

FIRE TOOLBOX:

Reducing Wildfire Severity With Prescribed Fire and Thinning

MEET THE SCIENTISTS!



◀ EMILY BRODIE, Ecologist/Forest Monitoring Scientist

I really love field work and data collection. In particular, there are times when the place where you are or the thing that you are measuring just blows you away. I have felt this while installing **subalpine** monitoring plots just feet from glaciers in North Cascades National Park in Washington State and measuring 6-foot-wide pine trees at the Stanislaus Experimental Forest in California!

I also love when having an experience in the field or crunching numbers on the computer unlocks a theoretical concept—maybe one that you learned years ago but now finally understand. Building this kind of understanding over time is gratifying.



◀ ERIC KNAPP, Forest and Fire Ecologist

There are many favorite science experiences, including collecting data after the Antelope Fire that occurred in California in 2021. It was fascinating trying to reconstruct how the fire moved and to experience how quickly fire effects **moderated** once fire encountered an area that had been previously treated with thinning or prescribed fire.

Experiences with a drip torch in my hand helping with ignition on prescribed burns also come to mind. It is fun to observe fire behavior in different fuel types and when varying the ignition pattern. The glow of the forest from a prescribed burn at night is incredibly beautiful.



Caution: Prescribed fires or prescribed burns are controlled fires that are monitored and extinguished by professionals only.



◀ **STACY DRURY,** **Plant Ecologist**

I focus on plant and fire interactions. I am interested in how fire helps shape the vegetative landscape around us. I have had a long, successful career, so picking out a specific science experience is difficult. But a few things come to mind—like flying around in a helicopter to identify historic fires in Alaska or learning how tree seedlings get established after fires in Mexico or looking at patterns of vegetation change in the Amazon forests of Brazil. Every day outside is a good one.

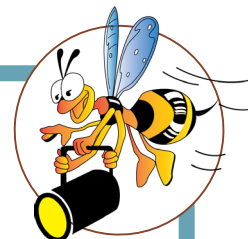
WHAT KINDS OF SCIENTISTS DID THIS RESEARCH?

ECOLOGIST: This scientist studies the relationship of living things with their living and nonliving environment.

FIRE ECOLOGIST: This scientist studies the relationship between fire and the environment that it affects.

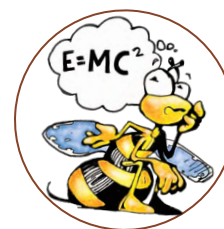
PLANT ECOLOGIST: This scientist studies the way plants interact with their environment or with other organisms, including other plants.

CAREER SPOTLIGHT



Did you know that there are many different types of ecologists? One of the ecologists in this study, Dr. Brodie, is also called a forest monitoring scientist. She studies and monitors different areas of the forest for changes. Dr. Brodie also works for a State science agency called California Department of Forest and Fire Protection (CalFire). As an ecologist, you can work in a variety of places such as private companies, nonprofit organizations, Federal agencies, and State governments.

Thinking About Science



Scientists work together to solve problems. They develop research studies to help them answer questions. Scientists often create experimental designs to help them answer those questions. With an experimental design, there is a structured process that uses an experiment to test a hypothesis.

In this study, the scientists had a unique opportunity to study wildfire using an experimental design. Due to the uncertain nature of wildfire, setting up an experimental design is difficult; it is hard to know with certainty where and when a wildfire will burn. Experiments with wildfire may also be difficult because of a lack of data on the condition of the forest before the fire.

However, the area that was burned by a wildfire in this study had been used for forest research for many years before the wildfire went through it. Therefore, there was a lot of data available about the land. This circumstance allowed the scientists to gather data for a large-scale wildfire forest management study.



Thinking About the Environment

Wildfires can be highly unpredictable. The fire behavior triangle is a way for people to think about how wildfires move and change, or basically how a wildfire behaves.

The fire behavior triangle helps people make predictions about what might happen during a wildfire. The three sides of the triangle are fuels, weather, and topography (**figure 1**).

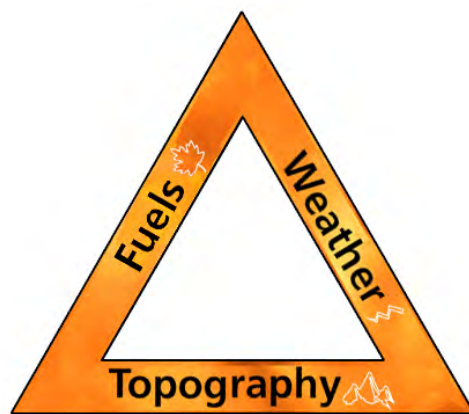


Figure 1. The fire behavior triangle shows how fuels, weather, and topography are important factors to consider when thinking about fire behavior.

