

1. Fire Behavior Basics

When designing treatments to reduce fuel and fire risk, develop roads, and develop water sources to aid wildfire suppression, it's essential to know:

- Where potential ignitions may come from.
- How the amount and arrangement of fuel affects fire (the “fire triangle”).
- How weather and topography interact with fuel to affect *fire behavior* (the “fire behavior triangle”).

Sources of ignition

Wildfires are ignited by either lightning or humans. Most ignitions on private forestland are from human activity, primarily debris burning, equipment fires, and arson (see Table 2). Although lightning set fewer fires in 2004–2008, those consumed more than three times the acreage of human-caused fires in the same period.

Identify the likely ignition sources around your property. For example:

- Do thunderstorms tend to produce lightning strikes in your area?
- Is a housing subdivision below your property?
- Is a railroad nearby, where trains could produce sparks?
- Do power lines run through or near your property?
- Does a road border your property, from which a driver might discard a cigarette and ignite roadside vegetation?
- Do you allow hunters and others to use your property?

All of these factors can increase the chance of an ignition. Some you have control over, others you don't. In either case, preventive action can reduce risk.

The fire triangle

To sustain a fire, three elements are needed: heat or an ignition source, fuel, and oxygen (Figure 1). Take any one of these elements away and the fire goes out (or doesn't start). For example, creating a fire line down to mineral soil, which is noncombustible, removes combustible material on the forest floor (*surface fuel*) and stops a fire's progress if the fire line encircles the fire.

The fire behavior triangle

Fire behavior means its rate of spread (in feet/hour) and its intensity (that is, how hot it burns and how long its flame is). Once a fire ignites in forest or rangeland, its behavior depends on the three factors that make up



Marty Main, Small Woodland Services.

The Epsteins own property with high wildfire risk in southwestern Oregon. To learn more about their story, see their case history on page 20.

the fire behavior triangle: the amount and arrangement of fuel, the topography, and weather conditions (Figure 2). A change in any one factor during the fire alters its behavior and type (whether it's a ground, surface, or crown fire). See Appendix B for details on the influence of topography, weather, and fuels on fire behavior.

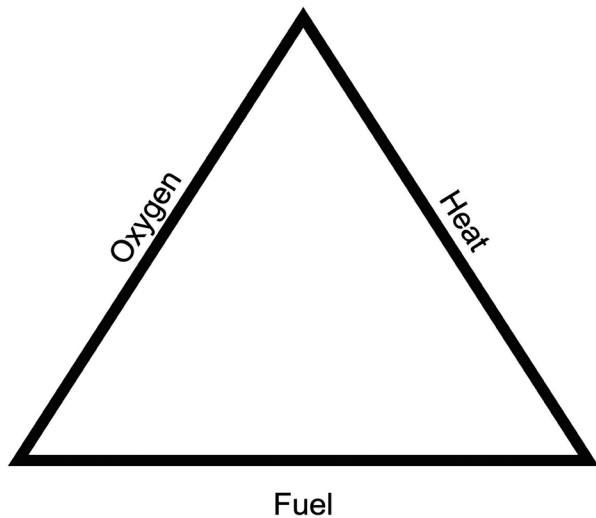
Other aspects of fire behavior

Other important aspects of fire behavior are as follows:

- Torching—movement of a surface fire up into tree crowns; the precursor to crowning.
- Crowning—active fire movement through the tree canopy.
- 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.

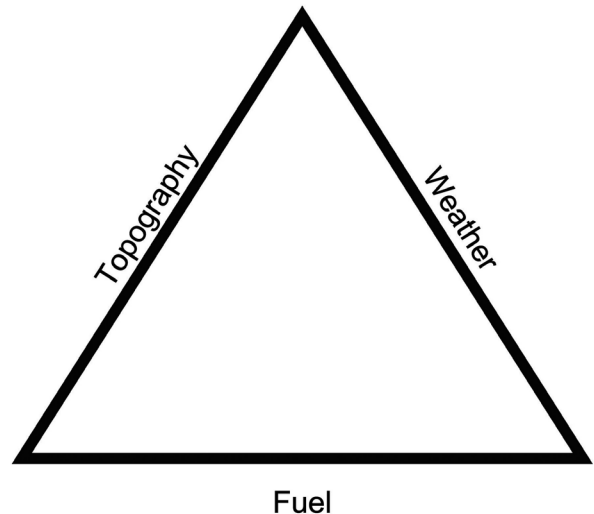
Types of fires

A wildfire may be composed of three different types of fire: ground, surface, and crown. The relative proportion of each type can provide clues to the overall severity of a particular wildfire.



