>
<td>USFS</td>
<td>National</td>
<td>FVS is a tool commonly used in forestry by land managers. FVS can provide useful insight into how to thin for various goals, especially the Fire and Fuels Extension.</td>
<td>✓</td>
</tr>
<tr>
<td>The Fire and Fuels Extension to the Forest Vegetation Simulator: Updated Model Documentation</td>
<td>Guidebook</td>
<td>2010</td>
<td>USFS</td>
<td>National</td>
<td>The Fire and Fuels Extension from FVS is a helpful tool for forest fuel management. This guidebook provides examples, stand visualizations, and outputs from the software.</td>
<td>✓</td>
</tr>
<tr>
<td>A Land Manager’s Guide for Creating Fire-Resistant Forests</td>
<td>Guidebook</td>
<td>2013</td>
<td>Oregon State University, Northwest Fire Science Consortium</td>
<td>Written for the western United States but most information is more broadly applicable</td>
<td>This guide provides information on different silvicultural treatments used to create and manage fire-resistant forests.</td>
<td>✓</td>
</tr>
</tbody>
</table>
**LIKENLY BENEFITS AND OUTCOMES**

Primary objectives for each strategy are highlighted.

**Climate Threat Reduction**

- **Reduced wildfire risk:** The most common climate-related goal of thinning is to reduce the risks of catastrophic wildfires. Thinning projects can reduce fires by decreasing fuel loads, alleviating tree stress, increasing space between trees, and reducing ladder fuels (Willis et al. 2022). Thinning can also increase the fire-tolerant species in a stand, which provides a more long-term benefit (Moreau et al. 2022).

- **Drought mitigation:** Many forests throughout the United States are overgrown as a result of long-running fire suppression practices. This overgrowth and increased evapotranspiration contribute to water shortages in these areas. A reduction in trees in the forest can reduce water stress in drought-sensitive regions (NSF 2018).

- **Improved air quality:** As a result of the subsequent decrease in severe wildfires, thinning projects have the potential to positively impact air quality (Westover 2021, Campbell 2022).

- **Carbon storage and sequestration:** Studies have shown that effective thinning treatments can increase carbon storage and sequestration (Collalti et al. 2018; Schaedel et al. 2016). Forest thinning can pose a carbon trade-off: while it does reduce carbon storage in the short term, in the long term it can allow for more carbon storage because of an increase in tree health and reduction in catastrophic wildfires (Folkard-Tapp et al. 2021).

**Social and Economic**

- **Property and infrastructure protection:** Thinning is often done within the wildland-urban interface (WUI), the area where people live within fire-adapted and fire-prone ecosystems. These thinning projects reduce the potential for catastrophic wildfires that could damage personal property and infrastructure (NPS 2017).

- **Jobs:** The USFS is increasing firefighter capacity funding by $259,180,000 moving into 2024, and these new employees will aid in thinning projects on USFS land (USFS 2023). DOI is planning to increase the firefighting workforce by 17,000 positions by the end of 2023 (DOI 2023). Many federal jobs are being added through the increase in fuel management projects.

- **Agriculture and timber yields:** Thinning is often done commercially, meaning the cut trees are sold for wood or other woody materials. This process can benefit future forest harvests and provide funding for agencies, organizations, or private landowners to perform thinning projects that offer various benefits (Hunter et al. 2007).

**Ecological**

- **Supports native plants:** Thinning treatments have been shown to increase tree growth (Hood et al. 2016) and lead to stronger and more resilient residual trees, which are more resistant to disturbances (Moreau et al. 2022). One of the main goals of thinning and fuel reduction projects is to bring the forest back to historical conditions (Hunter et al. 2007).
• **Invasive and nuisance species management:** Thinning can mitigate the impacts of insect damage within forests because of the reduction in stressed trees, to which pests are typically more attracted. Thinning can reduce the vulnerability of stressed trees by making it harder for insects to locate stressed trees, increasing moisture and sunlight entering through the canopy, and decreasing competition for the residual trees (Willis et al. 2022). Dwarf mistletoe and mountain pine beetle outbreaks are often treated with thinning projects (Hunter et al. 2007). Another study found that resin ducts increased after thinning projects in thinned ponderosa pine forests, which increased the trees’ resistance to the mountain pine beetle (Hood et al. 2016). USFS has found that thinning projects help to reduce the establishment of flammable invasive species such as nonnative cheatgrass (Westover 2021).

