2. Principles of Fire-resistant Forests

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

- 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 more fire-resistant forests at the landscape level (i.e., your surrounding private and public neighbors) by reducing fuels both vertically and horizontally.

Following these principles accomplishes three goals:

1. Reduces the intensity of a fire, making it easier for firefighters to suppress.
2. Increases the odds that the forest will survive a fire (Figure 8). 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.
3. Reduces the extent of restoration activities needed, such as replanting or erosion control measures.

Figure 8. Example of a fire-resistant forest, Squire Fire, 2002, near Jacksonville, Oregon. Note low flame lengths. About two years prior to the fire, the stand had been thinned and the slash piled and burned, giving it structural characteristics that helped it survive the wildfire: low levels of surface fuels, a large gap between the ground and the base of the live crown, and large, thick-barked, widely spaced trees.

Reduce surface fuels

The reason for reducing surface fuels such as slash and small shrubs is to reduce potential flame lengths, making fire easier to control and less likely to reach into tree crowns. "Reducing" does not mean removing all organic material down to mineral soil; instead, reduce significant accumulations of surface fuel. Specific treatment methods for various fuels are discussed in more detail in the following section.

Increase distance to base of tree crowns

Increasing the distance from the lower surface fuels up to the base of tree crowns means a longer flame is needed to ignite the 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. Pruning is particularly effective in young stands, where crowns may still be low to the ground.

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. It's important, however, to reduce the slash generated from thinning, to reduce 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 buds and roots.

When thinning to improve fire resistance, strive to leave the larger trees. Large trees have thicker bark, which insulates the cambium. Although a fire may scorch the foliage, the cambium is protected. Also, large trees tend to have higher crowns, so their foliage and buds are less likely to be damaged.

Species selection is important. Ponderosa pine, western larch, and Douglas-fir all tend to develop thick bark that insulates the cambium from heat, and their root systems are deeper and thus 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. Species such as lodgepole pine, the true firs, and hemlock have thin bark and shallow roots, and so are more likely to be killed in a fire, even a 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 contents than conifers; as a result, they burn at lower intensities. Evergreen hardwoods such as Pacific madrone, common in southwest Oregon, have intermediate flammability. Most hardwoods are readily killed by fire due to their thin bark, but with a few exceptions they will sprout back rapidly from stumps or root crowns.

Promote fire resistance at the landscape level

The four principles described in the preceding section aim to increase fire resistance in your forestland in part by creating vertical gaps in the ***fuel profile*** (that is, between the ground and the tree canopy).

Resistance to crown fire can also be promoted across a forest landscape by creating or enhancing horizontal gaps in fuels across your property and neighboring properties.

Examples include the following:

- Installing a shaded fuel-break in a strategic location such as a ridgetop or next to a road.
- Maintaining an area of relatively light fuels, such as an oak woodland, by removing encroaching brush and conifers.
- Thinning more heavily next to a natural feature such as a meadow or rock outcroppings.

Each tactic breaks up a continuous layer of fuels, which helps firefighters get a toehold when fighting a fire. To some extent, these actions emulate the historic role of fire in creating and maintaining a "mosaic" of vegetation, with reduced fuels in both horizontal and vertical directions, which results in a less wildfire-prone landscape.

3. 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 fuels reduction methods, their costs, and the effects of each on surface, ladder, and crown fuels. Since few methods are effective on all types of fuels, they are typically used in combination. For example, a stand may be thinned, pruned, and the resulting surface fuels piled and burned. For more information about fuels reduction methods, refer to the "For More Information" section on page 28.

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? In this section, we address these questions only with respect to creating fire-resistant stands. Making decisions about thinning will involve a variety of other considerations. See the "For More Information" section for references on thinning in general.

Tree selection

Remove smaller trees and retain larger, more vigorous trees (Figure 9). This approach, called ***thinning from below***, removes ladder fuels, raises the base of tree crowns, and 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 have thin bark and are often abundant in the understory.

