A Land Manager's Guide for Creating Fire-Resistant Forests

Stephen Fitzgerald and Max Bennett

Photo by Stephen Fitzgerald © Oregon State University

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Wildfires are a natural disturbance in Pacific Northwest forests. Historically, fire operated differently in various forest types (Figure 1, page 2) across the West. For example, fires were frequent but less severe in ponderosa pine and dry, mixed-conifer forests. In higher, cooler-elevation forests, fires were less frequent but more severe; many were 'stand-replacing' fires because most or all overstory trees were killed.

Over the last century and a half, forests have changed dramatically from their pre-settlement condition. This is particularly true in the drier forests of the West, where decades of fire exclusion have resulted in a buildup of fuel that has increased the size and intensity of wildfires. Climate change may also be a factor in this trend toward "mega-fires."

The emphasis today in forest management, particularly on federal lands and in wildland-urban interface areas, is on forest restoration and fuels reduction. Land managers can affect the total amount, composition (fuel sizes), and arrangement of fuels, and can thus influence the intensity and severity of a wildfire. This influence is more effective or pronounced when larger areas are treated.

This publication provides an overview of how various silvicultural treatments affect fuel and fire behavior, and how to create fire-resistant forests. In properly treated, fire-resistant forests, fire intensity is reduced

Silviculture is the art and science of manipulating forests to meet landowner objectives. It includes treatments such as thinning, pruning, underburning, and a wide variety of other practices.

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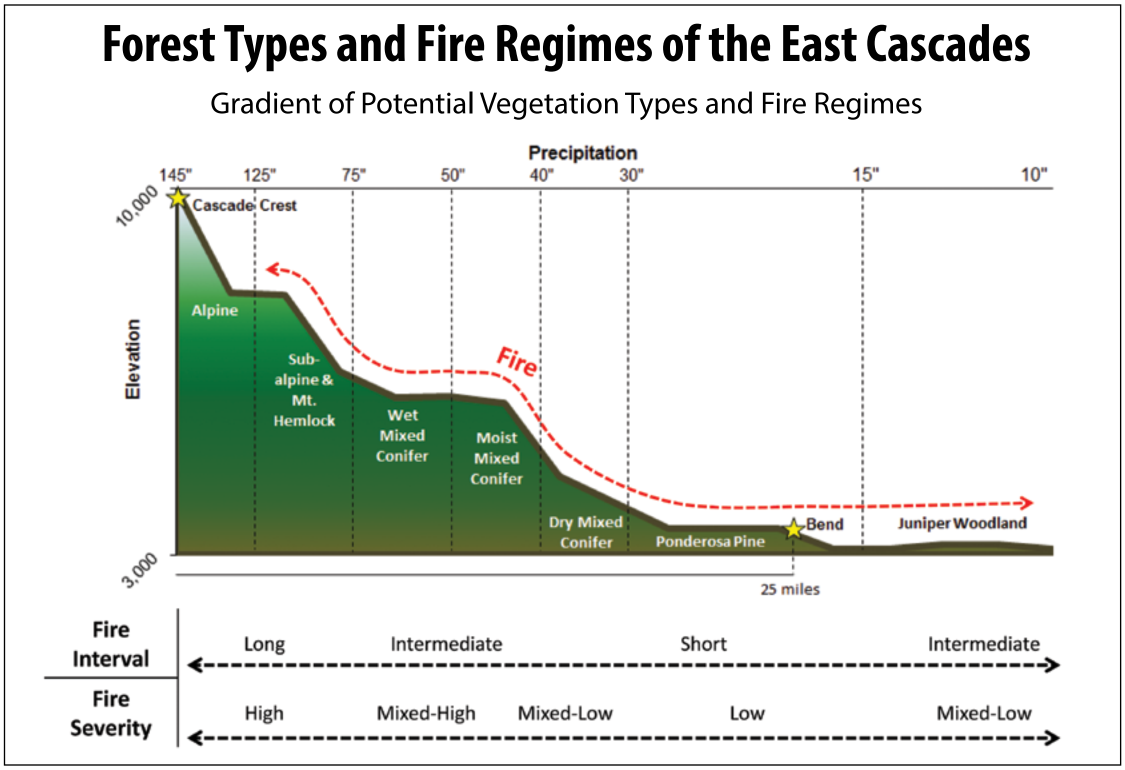

The Nature Conservancy

Figure 1

and overstory trees are more likely to survive than in untreated forests. Fire-resistant forests are not "fireproof" – under the right conditions, any forest will burn. Much of what we present here is pertinent to the drier forests of the Pacific Northwest, which have become extremely dense and fire prone.

