

Appendix B. The Effects of Topography, Weather, and Fuel on Fire Behavior

Fire behavior—its spread and intensity—is affected by topography, weather, and fuel (Figure 2). Fuel is the only factor that you can change, but let's take a closer look at how all three of these factors interact.

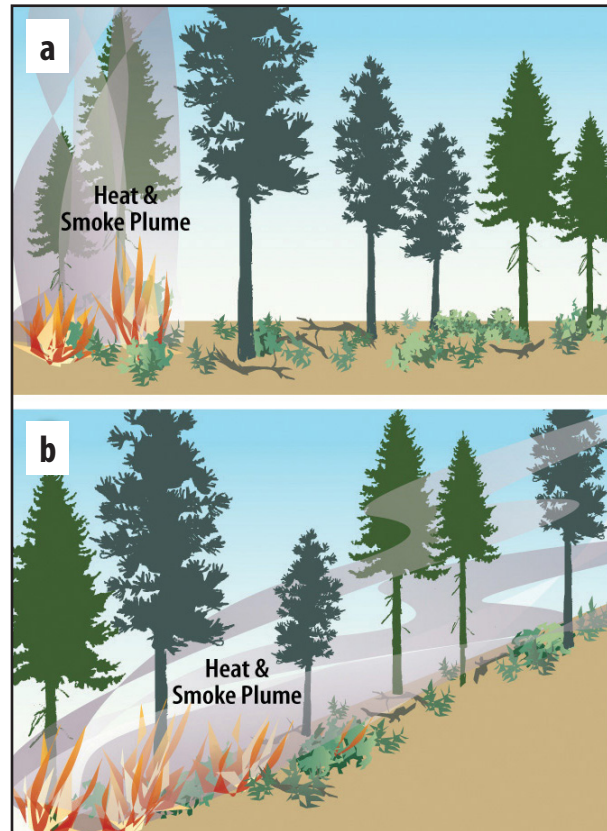
Topography

Topography is the most stable variable in the fire behavior triangle. Slope, aspect, elevation, and topographic features influence fire spread (how fast a fire moves in feet per hour). For example, fires tend to spread faster up a slope than down one. As heat rises in front of the fire, it more effectively preheats and dries upslope fuels, making for more rapid combustion (Figures 33a and 33b).

Aspect (direction of the slope) affects how much solar radiation a site receives and also the vegetation type. South- and west-facing slopes tend to have less vegetation and lighter fuel loads, particularly in lower-elevation forests. South slopes receive much higher solar radiation and are warmer, so fuels tend to dry out sooner and more thoroughly during the fire season. In contrast, north slopes have more vegetation and hence heavier fuel loads. North slopes are cooler and more shaded, thus delaying the drying of fuels long into the fire season. Because of their higher fuel loading, however, heavily vegetated north slopes can experience more severe wildfire. In western Oregon and Washington, fuel loads can be heavy on both north and south slopes because of higher rainfall and forest productivity.

Elevation affects fire behavior by influencing the amount and timing of precipitation, as well as exposure to prevailing wind. Elevation also affects the seasonal drying of fuel. In lower elevations (where most private land is located), fuels tend to dry out earlier in the year because of higher temperatures and lower precipitation. The opposite is true for fuels at higher elevations. There is also a tendency for more lightning strikes and subsequent ignitions at higher elevations.

Landscape features like narrow and wide canyons, ridges, and saddles can dramatically affect fire behavior. These features can change prevailing wind patterns by funneling air, increasing wind speed, and thereby intensifying fire behavior. Fires on lateral ridges (those coming off a main ridge) can burn in any direction and be affected by wind moving up through canyons and saddles. Other features, including rock outcroppings, streams, rivers, lakes, and roads, act as fire barriers and can be used as anchor points for developing fuelbreaks. Firefighters can take advantage of these natural and man-made features in attacking and suppressing wildfires. By analyzing a topographic map of your property, you may



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Figures 33a and 33b. Fire spreads more rapidly uphill. As heat rises in front of the fire, it more effectively preheats and dries upslope fuels, making for more rapid spread.

identify topographic features that can be used to your advantage.

Weather

Weather influences how fast and to what degree fuels dry out during the fire season. Weather is the most variable factor in the fire behavior triangle, and it can change quickly.

Extended periods of low relative humidity and high winds can quickly dry fuels. Extended drought periods leave fuels with very low moisture content, often resulting in increased fire activity and intensity. Under a given set of wind conditions, the intensity and rate of spread of a fire can change on a daily basis due to fluctuations in temperature and relative humidity. For example, during the warmer part of the day, fires spread more rapidly and burn with greater intensity, often producing a large smoke column. Lower temperatures and higher relative humidity late in the afternoon and early evening, however, increase moisture in the fine fuels, reducing the rate of spread and fire intensity, and collapsing the smoke column. During the summer months in mountainous

terrain, wind often shifts daily, moving upslope during the afternoon when most heating occurs and downslope during the evening when the land has cooled.