**BARRIERS AND SOLUTIONS FOR PRACTITIONERS**

**Common Barriers**

Several barriers are common across many of the nature-based solutions strategies; these are described in more detail in Section 1 of the Roadmap. Additional notes about the barriers specific to thinning are included here.

• **Expense:** Thinning project costs have an extensive price range dependent on the method, terrain, and equipment used. The cost of thinning ranges from $758 to $4,291 per hectare (~$307 to $1,737 per acre) for forests in the western United States (Chang et al. 2023).

• **Capacity:** Most federal agencies have limited resources to conduct thinning projects at large scales because of the staffing, funding, and time needed (Hunter et al. 2007). New federal legislation, such as the Bipartisan Infrastructure Law and Inflation Reduction Act, has provided increased funding to mitigate capacity and resource issues (DOI 2023).

• **Public opinion:** There are many conflicting reports on the efficacy of thinning, specifically targeting organizations that do commercial thinning projects for wildfire mitigation and therefore profit from the thinning project. Many environmental groups are adamantly against thinning practices. Both sides of the argument scientific research backing up their claims, so thinning is still considered a controversial practice (Thompson 2021).

• **Conflict with other land uses**

• **Regulation**

• **Lack of effectiveness data**

**Community**

• **Aesthetics:** The residual trees, piles, and other marks of a thinning project are often not well-received by the public, especially when they are in highly frequented areas (Hunter et al. 2007).
Ecological

- **Potential for increased fire activity:** Research has shown that if thinning is done at a low level, fire activity may increase as a result of the rise in wind speed when canopy moisture is low. Thinning at a higher level was shown to reduce fire severity, but fire spread might still be increased. It is essential to know what implications thinning may have on a specific site (Banerjee 2020). Increased fire severity may also be a threat if the fuel load left from the thinning project is not properly treated (i.e., removed or burned) (Hunter et al. 2007).

- **Susceptibility to ice storms:** Thinning projects in the southern United States have resulted in forests being more susceptible to damage and bending from ice storms because the residual trees are often weaker and have fewer neighboring trees that can support each other (Willis et al. 2022).

- **Wind damage to forests:** Thinning projects can increase a forest’s susceptibility to wind damage by opening up the stand, which takes away windbreaks and increases the space between trees. Trees typically become more wind resistant within 2 to 10 years after a thinning project is completed (Willis et al. 2022; Moreau et al. 2022).

- **Invasive species:** Invasive species frequently do well in disturbed environments, which thinning creates, so it is essential to be aware of the potential establishment of invasive species (Hunter et al. 2007).

- **Removal of habitat:** Some species prefer open stands, like various ungulates, while others prefer dense stands, like the spotted owl. It is also a common thinning practice to remove snags (standing dead trees) for human safety from both wildfires and fallen trees. Snags provide excellent habitats for many wildlife species. For these various reasons, it is vital to retain a variety of stand structures when implementing fuel treatment plans (Hunter et al. 2007).

- **Soil degradation:** Conducting a thinning project using heavy machinery can lead to soil compaction and displacement, which can affect the plants in the area. The buildup of slash, chips, and other woody material on the ground can also change the composition of the soil. Soil degradation can be avoided using hand crews or smaller, more maneuverable machines (Hunter et al. 2007).
### EXAMPLE PROJECTS