Fire Behavior 101

The fire triangle

Three elements are needed to sustain a fire: heat or an ignition source, fuel, and oxygen (Figure 2). Take any one of these elements away and the fire doesn't start or goes out. For example, digging a fire line down to mineral soil, which is noncombustible, removes combustible material on the forest floor (surface fuel) and stops a forest fire's progress if the fire line encircles the fire.

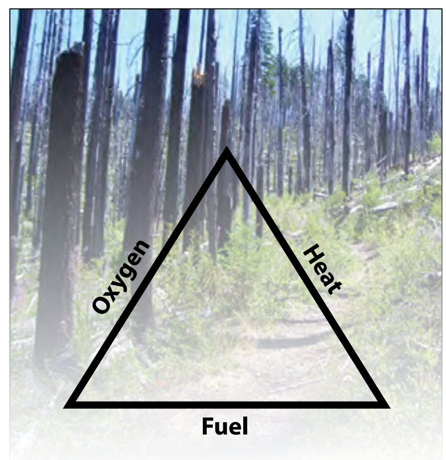

Photo by Stephen Fitzgerald, © OSU

Figure 2

The fire behavior triangle

Fire "behavior" is primarily described by its rate of spread (in feet per hour) and its intensity (i.e., how hot it burns and how long its flame is). Once a fire ignites in forest or rangeland vegetation, its behavior depends on the three factors that comprise the fire behavior triangle: the amount and arrangement of fuel, the area's topography, and weather conditions (Figure 3). A change in any one factor during a fire alters its behavior and type (i.e., whether it's a ground, surface, or crown fire). For example, if the weather becomes hot, dry and windy, the fire will burn with more intensity and move faster across the landscape. If a fire is burning in heavy fuels and then moves into an area with light or discontinuous fuels, fire intensity and spread decrease.

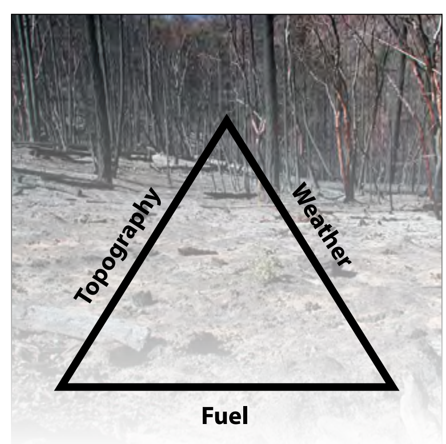

Photo by Stephen Fitzgerald, © OSU

Figure 3

Other important aspects of fire:

- Torching. Movement of a surface fire up into a tree crown; the precursor to crowning
- Crowning. Active fire movement through tree canopies
- Fire whirl. Result of an upward spinning column of air that carries flames, smoke, and embers aloft; whirls often form in heavy fuels on the lee (downwind) side of ridges and, in extreme conditions, can be powerful enough to twist off entire trees.
- Spotting. When firebrands (glowing embers) are lofted up and ahead of the main fire front, igniting multiple spot fires that then feed back into the main fire front to create very extreme and dangerous fire conditions.

Photo by Bureau of Land Management

Types of fires

A wildfire may be composed of three different types of fire: ground, surface, and crown. The proportion of each type determines the overall severity of the fire and how much vegetation the wildfire will consume or kill.

Ground fires

Ground fires consume mostly the duff layer and produce few visible flames (Figure 4). Ground fires also can burn out stumps and follow and burn decaying roots and decayed logs in the soil. A fire burning in tree roots often goes undetected except when it follows a root near the soil surface. Then, it can emerge, ignite surface fuels, and become a surface fire. Ground fires can often smolder for days and weeks, producing little smoke.

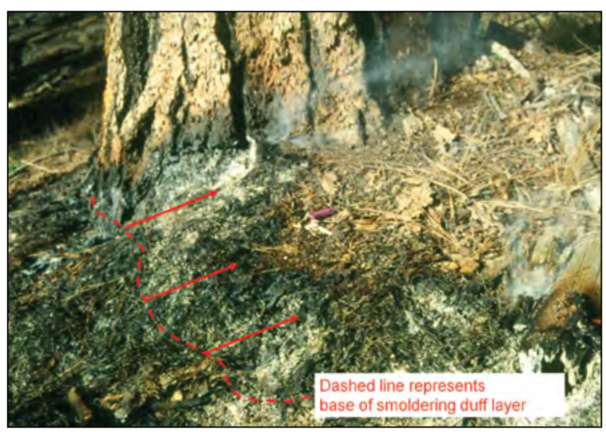

Photo by Stephen Fitzgerald, © OSU

Figure 4

Slash piles containing too much soil can allow a ground fire to smolder for weeks or months (called a “hold-over” fire), then re-emerge later and ignite surface fuels, causing a wildfire.