- **Surface fuels**—all living and nonliving material near the ground that can be burned by a fire. Dead branches, leaves, twigs, and other debris that pile up on the forest floor, plus low shrubs, are all examples of **surface fuel** (**figure 2**). There is also fuel in the **canopy** of a tree.

The most important factor in the fuels category is moisture level. High moisture content slows the burning process. If fuel moisture is very low, the fuel is consumed more rapidly, which can lead to extreme fire behavior.

- **Weather**—the wind, temperature, and humidity. Wind is the most important factor of weather because it brings oxygen to the fire. Fires need oxygen, heat, and fuel to burn.

Another weather factor is temperature. Generally, fuels ignite faster with higher temperatures. Finally, humidity is also an important weather factor. Low humidity means drier fuels. Drier fuels catch fire more quickly.

- **Topography**—the shape of the land. Topography can help or hinder the spread of the fire. For example, a rocky area can act as a fuelbreak.

Elevation is another important component of topography. Higher elevations tend to be windier but colder. The slope of the topography is also useful to understand. For example, fire at the bottom of a steep slope may move more quickly. This quick movement is because the heat rising from fire at the bottom of the slope may preheat the area above the fire. Then the preheated area catches fire more quickly as the fire moves up the slope.



Figure 2. Forest Service personnel complete pile burns. Pile burns help reduce surface fuels. The firefighter uses a drip torch to start the prescribed fire.

Introduction

People take care of forests for a variety of reasons. One reason is to prevent severe wildfires that can hurt people and damage land and property. As you read in Thinking About the Environment, wildfire behavior is influenced by the fuels in a forest (both on the surface and in the tree canopy), weather, and topography. People can't really control the weather or topography of a forest, but they can manage the availability of fuels.

Forest thinning and prescribed fire are two forest treatment tools that are used to help reduce canopy fuels and **ladder fuels** in the forest. Canopy fuels are fuels in the top portion of the tree, otherwise known as the crown of the tree (**figure 3**). Ladder fuels are fuels, like grass, shrubs, and low

branches, that allow fire to climb from the ground to reach the tree crown.

Forest thinning means that trees are removed from the forest in a planned way (**figure 4**). Thinning prevents the overcrowding of trees. Overcrowded areas create stress on the trees, which can lead to unhealthy and diseased trees. Additionally, overcrowded areas provide more fuel for wildfire if it burns through that area.

Thinning generally removes smaller trees that can act as ladder fuels. Crown fires, in the tree canopy, move quickly when a forest is overcrowded because the crowns of the trees are closer together (**figure 5**).

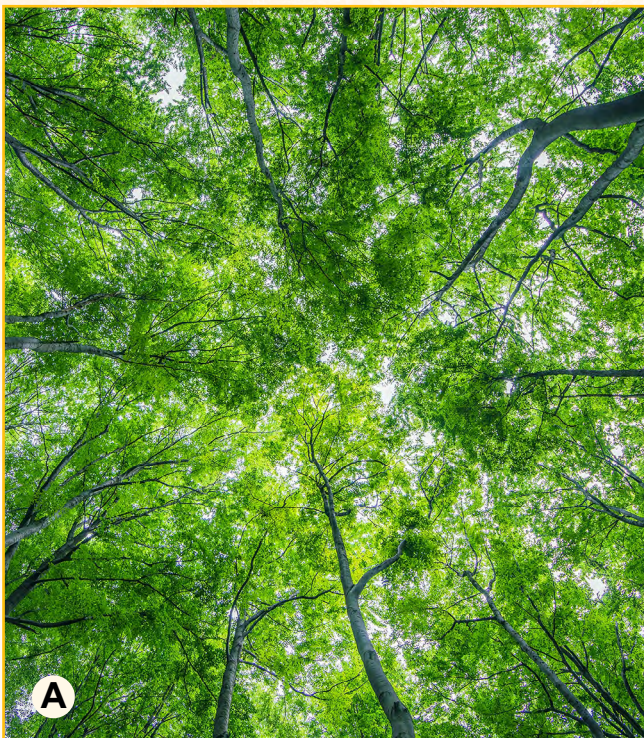


Figure 3A. A tree crown is the top portion of the tree with leaves and branches.



Figure 3B. Fire burns through trees and the tree crowns.