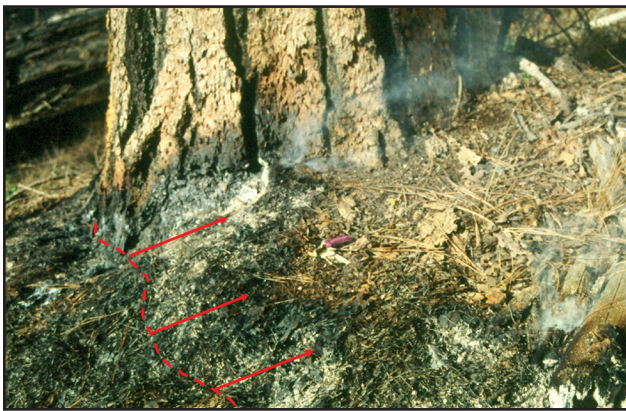
Stephen Fitzgerald, Oregon State University.

Figure 1. The fire triangle.



Stephen Fitzgerald, Oregon State University.

Figure 2. The fire behavior triangle.



Stephen Fitzgerald, Oregon State University.

Figure 3. Ground fire. Dashed line represents base of smoldering duff layer.



Teresa Brennan, United States Geological Survey.

Figure 4. Surface fire.

Ground fires

Ground fires consume mostly the duff layer and don't produce visible flames (Figure 3). Ground fires can also 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. In such cases, it can emerge, ignite surface fuels, and become a surface fire. Ground fires can often smolder for days or weeks, producing little smoke.

Slash piles containing too much soil can allow a ground fire to smolder for weeks or months (called a hold-over fire), only to re-emerge later to ignite surface fuels. To prevent this, a skilled tractor operator should use a **brush blade** to create clean slash piles or use hydraulic excavators to stack and pile slash without adding soil to the pile.

Surface fires

Surface fires produce flaming fronts that consume needles, moss, lichen, herbaceous vegetation, shrubs, small trees, and saplings (Figure 4). Surface fires can ignite large woody debris and decomposing duff, which can burn (glowing combustion) long after surface flames have moved past. Surface fire severity can be low to high. High-severity surface fires kill most trees (more than 70 percent). Surface fires with flame lengths less than four 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.



Scott Isaacson, National Park Service.

Figure 5. Torching.

Crown fires

Crown fires are either passive or active. Passive crown fires involve the torching of individual trees or groups of trees (Figure 5). Torching is the precursor to an active crown fire. Crown fires become active when enough heat is released to preheat and combust fuel above the surface, followed by active spreading of fires from one tree crown to the next through the canopy (Figure 6). Crown fires are usually intense and are strongly influenced by wind, topography, and tree (crown) density.

Four factors influence the transition from a surface fire to a crown fire (Figure 7):

- Foliage moisture content.
- Surface flame length.
- Height to the base of tree crowns (i.e., lower height of the canopy).



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Figure 6. Active crown fire.



Stephen Fitzgerald, Oregon State University.

Figure 7. Factors affecting the transition from surface to crown fire.

- Density of tree crowns (degree of overlapping of tree crowns).

The common denominator is fuel

We have little or no control over most factors governing the type of fire and fire behavior triangle. For example, we can't control the wind, topography, or oxygen, nor can we prevent every fire ignition. One element we can control is fuel. Reducing the amount of fuel and changing its arrangement before a wildfire erupts can affect fire behavior. Recent examinations of wildfires in the West show that where fuels have been reduced beforehand, fire intensity and severity are usually reduced. Thus, removing or reducing fuels in strategic locations on your property can lower fire risk and help make your property more resistant to wildfire.

Table 2. Number, cause, and extent of wildfires on private lands in Oregon, Washington, and Idaho, 2004–2008.

State	Human ¹		Lightning	
	No. of fires	Acreage	No. of Fires	Acreage
Oregon	3,905	24,071	1,519	67,124
Washington	2,692	4,009	595	15,770
Idaho	783	16,067	778	76,629
Total	7,380	44,147	2,892	159,523

¹ Includes wildfires caused by railroad, equipment, recreational use, smoking, debris burning, arson, juvenile, miscellaneous, and undetermined. Source: Oregon Department of Forestry, Washington Department of Natural Resources, and the Idaho Department of Lands.