To prevent this, a skilled tractor operator should use a brush blade to create clean slash piles, or use a hydraulic excavator to stack and pile slash without adding soil to the pile.

Photo by BLM

Surface fires

Surface fires produce flaming fronts that consume needles, moss, lichen, herbaceous vegetation, shrubs, small trees, and saplings (Figure 5). Surface fires can ignite large woody debris and decomposing duff, which can then burn (glowing combustion) long after surface flames have moved past. Surface fire severity can be low to high.

High-severity surface fires can kill most trees (up to or more than 75 percent) as a result of crown and bole scorch, but can be highly variable, leaving scattered individual trees and patches of green trees. Surface fires with flame lengths less than 4 feet can be controlled by ground crews. Surface fires can develop into crown fires if "ladder fuels" connect surface fuels to crown fuels, fuel moisture is low, or weather conditions favor torching and crowning.

Photo by Teresa Brennan, USGS

Figure 5. Surface fires consume needles, moss, lichen, herbaceous vegetation, shrubs, small trees, and saplings.

Wildlandfire.com

Figure 7. Active crown fires are intense and stand-replacing blazes influenced by wind, topography, and crown density.

Crown fires

Crown fires are either passive or active. Passive crown fires involve the torching of individual trees or groups of trees (Figure 6). Torching is the precursor to an active crown fire. Crown fires become active when enough heat is released from combined crown and surface fuels to preheat and combust fuels above the surface, followed by active crown fire spread from tree crown to tree crown though a canopy (Figure 7). Crown fires are usually intense and stand-replacing, and are strongly influenced by wind, topography, and tree (crown) density.

Photo by Scott Isaacson, National Park Service

Figure 6. Passive crown fires involve individual trees or groups of trees.

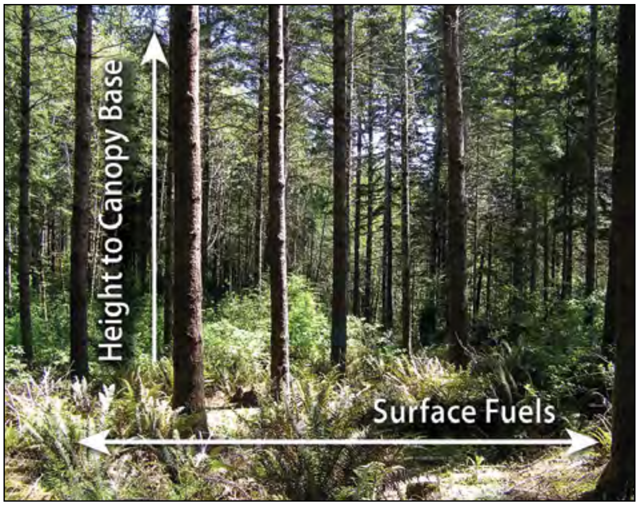

Photo by Stephen Fitzgerald © OSU

Figure 8. Surface fuels and height to canopy are two factors that affect the transition from a surface fire to a canopy fire.

Photo by BLM

Figure 9. Reducing surface fuelds and increasing the height to the crown base increase the odds larger proportions of a forest will survive a fire.

Four factors influence the transition from a surface fire to crown fire (Figure 8):

- Surface fuel and foliage moisture content
- Surface flame length (affected by fine surface fuel loading, wind, and slope)
- Height to the base of tree crowns (i.e., height of the canopy)
- Density of tree crowns (degree of overlapping of tree crowns)

The common denominator is fuel

We have little or no control over most factors in the fire and fire behavior triangles. For example, we can't control the wind, topography or oxygen, or stop every fire ignition. However, one element we can control is fuel. We can alter fire behavior by reducing the amount and changing the arrangement of fuel before a wildfire erupts. Recent examinations of large wildfires in the West show fire intensity and severity were usually significantly reduced when fuels had been reduced beforehand.

Principles of Fire-Resistant Forests

A fire-resistant forest has characteristics that make crown fires unlikely and allow the forest to survive surface fire without significant tree mortality in the main canopy.