Figure 4. (A) This photo shows a forested area before thinning on Lolo National Forest in Montana. (B) This photo shows the same area but after thinning. What differences do you notice?



Figure 5. Look at these two illustrations. Would the forest shown in (A) or (B) be more likely to have a crown fire? Why?

Prescribed fire is a treatment that uses controlled fire. Controlled fire is fire that is set on purpose by trained professionals and monitored by them. Prescribed fire burns surface fuels such as dead and downed wood and twigs and branches that have fallen to the forest floor (**figure 6**). It also helps to control **understory** shrubs (**figure 7**).

Prescribed fire can also help create fuelbreaks. Fuelbreaks are areas in a forest that contain less trees and vegetation (**figure 8**). The lack of fuel in fuelbreaks means that the wildfire may be slowed down or have nowhere else to go. Prescribed fire helps to reduce overall fuel

in a forest and to maintain a healthy forest ecosystem.

In this research, scientists were interested in understanding the impacts of different forest treatments, like thinning and prescribed fire, on forest conditions. Because it would be dangerous to test their hypothesis by creating a wildfire, they collected data on forest treatments like thinning and prescribed fire. When a real wildfire burned unexpectedly through those study plots, the scientists were then able to study how different forest treatments affected the behavior and severity of wildfire.



Figure 6. Prescribed fires help burn forest fuels.



Figure 7. Understory shrubs are plants that are lower to the ground.



Figure 8. This fuelbreak on Hungry Horse Mountain in the Flathead National Forest can help stop a wildfire from spreading.



What are the two forest treatments described in the Introduction section and why are they important?

In the form of a question, describe what the scientists were interested in learning from this research.

Methods

The study took place on the Klamath National Forest in northern California in an area where long-term research was

already being conducted (**figure 9**). In the late 1990s, scientists began studies in this area to assess different forest