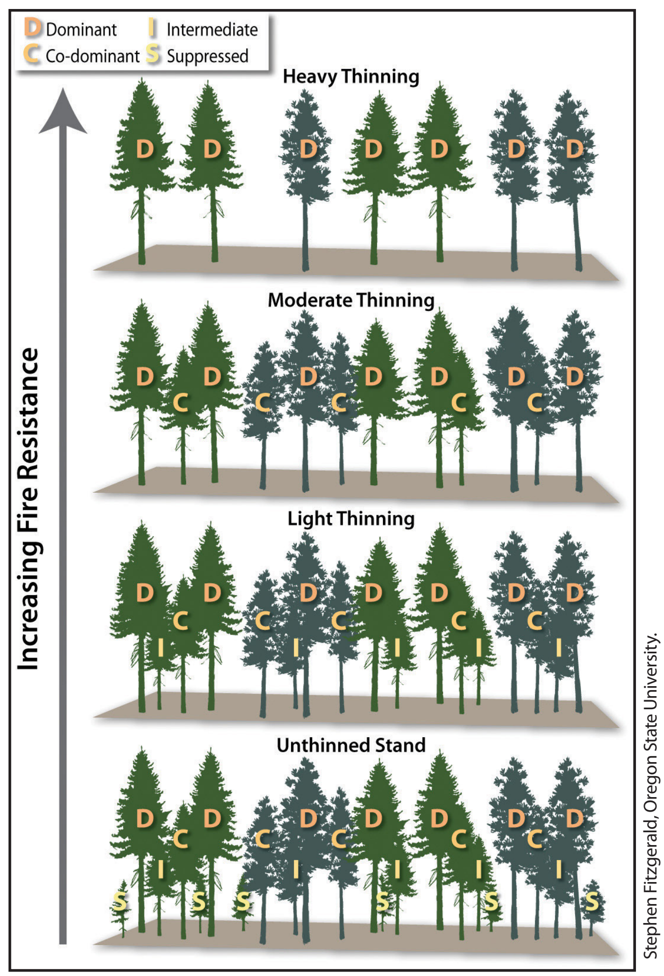

Figure 9. Thinning intensity diagram.

Thinning from below is a common approach in even-age stands. In cases where you want to maintain or promote an uneven-age forest (a forest containing three or more age classes), 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 an uneven-age character. Compared to an even-age 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 and terrain. 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 surface winds and temperatures. This may increase surface fire intensity and rate of spread, unless surface fuels are further reduced. In addition, thinning that allows significant light to reach the

Table 3. Effects, cost, and considerations of fuel-reduction methods when used as stand-alone treatments

Method	Effects on...			Cost per acre	Considerations
	Surface fuels	Ladder fuels	Crown fuels		
Thinning	Increase	Decrease	Decrease	\$100–\$800[1]	Requires slash abatement to be effective.
Pruning	Temp. increase	Decrease	No effect	\$50–\$250[2]	Best combined with thinning in young stands with low branches.
Prescribed under-burning	Decrease	Decrease	No effect	\$50–\$450	Initial mechanical treatment will facilitate safer burning; liabilities increase risk for private owners.
Cut and scatter	Increase	Decrease	No effect	\$50–\$450	Use where fuel loads are light. May substantially increase surface fire behavior in areas where slash is concentrated.
Cut, pile, and burn	Decrease	Decrease	No effect	\$275–\$1,500[3]	
Chip and scatter	Decrease	Decrease/ no effect	No effect	\$500–\$1,500	
Mowing	Decrease	Decrease/ no effect	No effect	\$40–\$150	Feasable only in fine fuels (e.g., bitterbrush)
Slash-busting/ mastication	Temp. increase	Decrease	Decrease/ no effect	\$250–\$700	
Utilization	Decrease	No effect	No effect	Offset costs or produce a small profit.	Labor intensive

[1] Depending on slope and other terrain factors, stand density, tree size, equipment, etc. [2] Depending on height and number of trees pruned.
[3] Major cost is piling.

forest floor may result in the re-growth of small trees and brush, which over time become new ladder fuels, so understory maintenance is needed from time to time. Other issues with very wide tree spacing include increased risk of blowdown, reduced timber yields, and potential for triggering reforestation requirements (if, for example, tree stocking is reduced below State stocking thresholds). These trade-offs should be considered in making decisions about tree spacing.

Timing

Pay attention to timing when thinning in pine stands. Green pine slash larger than three inches in diameter generated from winter through mid-July can provide breeding material for ips bark beetles, which may emerge to attack healthy trees. Avoid thinning pine species during this time period or make sure slash is rapidly cleaned up. 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.

Utilization

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 log utilization includes the sale of commercial products, such as sawlogs, posts, and poles, as well as production of firewood and other materials for home use. Sales of products may help offset the costs of treatment, and thinning of larger-diameter logs may even generate a profit. When markets are available, utilization of biomass also may help offset costs.