We can lower fire risk and wildfire damage by removing or reducing fuels in strategic locations. Again, we can't truly "fireproof" a forest, but we can influence forest fuels so that fire acts and plays out in a more natural way and pattern, particularly in ponderosa pine and drier, mixed-conifer forests.

There are five principles of creating and maintaining fire-resistant forests:

- Reduce surface fuels
- Increase the height to the base of tree crowns
- Increase spacing between tree crowns
- Keep larger trees of more fire-resistant species
- Promote fire-resistant forests at the landscape level

By following these principles we can:

- Reduce the intensity of a fire, making it easier for firefighters to suppress
- Increase the odds that larger proportions of a forest will survive a fire (Figure 9). Small trees, shrubs, and other understory vegetation may be injured or killed, but larger trees in the stand will only be scorched, and soil damage also will be reduced
- Reduce extent of post-fire restoration activities needed, such as replanting.

Reduce surface fuels

Reducing surface fuels, such as slash and small shrubs, impairs potential flame length and fire intensity, making fires easier to control and less likely to reach into tree crowns. Reducing surface fuels means removing significant accumulations of flammable organic material, but not eliminating all organic material down to mineral soil. Specific fuels treatment methods are discussed in more detail on page 9.

Photo © Oregon State University

Ponderosa pine has an open crown, high moisture content in the foliage, and thick bud scales that help it survive fire.

Increase distance to base of tree crowns

When tree crowns ignite (torching), the stage is set for a crown fire. Removing ladder fuels, including surface fuels, and pruning the larger trees raises the base of the forest canopy so that a longer flame is needed to ignite the crowns. Pruning is particularly effective in young stands, when crowns may still be low to the ground. Prescribed underburning can also increase the height of the lower canopy due to scorching and killing of lower branches.

Increase spacing between tree crowns

When tree crowns are farther apart, it is harder for fire to spread from one crown to another, even when the wind is blowing. Thinning reduces crown density. Reducing the slash generated from thinning will diminish the potential for a high-intensity surface fire.

Keep large trees of more fire-resistant species

Fire kills trees by killing the cambium layer (a layer of cells just inside the tree bark that produces new wood and bark), scorching the foliage and killing the buds, and damaging and killing roots.

When thinning to improve fire resistance, leave larger trees with thicker bark that insulates the cambium. Although a fire may scorch the foliage above, the cambium is still protected. Also, large trees tend to have higher crowns, so their foliage and buds are less likely to be damaged by heat from a surface fire.

Ponderosa pine, western larch, and Douglas-fir tend to develop thick bark that insulates the cambium from heat, and their root systems are deeper and more protected. Ponderosa pine has other features that help it survive fire, including an open crown, high moisture content in the foliage, and thick bud scales. Western larch also is very fire-resistant. Lodgepole pine, the true firs, and hemlock have thin bark and shallow roots, and are more likely to be killed in a fire, even a light surface fire.

Hardwood trees are a significant component of many Pacific Northwest forests, particularly west of the Cascades. Some hardwoods, especially deciduous species such as bigleaf maple, red alder, and Oregon white oak, have higher moisture content and less volatile oils in their foliage than conifers; as a result, they burn at lower intensities. Evergreen hardwoods such as Pacific madrone, common in southwest Oregon,

Continued on page 9

Table 1. Fuels reduction options

This table shows the effect of different fuel-reduction methods when used as a stand-alone treatment.

Method	Surface fuels	Ladder fuels	Crown fuels	Contract cost ($/acre)	Notes
Thinning	Increase	Reduce	Reduce	Highly variable depending on slope and other terrain factors, stand density, tree size, equipment available, etc. Up to $800 per acre for smaller, noncommercial material but can yield money from larger commercial material.	Not a stand-alone treatment; requires post-operation slash abatement. Pre-commercial thinning to reduce ladder fuels can result in considerable surface fuel on the ground that must be abated. Commercial thinning can utilize most woody material for biomass or saw logs. The value can help offset the cost of treatment and slash abatement.
Pruning	Increase	Reduce	Little to no effect	$50-$250 per acre depending on height and number of trees pruned	Usually done in conjunction with thinning. As a stand-alone treatment (without removal of pruned material), may substantially increase surface fire intensity at base of tree.
Cut-and-scatter	Increase	Reduce	No effect	$25-$45	Use where fuel loads are light. May substantially increase surface fire intensity.
Prescribed underburning	Decrease	Decrease	Little to no effect	$50-$250	Often an initial mechanical treatment is needed to "step down" fuels to a point where safe burning is feasible; liability concerns make it risky for most private owners; smoke management required.
Cut, pile and burn	Small decrease	Reduce	No effect	$275-$1,500. Major cost is piling.	
Cut, chip-and-scatter	Redistribute	Decrease	No effect	$500-$1,500	
Mowing	Redistribute	Little to no effect	No effect	$40-$150	Only fine fuels
Slashbusting/ mastication	Increase/ redistribute	Decrease	Little to no effect	$250-$700	

have intermediate flammability. Other than Oregon white oak, most hardwoods are readily killed by fire due to their thin bark, but they will sprout back rapidly from stumps or root crowns with few exceptions.