Some wildfires are wind-driven, meaning that wind is pushing the fire rapidly in one direction (often with high intensity), resulting in a cigar-shaped fire with a long, narrow fire front. A subsequent change in wind direction can create a very long fire front that is difficult to control. In contrast, a change in weather from hot and dry to cooler, moister conditions reduces fire intensity and rate of spread. Often firefighters have to wait for a change to cooler weather with higher relative humidity before they can safely attack a wildfire head-on.

Fuel

Fuel is the third leg of the fire behavior triangle, and the only leg that landowners can influence.

Fuels consist of dead woody material (needles, fallen branches, dried herbaceous vegetation, snags, and logs) or live trees and other vegetation, like shrubs. Fuels can be grouped in the following manner:

- Ground fuels: duff (decomposed needles and other organic material), buried punky (rotten) roots and logs, and accumulations of decomposing bark at the base of trees.
- Surface fuels: litter or undecomposed needles; moss; lichens; rotten and sound logs; woody debris and slash piles; stumps; low vegetation like grass, herbs, and small shrubs.
- Ladder fuels: large shrubs; small and medium-size trees; low-growing branches on medium to large trees that allow a surface fire to move up into the overstory tree crowns.
- Crown fuels: lichen, tree needles, and small branches that compose the forest canopy; and snags.

The amount of fuel—known as fuel loading and expressed in tons per acre—and its vertical and horizontal arrangement affect fire intensity and the ability of surface flames to begin torching tree crowns or support active crown fire. The size and the moisture and chemical content of fuels also influence combustion and fire behavior. Figures 34a, 34b, and 34c show low, medium, and high surface fuel loadings. These photos do not quantify fuels above the surface, however.

Fuels are also classified according to their size and their ability to gain or lose moisture (see Table 8). The designation of 1-, 10-, and 100-hour fuel categories indicates the time required for fuels of different sizes to dry or to absorb moisture depending weather (relative humidity) and moisture within the forest floor over the spring, summer, and fall fire season. Assuming they are dry enough to ignite, 1- and 10-hour fuels are largely responsible for supporting ignition and initial fire spread due to their small size (or, more specifically, their high surface area to volume), which

allows them to be easily preheated and combusted. The 100- and 1,000-hour fuels can support a self-perpetuating surface fire, but only when combustion of the smaller fuel sizes preheats and ignites them. Slash left after logging is composed of these smaller fuel sizes, and thus represent a high fire hazard. Larger 10,000-hour fuels typically don't influence fire spread much, but can affect what firefighters call **resistance to control** and fire severity, because once ignited (after the flaming front has passed), these larger fuels can burn for hours or days, heating the soil or, if adjacent to trees, killing tree roots and trees directly. Moreover, because large fuels can harbor smoldering fires for long periods, mop-up is more difficult and expensive.



Figures 34a, 34b, and 34c. (a) Low, (b) medium, and (c) high surface fuel loadings.

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The chemical content of fuels affects heat output and fire intensity. Some native shrubs such as bitterbrush, ceanothus, and manzanita contain volatile oils in their branches and leaves and have higher heat content and burn with higher intensity. Because shrubs also have many small branches and twigs, they readily combust when ignited and can produce long flame lengths.

Table 8. Fuel categories (size) and their contribution to fire behavior.

Fuel category	Diameter (in.)	Description	Impact on fire behavior
1-hour	0.00–0.25	Needles, twigs, moss, lichens, small shrubs and grasses	Easily ignited. Supports initial fire spread and the heating and combustion of larger fuels. Under dry conditions, these fuels are flashy and surface fires spread quickly.
10-hour	0.25–1.00	Small branches, shrubs	Supports fire spread and the heating and combustion of larger fuels. Under very dry conditions fires spread quickly.
100-hour	1.00–3.00	Medium-size branches	Supports fire spread and the heating and combustion of larger fuels.
1,000-hour	3.00–8.00	Large branches, small logs	Supports fire spread. Increases fire duration and influences fire severity, depending on loading.
10,000-hour	> 8.00	Large downed logs that are solid or moderately decayed	Ignites after flaming front has passed. Large fuel pieces do not support fire spread, but can increase fire duration and severity near the log. If fuel loading is high and distributed across the site (such as from beetle-killed trees), high fire severity can be more widespread and increase resistance to control and the duration of burning.
Snags	Variable	Bole only or bole with large branches, depending on snag condition	When snags combust, they can torch, lofting embers and firebrands ahead of the main fire, starting additional spot fires. Snags may increase resistance to control.