<table>
<thead>
<tr>
<th>Name and Link</th>
<th>Location</th>
<th>Leading Organizations</th>
<th>Techniques Used</th>
<th>Size</th>
<th>Cost</th>
<th>Duration</th>
<th>Project Description</th>
<th>Climate Threats Targeted</th>
<th>Lessons Learned or Adaptive Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest Fuel Treatment Efficacy in BC</td>
<td>British Columbia, Canada</td>
<td>BC Wildfire Service, Ministry of Forests, Lands, Natural Resource Operations and Rural Development</td>
<td>Fuel treatments, including thinning, debris removal, and ladder fuel reduction</td>
<td>2 to 22 hectares, dependent on the site</td>
<td>$1,800 to $3,800 per hectare</td>
<td>9 years (case study examining 10 fuel management treatments)</td>
<td>This case study looked at the different methods to reduce wildfire severity to see if previous treatments had an impact on wildfires that went through the treatment areas.</td>
<td>Catastrophic wildfires</td>
<td>Fuel treatments (thinning, debris removal, and ladder fuel reduction) were effective and feasible on large scales. Fuel treatments that left up to 25 tons/ hectare were still effective as long as the fuels were patchy.</td>
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<tr>
<td>Oakridge/ Westfir Thinning &amp; Fuel Reduction Project</td>
<td>Oregon</td>
<td>USFS; Hazeldell Rural Fire District; Oakridge, OR; Westfir, OR</td>
<td>Mechanical commercial and non-commercial thinning, prescribed fire, creation of fuel breaks</td>
<td>~4,200 acres</td>
<td>Not provided</td>
<td>Ongoing (began 2007)</td>
<td>This long-term project is designed to continually reduce wildfire risk to communities near the project sites.</td>
<td>Reduce long-term fire risk, habitat restoration</td>
<td>Not provided</td>
</tr>
<tr>
<td>Oregon Mountain Forest Health and Thinning Fuels Reduction</td>
<td>Weaverville, California</td>
<td>Bureau of Land Management</td>
<td>Upland and riparian zone thinning with emphasis on unhealthy trees, removing horizontal and vertical fuel continuity</td>
<td>139 acres</td>
<td>Not provided</td>
<td>2 years (total project time including archeological site assessment)</td>
<td>This project was designed to conduct thinning and post-thinning activities within the WUI. Specifically, the project focused on removing unhealthy trees and conifers encroaching on oak woodlands.</td>
<td>Wildfire and fuel management, wildlife protection</td>
<td>Not provided</td>
</tr>
<tr>
<td>Name and Link</td>
<td>Location</td>
<td>Leading Organizations</td>
<td>Techniques Used</td>
<td>Size</td>
<td>Cost</td>
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<td>Project Description</td>
<td>Climate Threats Targeted</td>
<td>Lessons Learned or Adaptive Management</td>
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<td>Saint Vrain Forest Health Partnership Project</td>
<td>Boulder, Colorado</td>
<td>St. Vrain Forest Health Partnership; The Watershed Center; Boulder County, CO; Longmont, CO; Boulder Valley and Longmont Conservation Districts; Colorado State Forest Service; USFS- Arapahoe, Roosevelt, Pawnee Boulder District</td>
<td>Hand thinning, mechanical thinning</td>
<td>Current project area: 380 acres (total project area: ~4,000 acres)</td>
<td>$3,477,770</td>
<td>Ongoing (began 2023 and runs through at least 2025)</td>
<td>This project aims to implement fuel reduction to provide infrastructure and human protection.</td>
<td>Reduce catastrophic wildfires</td>
<td>Not provided</td>
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<tr>
<td>North Cherokee Park</td>
<td>Larimer County, Colorado</td>
<td>Larimer Conservation District</td>
<td>Mechanical thinning, whole-tree harvest</td>
<td>625 acres</td>
<td>$1,560,000</td>
<td>Not provided</td>
<td>Multilandowner forest restoration project.</td>
<td>Reduce wildfire risk, restore forest health</td>
<td>Not provided</td>
</tr>
</tbody>
</table>

**Bolding** indicates DOI affiliates.
REFERENCES


Forest Habitats: 12. Thinning


This strategy is one section of a larger work, the Department of the Interior Nature-Based Solutions Roadmap, written in collaboration between the Nicholas Institute for Energy, Environment & Sustainability at Duke University and the US Department of the Interior. This section and the whole document is a work of the United States Government and is in the public domain (see 17 U.S.C. §105).

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