Promote fire-resistant forests at the landscape level

The larger an area treated, the more effective fuels treatments will be at moderating fire behavior. This includes creating gaps and openings to further reduce the potential for crown fire. Treating in strategic locations can help break up both continuous horizontal and vertical layers of fuels. For example, reducing fuels adjacent to natural features, such as meadows and rock outcroppings, and manmade features, such as roads, helps firefighters connect firelines to these locations.

Fuel Reduction Methods

There are a variety of ways to reduce or treat surface, ladder, and crown fuels to create fire-resistant forests. Table 3 lists fuel-reduction methods, their costs, and the effects of each on surface, ladder, and crown rules. Since few methods are effective on all types of fuels, they are typically used in combination. For example, a stand may be thinned and pruned, and the resulting surface fuels piled and burned.

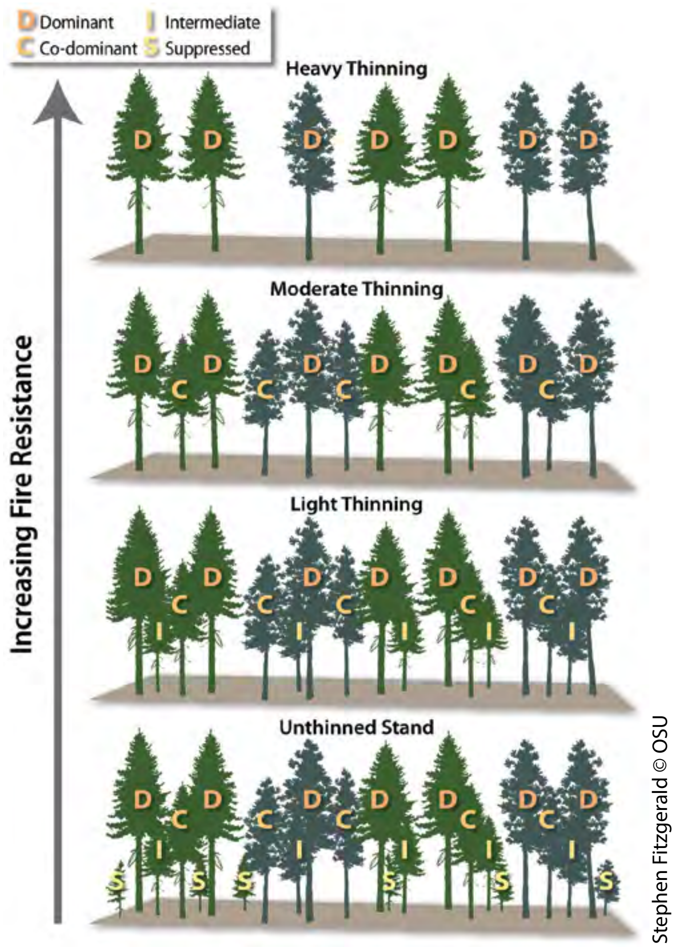

Figure 10

Thinning

Common questions about thinning include: Which trees should be selected? How far apart should trees be spaced? And, when should I thin (or not thin) during the year? Below, we address these questions only with respect to creating fire-resistant stands. Making decisions about thinning will involve a variety of other considerations.

Tree selection

Remove smaller trees and retain larger, more vigorous trees (Figure 10). This approach, called "thinning-from-below," removes ladder fuels, raises the base of tree crowns, and, if enough larger trees are removed, increases the spacing between tree crowns. Large trees are more fire-resistant due to thicker bark. This approach tends to shift species composition away from shade tolerant species that are often abundant in the understory.

Thinning from below is a common approach in even-aged stands. In cases where you want to maintain or promote a multi-aged forest (a forest containing three or more age classes of trees), a modified approach can be used. Trees can be thinned across the range of diameter or age classes so that stand density and ladder fuels are reduced while maintaining a multi-aged character. Compared to an even-aged stand, such a stand will have a higher risk of crown fire because some younger understory trees (ladder fuels) would remain.

