# Fire in the Wildland-Urban Interface: Understanding Fire Behavior[1]

Cotton K. Randall[2]

## Introduction

Wildland fires pose a serious threat to human life and property when homes are built in fire-prone ecosystems (See fact sheet *Fire in the Wildland-Urban Interface: Considering Fire in Florida's Ecosystems*). Several factors influence the intensity of wildfires and their potential to damage or destroy structures. Developing a basic understanding of the factors that determine wildfire movement and intensity (collectively called fire behavior) will allow homeowners and builders to assess fire hazard on their property and determine what they can do to minimize their risk. Research has shown that the most important factors influencing building survival during a wildfire are fire intensity, vegetation characteristics, and building materials (especially roofing). Strategies for protecting homes from wildfires have been developed with these factors in mind. This extension fact sheet examines factors that affect fire behavior, strategies to reduce fire risk, and examples of risk reduction.

## How Do Wildfires Move? The Concept of Heat Transfer

An important aspect of fire behavior is the manner in which it moves. Fire requires the presence of oxygen, fuel, and heat. Oxygen is abundant from the atmosphere, and therefore it generally does not limit wildfire movement. Plants are the primary fuels during wildfires, and their arrangement greatly influences the transfer of heat. Three basic mechanisms of heat transfer are *convection, radiation, and conduction*.

- **Convection:** The transfer of heat by the movement of a gas or liquid is called *convection*. Because hot air rises, heat transfer through convection tends to move upward. During wildfires, burning materials on the forest floor create convection currents that preheat the leaves and branches of shrubs and trees above the fire. The vertical air currents can also lift burning materials. The floating embers, also called **firebrands**, can settle in unburned areas ahead of the fire and start small fires. This phenomenon is called spotting and can result in rapid advancement of the fire. Firebrands can also ignite homes directly if they land on flammable roofing or accumulations of leaves or needles in gutters or on roofs.

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2. Cotton K. Randall is the Wildland-Urban Interface Fire Project Coordinator, School of Forest Resources & Conservation, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 32611.

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- **Radiation:** Burning objects release energy in the form of heat. You feel radiant heat when you stand near burning logs in a fireplace. In general, the size of the burning object determines the amount of radiant heat released, with larger fuels burning hotter. In most cases, radiant heat from a wildfire will not ignite materials on homes at distances greater than 30 feet from the house. During prescribed fires in the wildland-urban interface, fire professionals carefully monitor the amount of radiant heat being released from the flaming fire front (Figure 1). Prescribed fires are set intentionally and strictly controlled to meet land management objectives.

- **Conduction:** The last mechanism of heat transfer is from direct contact or *conduction*; an example is the heat that you feel when you touch a cup of hot water. Conduction carries heat through fuels, such as logs or house walls, and can raise their temperature to ignition points. Heat transfer through conduction can only occur within the same object or between objects that are touching.

With an understanding the fundamentals of heat transfer, one can see how the arrangement of plants can determine the movement of a wildfire. If flammable vegetation is abundant and continuous, all three mechanisms may interact to produce a rapidly advancing fire. Plants near the fire are dried, preheated, and even ignited through the effects of convection and radiation. Conduction preheats and dries larger fuels that are touching each other and may prolong the time those fuels burn by facilitating the internal transfer of heat.

## What Determines Fire Behavior?

Multiple factors interact to determine the behavior of wildland fires. Fire behavior refers to the intensity at which a fire burns and how it moves. General descriptions of wildfire behavior focus on where the fire occurs in the vegetation: underground, on the surface, and in tree crowns. Ground fires are fires that burn below the surface. In the South, muck

**Figure 1.** The vertical flames in this prescribed fire demonstrate the convective air currents carrying heat, smoke, and firebrands vertically into the sky. The smoke and firebrands can cause problems if they settle on roads or houses. In this picture, firefighters are standing between the fire and the house to detect the radiant heat being released and will hose the fire down if it gets too hot. Credits:

fires are a type of ground fire where dead plant materials burn and smolder below the surface in dry wetlands (Figure 2). During surface fires, fuels at or near ground level, such as grass, shrubs, and/or fallen leaves and branches, carry the fire (Figure 3). Crown fires burn through the tops of trees (Figure 4). In general, the relative intensity, or amount of heat released, of the different types of wildfire increases from ground to surface to crown fires. Firebrands may originate from surface fires or crown fires. Structural fires, or burning homes or buildings, are another type of fire that can produce firebrands. Three factors interact to determine fire behavior in wildland fires: *fuels, weather, and topography*.