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 10). A good height to shoot for from a fire-resistance standpoint is 10 feet, though pruning even higher (12 to 15 feet) is beneficial. The pruning slash should be disposed of through piling and burning, chipping, or if surface fuel loads are light, cut-and-scatter. There are a wide variety of pruning tools, including hand-held saws, loppers, pneumatic shears, power pruners, and ladders. You may also be able to use your chainsaw in some situations. To maintain tree vigor, pruning should leave at least a 50 percent live crown ratio (the ratio of the length of the tree crown to the total height of the tree). Pruning is particularly effective in young stands where tree crowns have not yet lifted (gradual death and branch shedding of lower tree branches from shading) on their own.

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. The material varies in size but is usually coarser than that produced by most chippers. Compared to more loosely arranged fuels, the available oxygen supply in this dense fuel bed is reduced, resulting in potentially slower rates of fire spread than would have occurred if the area were left untreated. The intensity and ***duration*** of fire in masticated fuels may be higher than in other types of fuels treatments.

Mechanical fuels reduction equipment includes slash-busters, brush mulchers, mowers, and other devices. The slash-buster is a rotating cutting head mounted vertically on a tracked excavator. The brush mulcher consists of a cutting drum mounted horizontally to the front of an all-terrain vehicle (Figures 11a and b). One attraction of mechanical treatments is their relatively low cost compared to hand treatments or chipping (Table 3). Drawbacks include the potential for wounding trees if the operator is not careful or skilled, and soil compaction if operating when soils are very moist.

Slash disposal

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 or patchy 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 immediate area, 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 also creates a patchy layer of fuels across the ground. Although ladder fuels may be reduced, overall fire hazard may be temporarily increased. As the material decays over time, 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

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Figure 10. Pruning increases the height from the ground to the base of the tree crown. The slash should be treated.

Chris Schnepf, University of Idaho.

Max Bennett, Oregon State University.

Figures 11a and 11b. Mechanical fuels reduction.

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). Use in low-density stands where existing surface fuels and ladder fuels are light, where decomposition will proceed rapidly (i.e., western Oregon), 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, discussed below, in areas with heavier slash concentrations

Pile-and-burn

Pile-and-burn is a common method for reducing surface fuels generated in thinning and pruning. 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 (See "Guidelines for pile burning" on page 12).

Chipping

Chipping is effective but also labor intensive and requires good access. It is probably best suited to homesite 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. Large piles of chips are a fire hazard from spontaneous combustion, and can interfere with soil air and water movement. The chips can be scattered across the ground or, better yet, used as mulch for covering skid roads and trails. Avoid piling chips uniformly across the site. Instead, spread them in a mosaic so that some areas have no chips.

Prescribed Burning

Prescribed burning is the controlled 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 fuels after various silvicultural treatments and is usually done by (1) broadcast burning in larger units, usually

Key points: Prescribed burning

- Prescribed burning, especially underburning, is risky, with high potential liability!
- A professionally developed burn plan is a must.
- Contact your state fire control agency well in advance to discuss your plans to burn and obtain needed permits.

clear-cuts; or (2) piling and burning. Prescribed underburning is the use of fire in the forest understory. The primary objective of underburning is often fuels reduction, but it is also used to achieve other objectives such as thinning, wildlife habitat improvement, and control of unwanted vegetation. Prescribed underburning has become more common as the understanding of the ecological role of fire has increased.

Prior to initiating any prescribed underburn, a professionally developed burn plan is a must for an interested landowner. Good planning helps minimize the chance of an escaped burn. An important part of any burn plan is a prescription carefully designed to meet predetermined objectives. Key elements of prescriptions include the following:

- 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 burn day.
- Predictions of fire behavior and fire spread based on the above factors.
- Ignitions patterns and arrangements for holding (maintaining the fire within the desired area).
- Timing and seasonality of the burn.
- Smoke management guidelines.

The prescription is part of the larger burn plan, which 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, backup contingency plans in the event of an "escape," medical and communications plans, public awareness and coordination with other agencies as needed, and postburn plans for "mop-up" and monitoring. Often the area to be burned will need some type of pretreatment in order to meet objectives. This could include tree felling and brushing of unwanted vegetation (particularly on the perimeter) in order to carry a fire, or raking/pulling slash away from desired leave trees to increase their likelihood of survival during the burn. Careful and constant monitoring of weather on the burn day and/or constant contact with a local weather service 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, nonindustrial woodlands. 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. The risk of escape is higher with underburning than with piling and burning. The need to reduce liability exposure points to the importance of good planning and documentation, including the development of a burn plan.