Tree spacing

How far apart do crowns need to be to reduce crown fire? In general, if the branches of adjacent trees are overlapping within the stand, crown density is high enough to sustain crown fire under the right weather conditions. Conversely, if trees are widely spaced, say with crowns spaced more than one dominant tree crown width apart, crown fires are much less likely to occur. Factors that tend to increase the required crown spacing include steep slopes, locations with high winds, and the presence of species like grand fir with dense, compact foliage. Tree spacing does not have to be even. Small patches of trees can be left at tighter spacing, benefiting some wildlife.

Opening up the stand significantly will dry surface fuels due to increased light levels, surface winds and temperatures. This may increase surface fire intensity and rate of spread unless total surface fuel loading is reduced. In addition, thinning that allows significant light to reach the forest floor may result in the re-growth of small trees and shrubs, which over time become new ladder fuels. Other issues with very wide tree spacing include increased risk of blowdown, reduced future timber yields, and potential for triggering reforestation requirements. Consider these tradeoffs when making decisions about tree spacing.

Timing

Pay attention to timing when thinning in pine stands. Green slash larger than 3 inches in diameter generated from winter through mid-August can provide breeding material for pine engraver (Ips) bark beetles, which may emerge to attack healthy trees. Avoid thinning pine species during this time period or make sure slash is cleaned up quickly after. In some areas, there may be additional concerns with Douglas-fir beetles, fir engraver beetles, or spruce beetles breeding in larger diameter green slash or downed logs.

Pruning

Pruning can be combined with thinning or done as a stand-alone treatment. Pruning removes lower tree limbs, increasing the height of tree crown bases (Figure 11). A good height to shoot for from a fire-resistance standpoint is 10 to 12 feet, though pruning even higher is beneficial. The pruning slash should be disposed of through piling and burning, chipping, or, if fuel loads are light, cut and scatter. There are a wide variety of pruning tools, including hand-held saws, loppers, and pneumatic shears, power pruners, and ladders. You may also be able to use your chainsaw in some situations. To maintain tree health, pruning should leave at least a 50 percent live crown ratio (ratio of the length of the tree crown to the total height of the tree) and should not damage the tree bole. Pruning is particularly effective in young stands where tree crowns have not yet lifted (the gradual death and branch shedding of lower tree branches from shading) on their own.

Photo by Chris Schepf, University of Idaho

Figure 11. Pruning removes lower tree limbs, increasing the height of tree crown bases.

Prescribed Burning

Prescribed burning is the regulated use of fire to achieve specific forest and resource management objectives. It consists of two general categories: slash burning and prescribed underburning.

Slash burning reduces surface fuels after various silvicultural treatments and is usually done by (1) broadcast burning in larger units, usually clearcuts, or (2) piling and burning within stands. Prescribed underburning is the use of fire within the forest understory. The primary objective of underburning is often fuels reduction, but underburning is also used to achieve other objectives, such as pre-commercial thinning, nutrient release, wildlife habitat or forage improvement, and control of unwanted vegetation. Prescribed underburning has become more common as the understanding of the ecological role of fire has increased.

PRESCRIBED BURNING

Key points to consider:

- Prescribed burning, especially underburning, is risky with high potential liability.
- A professionally developed burn plan is a must, and professional contract burners are recommended.
- Contact your state fire control agency in advance to discuss your plans to burn and obtain necessary permits.

Photo by BLM

Prior to initiating any prescribed underburn, a landowner must develop a profession burn plan. Good planning helps meet pre-determined objectives and minimize the chance of an escaped burn. Key elements of a burn plan include:

- A clear description of the stand or vegetation to be enhanced by underburning and expected outcomes for that vegetation
- Data on fuel amount, distribution, and moisture content, as well as the topography and desirable weather conditions on a potential burn day
- Predictions of fire behavior (intensity and spread) based on the above factors
- Ignition patterns and arrangements for holding (maintaining the fire within the area)
- Timing and seasonality of the burn
- Smoke management guidelines

Burn plans should include a map of the unit to be burned, the various types of equipment and other resources needed to implement the project, needed permits, back-up contingency plans in the event of an "escape," medical and communications plans, public awareness and coordination with other agencies as needed, and post-burn plans for "mop-up" and monitoring. Often the area to be burned will need some type of fuel pre-treatment in order to meet objectives. This could include tree falling and brushing of unwanted vegetation in order to carry a fire, or raking or pulling slash away from trees you want to keep (called 'leave trees') to increase their likelihood of survival during the burn. Careful and constant monitoring of weather on the burn day, constant contact with a local weather service, or both is imperative; sudden changes in weather can rapidly change fire behavior, increasing the risk of escape.