**Figure 2.** A ground fire burned the peat in a baldcypress swamp and created the hole that contains standing water in this photo. Credits: Dale Wade, USDA Forest Service, www.forestryimages.org


**Figure 3.** This surface fire burns through understory shrubs during a prescribed burn in a southern pine forest. Credits: Dale Wade, USDA Forest Service, www.forestryimages.org


**Figure 4.** This high intensity crown fire exhibits long flames that are supported by and carried through the crowns of trees. Credits: Dave Powell, USDA Forest Service, www.forestryimages.org

**Fuels:** The primary fuels in wildland fires are living and dead vegetation. During extended periods of warm and dry conditions, all plants will burn if exposed to enough heat. However, plants differ in how readily they ignite and how hot or long they burn. Flammability depends on plant size, arrangement of branches and leaves, and chemical properties of leaves, branches and bark. Both the horizontal and vertical arrangement of vegetation influences fire behavior. The arrangement of vegetation across a tract of land is influenced by the frequency of past disturbance. Wildfire is a natural disturbance that reduces the amount of dead plant material and light fuels (see definition below) at a site. A common firefighting technique for slowing or stopping an advancing wildfire involves creating breaks in the fuels by clearing all vegetation from strategic locations. Fire professionals have a few key terms that they use to describe wildland fuels.

- **Light fuels** include grasses, shrubs, and tree leaves or needles. They are referred to as light and flashy fuels because they ignite easily and burn rapidly. Light fuels affect the rate of spread of an advancing fire. They are the primary fuels that carry fires and ignite homes in many wildfire situations.

- **Heavy fuels**, such as large tree branches, downed logs, and buildings, require more heat energy to ignite, but they burn longer and produce more heat once ignited.

- **Ladder fuels**, such as shrubs or small trees of intermediate height, act as ladders carrying the flames from the forest surface up into the tops of trees (Figure 5).

- **Fuel breaks** are areas lacking vegetation or other fuels that stop or impede the horizontal movement of an advancing fire. Fuel breaks can be natural, such as rivers or streams, or artificial, such as roads or plowed agricultural fields.

**Figure 5.** Ladder fuels are medium-sized shrubs or trees that connect fuels at the forest floor to the tree crowns. Credits:

**Weather:** Precipitation, humidity, wind, and temperature are important weather variables that influence fire behavior. Precipitation and humidity, which is influenced by air temperature, directly influence the flammability of forest fuels by affecting moisture content of living and dead leaves, branches, and grasses. Plant materials dry out quicker and ignite more easily during hot, dry weather. Windy conditions increase the rate of spread of fires and may increase fire intensity.

Fire fighting professionals have developed classification systems that incorporate current weather conditions into an index to rate fire risk, called a fire danger index. Many southern states post current fire danger indices on their Web sites during the wildfire season (see Appendix for links). The Keetch-Byram drought index is a commonly used drought index associated with wildland fire danger that provides an estimate of dryness in the soil.

**Topography:** Topography significantly affects fire behavior. Fires move faster uphill than downhill. Slope orientation also influences fire behavior. Forests on southern or southwestern slopes generally have lower humidity and higher temperatures than those on north or northeast slopes because of the path of the sun. Consequently, fire hazard is often higher on south and southwest facing hills.

Of the three factors affecting fire behavior, fuels are the easiest to manage by homeowners and land managers to lower fire hazard.

## Strategies to Reduce the Risk of High Intensity Fires

**Homeowners:** Homeowners in high fire hazard areas (see fact sheet *Fire in the WIldland-Urban Interface: Considering Fire in Florida's Ecosystems*) can reduce the risk of high intensity fires affecting their property. An important concept for homeowners living in hazardous areas is that of defensible space. Defensible space is defined as an area of modified vegetation between wildland fuels and homes that allows firefighters to protect the home or, in absence of firefighters, allows the home to better survive on its own. The most extensive modification of vegetation should occur within an area extending at least 30 feet outward from the house. Beyond this area, additional modification of wildland vegetation creates a larger buffer from an approaching wildfire and further decreases the risk of damage.

1. Create and maintain a defensible space by removing the lower branches up to 10 feet from the ground on large trees, separating beds of landscape plants, and removing flammable vegetation from within 30 feet from your house. Homeowners living on a steep slope (or hillside) should maintain a larger primary zone of defensible space by clearing flammable vegetation from an area extending up to 100 feet outward from the house. Consult your local forester or extension agent to determine the appropriate area of defensible space for your neighborhood.

2. Landscape your yard with fire-safe plants with the following characteristics: slow growth with little accumulation of dead vegetation, high moisture content and low concentrations of oils or other flammable chemicals in the leaves and branches, and open and loose branching pattern.

3. Maintain healthy landscape plants by watering periodically (as needed) and removing dead branches (pruning).

4. If natural areas exist on your lot, reduce the intensity of an approaching fire by removing highly flammable shrubs/trees (contact your local forestry agency for information on plants with high fire hazard), reducing overall tree density by removing small trees (called thinning), and reducing the continuity of ladder fuels. This area can serve as a buffer between unaltered natural areas and a modified area of defensible space.

**Land Managers:** Individuals who manage larger tracts of woodlands surrounding developed areas can also reduce the risk of high intensity fires. This is particularly important if the lands have a high fire hazard, such as many southern pine forests. Fuel reduction on these lands should focus on, but not be restricted to, creating 30-foot wide buffers at the edges of the property next to residential or commercial developments. When prescribed fire is used to manage these buffers, a zone extending from 50 to 100 feet into the forest or natural area is usually burned.