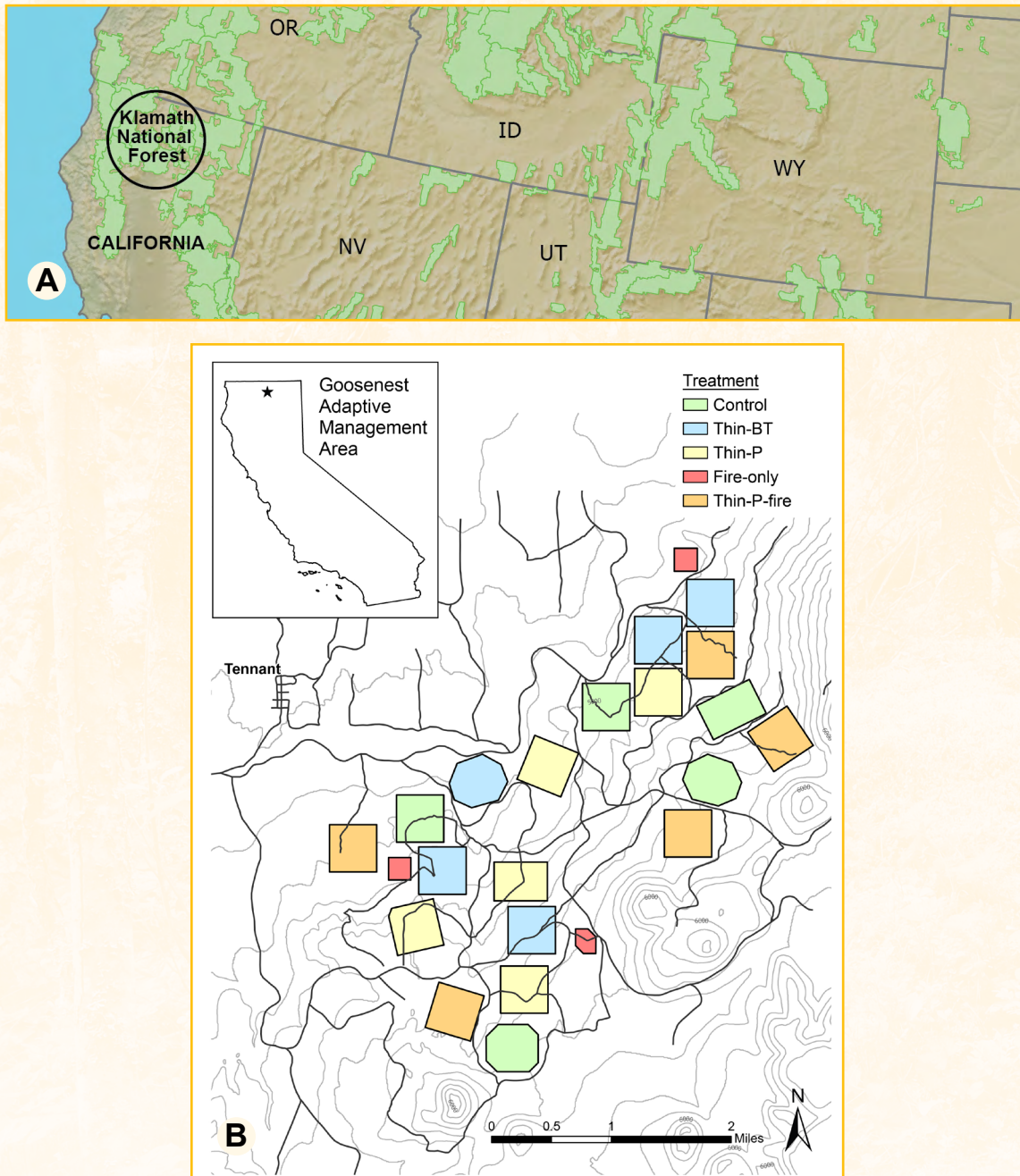


Figure 9. (A) California is located on the west coast of the United States. The Klamath National Forest is located in northern California. (B) The map shows the study locations in the Klamath National Forest. The dark black lines on the map show the roads in the area. The lighter gray lines are contour lines. Contour lines are used on topographic maps to show elevation.

treatment methods such as thinning and prescribed fire. The study area contained mostly ponderosa pine and white fir. The scientists visited the plots **periodically** to assess the effects of the treatments.

Over a century ago, long before these research plots were installed, forests in the study area were quite open. Studies of the tree rings show that in the past this area burned about every 11 years, which helped thin the forest and benefited ponderosa pine. Ponderosa pine is a species that is well adapted to frequent fire.

The forest was logged in the 1920s and many of the larger pines were cut. Larger trees can also be more resilient to fire. Wildfires, which occurred frequently before, were extinguished. Because of this management, smaller ponderosa pine and white fir trees grew back (**figure 10**). Smaller trees and white fir are more sensitive to fire. This combination of trees was far **denser** than the original forest.

The research area contained control plots that were not treated. Therefore, the control plots had more trees and greater tree canopy cover than the other treated



Figure 10. (A) Ponderosa pines can be seen in the photo on the left. (B) The photo on the right shows a white fir tree.

areas. Controls are important in scientific experiments because they provide a point of comparison. Controls allow a scientist to know that what is being observed is not just a random event. Scientists compared the different forest treatment plots with the control plots to determine the impact of the treatments.

The plots that were treated had four different treatments applied. They were:

- Thinning with an emphasis on keeping big trees (Thin-BT)
- Thinning with an emphasis on keeping pine trees (Thin-P)
- Prescribed fire only (Fire-only)
- Thinning with an emphasis on keeping pine trees plus the addition of prescribed fire (Thin-P-fire)

The scientists repeated each treatment in multiple plots (**table 1**).

In the summer of 2021, the Antelope Fire, which started with a lightning strike, burned through all the plots in the study area. The study area burned from August 4 through August 9 under a range of weather conditions.

Some of the study units burned while a Red Flag Warning was in place. A Red Flag Warning means that there are extreme conditions such as high wind, low humidity, and dry fuels that make conditions ideal for wildfires to start or for ones already burning to spread more quickly (**figure 11**).

The scientists realized that, although the research plots had been heavily damaged by the wildfire, there was another research opportunity available. The scientists could study how the wildfire affected the treatment areas in the research site. This information would provide valuable

Table 1. Plot names and treatment descriptions for the study in the Klamath National Forest

Plot name	Description	Number of times the treatment was repeated	Total number of plots
Control	No treatments since logging occurred in the 1920s	5	90
Thin-BT	Thinning only, with an emphasis on keeping big trees	5	91
Thin-P	Thinning only, with an emphasis on keeping pine trees	5	89
Fire-only	Prescribed fire occurred in fall 2002 and fall 2011	3	30
Thin-P-fire	Thinning with an emphasis on keeping pine trees and prescribed fire (prescribed fire occurred in fall 2001 and fall 2010)	5	91

data about how best to manage forests to survive wildfires.

After the Antelope Fire, the scientists inspected the trees from all the plots in the study area, collecting data on fire

damage—also known as fire severity. The severity ranged from mild to high.