Because of its complexities and the associated liability, prescribed underburning is rarely done on private, non-industrial woodlands because the cost of an escaped burn can be considerable, as it includes not only the cost of suppression, but also the cost of reimbursing any neighbors whose properties may be damaged. On federal lands, prescribed burning is conducted regularly. Federal agencies are much more willing to accept potential liability as they have the know-how, trained personnel, and the equipment to manage a prescribed burn.

Mechanical Fuels Reduction (Mastication)

Mechanical fuels treatments utilize several different types of equipment to chop, mow, or otherwise break apart (masticate) ladder fuels, such as brush and small trees, into relatively small chunks or chips, forming a compact layer of woody material that is distributed across the site.

Mechanical fuels reduction equipment includes "slashbusters," "brush mulchers," mowers, and other devices. The "slashbuster" is a vertically mounted rotating cutting head mounted on a tracked excavator. The "brush mulcher" consists of a horizontally mounted cutting drum attached to the front of an all-terrain vehicle (ATV)

Figure 12a and 12b. Mechanical "brush mulchers" masticate ladder fuels into small chunks or chips.

(Figures 12a and 12b). One attraction of mechanical treatments is their relatively low cost compared to hand treatments or chipping (Table 1, page 8). Drawbacks include potential for wounding leave trees if the operator is not careful or skilled, and soil compaction if operating when soils are very moist.

The material produced by these processes varies in size but is usually coarser than that produced by most chippers. It still forms a dense fuel bed, however. Compared to more loosely arranged natural fuels, moisture is retained longer and the available oxygen supply is lower, resulting in potentially slower rates of fire spread than would have occurred if the area were left untreated. However, the duration and severity of fire in masticated fuels may be higher than in other types of fuels treatments.

Utilization and slash disposal

During thinning, trees are felled, limbed, and bucked into logs of various lengths. These logs can often be utilized rather than left in the woods. Small logs can be sold as saw logs, posts and poles, as well as for firewood and other materials for home use. Product sales may help offset the treatment costs, and thinning of larger-diameter logs may even generate a profit. When markets are available, utilization of biomass also may help offset costs.

Once you have utilized all the material that is practically and economically possible, the next step is to treat the remaining slash. There are three primary slash disposal methods: cut and scatter, pile and burn, and chipping. It's critical to consult your state forestry agency in advance to determine if the proposed slash disposal method will result in acceptable slash levels.

Cut and scatter

Cut and scatter is most appropriate for stands with light fuel loads or in areas that are a low priority from a wildfire management perspective. Understory trees, branches, brush, and other fuels are simply cut, sectioned into smaller pieces, scattered across the site, and left to decompose. This technique does not eliminate fuels — it just redistributes them. Cut and scatter temporarily increases the total amount of surface fuel, and creates a continuous layer of fuels across the ground.

Although ladder fuels may be reduced, overall fire hazard may be increased initially. As the material decays over time, or is burned, the fire hazard declines. A common problem in dry forests is that the slash may take a decade or more to decompose to the point where it no longer poses a significant fire hazard. In higher elevation areas with a winter snowpack, or in higher precipitation zones, decomposition proceeds more rapidly.

Regardless of the climate, getting the material into contact with the ground will speed decomposition. Ideally, cut and scatter the material to a depth of 18 inches or less. Do not use this method of slash disposal within your home's defensible space (30 to 100 feet around your home). Use in low-density stands where existing surface fuels and ladder fuels are light, where decomposition will proceed rapidly, and where a potential short-term increase in fire hazard is acceptable. Also, consider slash levels in adjacent stands. A common practice is to use cut and scatter in areas with light slash loads and use hand piling in areas with heavier slash concentrations.

Photo by BLM

Figure 13. Examples of slash piles waiting to be burned. With pile burning, you have the option to cut, pile, and immediately burn ("swamper burning"), or cut, pile, cover, and burn later in the fall and winter months when the forest is moist and the pile is dry.

Pile and burn

Pile and burn is a common method for reducing surface fuels generated in thinning and pruning. (Figure 13).

Another option is to leave the slash over the winter to let some of the nutrients leach out, and then pile and burn later.