Fuel reduction at the interface between natural lands and developments can reduce the intensity of the fires before they enter populated areas. Land managers have several options to reduce fuels: prescribed fire, mechanical reduction (using mowers or heavy equipment), herbicides, and grazing animals. Land managers need to check local ordinances for restrictions on the use of these treatments.

## Applying Fire Behavior Knowledge to Assess Fire Hazard

With a basic understanding of fire behavior, we can rapidly assess the relative fire hazard of different landscapes. Consider the following two examples:

Landscape A, a natural forest composed of mature pine trees and a dense understory of hardwood shrubs and small trees, is left unmanaged within 15 feet of a woodland home (Figure 6). Fire has been excluded from the forest for more than 10 years. Landscape B also includes a natural pine forest located adjacent to a housing development (Figure 7). However, the owner of the pine forest has implemented a fuel reduction program that involves the removal of all ladder fuels within a 100-foot buffer of the development and the use of prescribed fire every 3 to 5 years to reduce surface fuels, such as dead pine needles, downed branches, grasses, and shrubs. Notice the vertical and horizontal separation of fuels in Landscape B. In addition, the homeowner created a 30-foot area of defensible space.

**Figure 6.** Landscape A with an unmanaged surrounding forest and insufficient defensible space. Credits:

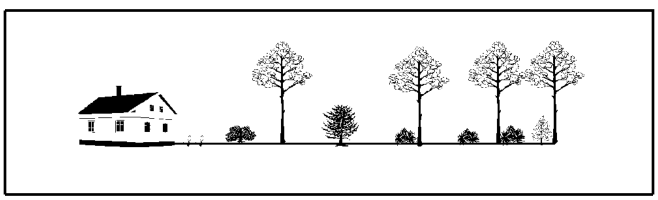

**Figure 7.** Landscape B with a managed pine forest and appropriate area of defensible space. Credits:

**Predicted Fire Behavior:** In Landscape A, the presence of ladder fuels could facilitate the development of a high intensity crown fire in the surrounding forest. Even without a crown fire, the fire could exhibit a rapid rate of spread through the understory and high radiation (hot temperatures). The potential for firebrands would also be great. Possible sources of ignition for the home would be: (1) firebrands landing on the roof or entering the vents, (2) radiant heat igniting blinds through the windows or raising the temperature of the houses exterior to the point of ignition, or (3) flames carried directly from the forest to the side of the house through burning fuels (shrubs, pine needles, dry grasses, or dead leaves).

In Landscape B, a low intensity surface fire could develop in the surrounding forest. With the absence of ladder fuels and a lower density of pine trees, the likelihood of a crown fire developing is significantly less than in Landscape A. If a crown fire should reach this forest, it may be reduced to a surface fire due the lack of sufficient understory fuels to sustain it. Assuming that only a surface fire develops in Landscape B, how do the same three potential home ignition sources fare? (1) The risk of ignition from firebrands would be lower than with Landscape A because there are fewer plants to produce firebrands. (2) The 30 feet of defensible space reduces the amount of radiant heat to which the house is exposed and consequently, reduces the preheating or ignition of interior items and exterior features of the house. (3) Finally, the defensible space reduces the chance of any flames reaching the exterior walls of the house.

## Conclusion

When wildfires occur near homes, homeowners often feel powerless to protect their property. An approaching fire may seem unpredictable and difficult for trained firefighters to control. However, with an understanding of the concepts of fire behavior outlined in this paper, you can anticipate the intensity and movement of a fire by considering several key conditions: fuel structure, local weather, and topography. Furthermore, by altering the conditions around your house, such as the arrangement of landscape vegetation, type of vegetation, and distance of vegetation from the house, you can influence the movement and intensity of fires, and consequently, improve the survivability of your home.

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## Other Fact Sheets in the Series "Fire in the Wildland-Urban Interface" (http://edis.ifas.ufl.edu):

Circular 1431: Fire in the Wildland-Urban Interface: Considering Fire in Florida's Ecosystems by Anna L. Behm and Mary L. Duryea

## Appendix

Fire Danger indices/maps on the Web:

Arkansas: http://www.forestry.state.ar.us/fd/bbmap_png.php3

Florida: http://flame.fl-dof.com/fire_weather/kbdi/

Georgia: http://weather.gfc.state.ga.us/

Kentucky: http://www.environment.ky.gov/nrepc/dnr/forestry/fireweatherinfo.asp

North Carolina: http://www.dfr.state.nc.us/weather_danger_links.htm

Oklahoma: http://agweather.mesonet.ou.edu/models/fire/default.html

South Carolina: http://water.dnr.state.sc.us/climate/sco/drought_info.html

Texas: http://www.tamu.edu/ticc/fire_risk_assessment.htm

Virginia: http://state.vipnet.org/dof/fire/csi-drought-index.htm

National map: http://www.fs.fed.us/land/wfas/fd_class.gif