The scientists gathered data on the amount of tree crown that was scorched or consumed by the wildfire and the

WHAT IS A RED FLAG WARNING?

A warning issued when **critical fire weather conditions** are happening or about to happen.

It does not necessarily mean there is a fire, but that conditions will be very dry and windy. If a fire is present, it can become extreme!

Avoid activities that could spark a wildfire!



Take Action!

- ✓ Make your wildfire plan, with at least 2 evacuation routes
- ✓ Maintain your go kit
- ✓ Follow fire prevention tips and regulations
- ✓ Listen to local officials for updates and evacuation orders

weather.gov



Figure 11. This is an example of a Red Flag Warning.

did you know?

Did you know that wildfires are often named for a geological feature that is close to the wildfire? For example, the 2021 Antelope Fire was named after Antelope Creek, an area close to where the fire started. Naming wildfires something simple is a way to quickly and easily identify a wildfire and streamline communication with the public regarding the fire.



height of charring on the bark (**figure 12**). Trees that had any green needles left on them were considered “live.” The scientists also collected the same data in the untreated control areas. The scientists

used all the data they gathered and information about forest treatments in the past to determine if the forest treatments influenced wildfire behavior and severity.



Figure 12. Scientists examine the burned area and record data.



The area that was burned by the Antelope Fire had also been a long-term research site before the fire. Why did that fact end up being useful for the scientists?

After reading about the Red Flag Warning, think about what you read about the fire behavior triangle (see Thinking About the Environment). Why does it make sense that a Red Flag Warning signals the potential for a more severe fire?

Findings

Before the wildfire, the control plots had five to seven times more trees per hectare than the thinned treatment areas. One hectare is about 2.5 times the size of an acre (and just slightly smaller than a soccer field). The treatment areas that included thinning contained 98–120 trees per hectare. After the wildfire, the

scientists found that all treatment areas experienced lower fire severity than the control.

The most noticeable decrease in fire severity was for treatment areas that had been both thinned and treated with prescribed fire (Thin-P-fire) (**figure 13**).



Figure 13. In this photo, the area to the left of the road is a control plot and the area on the right of the road had treatments applied. What do you notice about how the wildfire affected the two areas?

Number Crunch

Based on the scientists' calculations, what is the approximate highest number of trees that might be in 1 hectare of the control plot?



The scientists found some interesting results depending on the condition of the treatment area before the wildfire. Within a treatment area, fire severity increased if the plots had a dense canopy and a large amount of surface fuel (**figure 14**).

Plots with a less dense canopy and/or less surface fuel had lower fire severity.

Additionally, the scientists found that larger trees were less likely to die in the wildfire and had less of their crown affected or killed by the fire.



Figure 14. Scientists discuss what happened at the burn site.



The severity of the fire increased in areas with a dense canopy and a lot of surface fuel. Why do you think this might have been the case?

What is one finding you thought was interesting or surprising? Why?

Discussion

This research is the first large-scale study with treatment areas for thinning and prescribed fire that burned almost entirely during a wildfire. The scientists found the treatments helped with fire behavior, fire severity, and tree **mortality** even though it had been 20 years since thinning and 10 years since a prescribed fire for some of the plots. Moreover, all treatment areas did better than the control plots.

The results held true even when fire weather conditions were the most extreme, like during the Red Flag Warning,

indicating that thinning and prescribed fire are useful ways to help **mitigate** fire behavior and severity. Additionally, the findings suggest an advantage to retaining the larger trees when thinning, as the larger trees showed more **resilience** to the fire.