Guidelines for pile burning:

- Carefully evaluate locations of piles. Place at least 10 to 20 feet away from trees, stumps, brush, and logs, and 50 feet from streams. Stay well away from snags, structures, power lines, etc.
- Construct the piles so they will burn easily. Put small branches, twigs, and brush less than ½-inch diameter at the bottom of the pile to provide "kindling," then lay larger limbs and chunks of wood parallel to minimize air pockets. For hand piles, 4-by-4-foot piles are a good size; machine piles may be much larger.
- When machine piling, use a brush blade or excavator to avoid getting dirt in the pile. This helps prevent "holdover" fires that smolder for weeks, suddenly flaring up when winds and temperatures increase.
- Cover piles if they are not to be burned immediately. Cover when pile is about 80 percent complete, placing the remaining material to hold the cover in place. In Oregon, you must remove the cover prior to burning unless it is made of pure polyethylene plastic (not all plastic is pure polyethylene). Cover just enough of the pile to keep it dry in the center so it will burn easily.
- Burn when conditions are wet or rainy with little or no wind, and during daylight hours.
- Avoid piling green pine slash (more than 3 inches diameter) in the late winter through mid-August due to the risk of attracting pine beetles.
- Make sure you have a burn permit from the state forestry office, fire warden, or other local authority that regulates open burning.
- Some areas have a system utilizing 'good burn days' based on ventilation index. Make sure you are in compliance.
- Monitor the piles to make sure they are out.

Chipping

Chipping is effective but is also labor intensive and requires good access. It is probably best suited to homesites and defensible space treatments.

Many contractors, including arborists and tree service companies, have large chippers that can process relatively large-diameter material efficiently. Self-propelled, whole tree chippers have been developed and may be available for contract work in some areas. Be aware that large piles of chips are a fire hazard from spontaneous combustion. The chips can be scattered across the ground or, better yet, used as mulch for covering skid roads and trails.

Maintaining Your Investment

Fuels reduction is an ongoing process. The effects of thinning and other fuels treatments last 15 years or less. New trees and brush grow in the understory and develop into ladder fuels. When cut, many brush and hardwood tree species re-sprout vigorously from root crowns and rhizomes.

Other species, such as manzanita and several species of ceanothus, have seeds that remain viable in the soil for many years, even decades, and germinate readily when soils are disturbed.

Follow-up treatments will be needed, but they should be less expensive than the initial treatment. Do some fuel reduction on a portion of your property every year so the work is spread out and more manageable.

For More Information

OSU Extension publications listed below can be found at http://extension.oregonstate.edu/catalog/.

Bennett, M., and S. Fitzgerald. 2005. *Reducing Hazardous Fuels on Woodland Properties: Disposing of Woody Material*. EC 1574. Corvallis, OR: Oregon State University Extension Service.

Bennett, M., and S. Fitzgerald. 2005. *Reducing Hazardous Fuels on Woodland Properties: Mechanical Fuels Reduction*. EC 1575. Corvallis, OR: Oregon State University Extension Service.

Emmingham, W.H., and N.E. Elwood. 2002. *Thinning: an Important Timber Management Tool*. PNW 184. Corvallis, OR: Oregon State University Extension Service.

Holmberg, J., and M. Bennett. 2005. *Reducing Hazardous Fuels on Woodland Properties: Pruning*. EC 1576. Corvallis, OR: Oregon State University Extension Service.

Parker, B., and M. Bennett. 2005. *Reducing Hazardous Fuels on Woodland Properties: Thinning*. EC 1573-E. Corvallis, OR: Oregon State University Extension Service.

Additional resources

Fitzgerald, S. 2002. *Fire in Oregon's Forests: Risks, Effects, and Treatment Options. A synthesis of current issues and scientific literature*. Oregon Forest Resources Institute, Portland, OR.

Know Your Forest, Reducing Fire Hazard page. http://www.knowyourforest.org/learning-library/reducing-fire-hazard

Landowner Fire Liability. Oregon Department of Forestry. http://www.oregon.gov/odf/pubs/docs/landowner_fire_liability_reduced.pdf

Oregon Department of Forestry, general fire page. http://www.oregon.gov/ODF/Pages/fire/fire.aspx

Oregon State University Extension Service Emergency Resources, Wildfire in Oregon page. http://extension.oregonstate.edu/emergency-resources/wildfire

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The Northwest Fire Science Consortium is a multi-disciplinary, multi-institutional network consisting of federal and state agencies, non-governmental organizations, universities, and private landowners within Washington and Oregon. **www.firescience.org**