Before conducting any burning, contact your state forestry agency to see what kind of notification or permits you will need. Your state forestry agency may also be a source for technical and logistical assistance, and occasionally may be able to assist in the implementation of a well-planned prescribed burn.

Maintaining your investment

Fuels reduction is an ongoing process. The effects of thinning and other fuels treatments are temporary (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 to maintain the desired effects, but they should be less expensive than the initial treatment. Fuels reduction re-treatment research in Idaho has demonstrated that machines, hand treatments, herbicides, and goats all achieved acceptable initial control of woody brush. (See "Fuels re-treatment options" on page 12.)

Guidelines for pile burning

Figure 12. Stand thinned and piled, ready for burning when weather conditions are right.

- Carefully evaluate locations of piles. Place at least 10 to 20 feet (depending on pile size and slope) away from trees, stumps, brush, and logs, and 50 feet from streams. Stay well away from snags (standing dead trees), structures, power lines, and so forth.
- Construct the piles so they will burn easily. Put small branches, twigs, and brush (less than one-half inch in 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, four feet by four feet is a good size; machine piles may be much larger.
- When machine piling, use a *brush blade* or excavator to avoid getting soil in the pile. This helps prevent "holdover" fires that smolder for weeks, suddenly flaring up when winds and temperatures increase.
- Cover piles if not immediately burned. Cover when pile is about 80 percent complete, placing remaining material on top to hold the cover in place. In Oregon, you must remove the cover prior to burning unless it is made of pure polyethelene plastic (not all plastic is pure polyethelene). Cover only enough of the pile to keep it dry in the center so it will burn easily.
- Burn when wet or rainy with little wind during daylight. Burning on warm and/or windy spring days is risky. Piles with soil and piles constructed by stumps may smolder for days or weeks, igniting a fire when temperatures warm up and the wind blows.
- Avoid piling green pine slash (more than three inches in diameter) in the late winter through mid-August due to the risk of attraction the pine engraver beetle (sometimes referred to as the ips beetle).
- Make sure you have a burn permit from the state forestry office, fire warden, and/or other local authority that regulates open burning.
- Some areas have a system to identify good burn days based on a ventilation index. Make sure you are in compliance.

Fuels re-treatment options—research results

Fuels reduction retreatment research in Idaho showed that, with some variation, machines, hand treatments, herbicides, and goats all achieved acceptable initial control of target vegetation, primarily woody brush species.

Herbicide application achieved the best control on target species, and was the only selective method (that is, non-target vegetation was not affected). After one growing season, goat grazing, the most expensive option, resulted in increased height and cover of the target species. Herbicides had the most lasting control over target species, but some less hazardous species increased in cover and height. In addition, herbicides left dead stems, some of them dense and tall enough to still constitute a fire hazard.

Machine-mechanical control was spotty because the machines missed some plants on irregular terrain and could not get as close to trees and other desired residual vegetation. Hand-mechanical control using a variety of tools was very effective initially. After the next growing season, it became evident that all alternatives caused some shift in vegetation composition, especially an increase in grass species and a temporary decline in shrub dominance.

Several operational and environmental factors not under the control of this experiment may have affected the results. The goat retreatment would have been more effective if there were two entries. That is, the goats could be grazed in early summer and again in late summer to have a greater impact on nutrient stores and re-sprouting vigor in the shrubs. Or, if the animals had been left on site longer and forced to eat the stems, perhaps the treatment would have been more effective.

Herbicides had the most consistent control of target shrub species while avoiding collateral damage of nontarget shrubs. The herbicide retreatment also was the least costly method.

Although the hand-mechanical retreatment was very effective at controlling target shrubs, it was the most expensive of the treatment alternatives. Without killing the individual shrubs, there will be re-sprouting from remaining stems, rhizomes, and root crowns in the goat, hand-mechanical, and machine-mechanical retreatments. A combination of herbicide and machine-mechanical would reduce the fuel hazard and prevent resprouting. The retreatment cost would be cheaper than hand-mechanical retreatment alone and should have long-lasting, effective results.