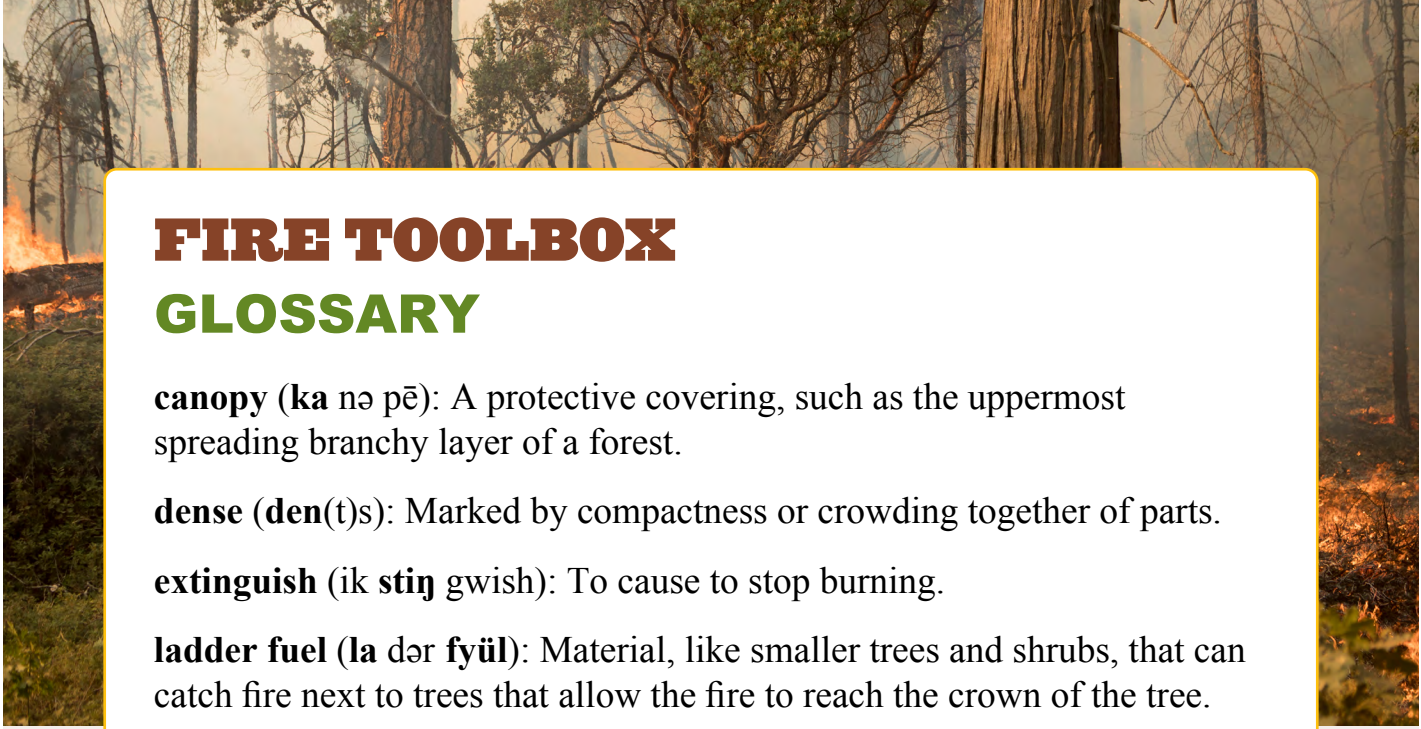
These results can help land managers and people who work in forest management and with wildfires to understand how thinning and prescribed fire may impact wildfire behavior and reduce wildfire severity.



Imagine that you manage a large area of forested land. Describe one way you would try to reduce the impact of wildfire on your forest.

Why do you think it is important to understand ways to manage a forest so that wildfires are not as severe?

Adapted from: Brodie, Emily G.; Knapp, Eric E.; Brooks, Wesley R.; Drury, Stacy A.; Ritchie, Martin W. 2024. Forest thinning and prescribed burning treatments reduce wildfire severity and buffer the impacts of severe fire weather. *Fire Ecology*. 20(1): 11770. <https://doi.org/10.1186/s42408-023-00241-z>.



FIRE TOOLBOX

GLOSSARY

canopy (ka nə pē): A protective covering, such as the uppermost spreading branchy layer of a forest.

dense (den(t)s): Marked by compactness or crowding together of parts.

extinguish (ik stiŋ gwish): To cause to stop burning.

ladder fuel (la dər fyül): Material, like smaller trees and shrubs, that can catch fire next to trees that allow the fire to reach the crown of the tree.

mitigate (mi tə gāt): To make (something) less severe, painful, or intense.

moderate (mä də rāt): To lessen the intensity or extremeness of.

mortality (mòr ta lə tē): The number of deaths in a population during a given time or place.

periodically (pir ē ä di k(ə-) lē): At regular intervals of time; from time to time.

resilience (ri zil yən(t)s): The ability to recover from or adjust to misfortune or change.

subalpine (səb al pīn): Of, relating to, or inhabiting high upland slopes and especially the zone below the timberline.

surface fuel (sər fəs fyül): Material found on or near the forest floor that can catch fire, such as twigs, branches, leaves, and low shrubs.

understory (ən dər stòr ē): The plant layer, especially the trees and shrubs, between the forest canopy and the ground cover.

Accented syllables are in **bold**. Definitions are based on those from <https://www.merriam-webster.com/>. Definitions are limited to the word's meaning in the article.

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