Using Relative Humidity to Predict Spotfire Probability on Prescribed Burns

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Abstract: Spotfires have and always will be a problem that burn bosses and fire crews will have to contend with on prescribed burns. Weather factors (temperature, wind speed and relative humidity) are the main variables burn bosses can use to predict and monitor prescribed fire behavior. At the Oklahoma State University Research Range, prescribed burns are conducted during different seasons of the year and in different fuel types all over the state of Oklahoma. Since 1996 records have been kept to track spotfires that occur on these prescribed burns. Most of these spotfires were due to firebrands caused by crowning eastern redcedar (*Juniperus virginiana*). Leaves from oak (*Quercus* spp.) trees or tallgrasses floating or blowing across the fireline and smoke or fire whirls were responsible for most of the other spotfires. When burn data were reviewed, one weather variable stood out as the main cause of spotfires, low relative humidity. Of the 99 burns conducted there were 21 spotfires. From the data, the probability of a spotfire occurring on any prescribed burn with the relative humidity between 20 and 80 percent was determined to be 21.2 percent or approximately one out of five burns. Looking at the 40 percent relative humidity threshold, there is a probability of 41.3 percent for a spotfire occurring below 40 percent and 3.8 percent above 40 percent. There also appears to be another threshold at less than 25 percent relative humidity. At this point, there is a 100 percent probability of a spotfire occurring. With this information burn bosses can determine spotfire potential when considering burn units or burn days. It can also assist them when considering crew size and equipment needed. Most of all, inexperienced burn bosses can use this to help reduce risk (liability) and increase safety for their crews.

Introduction

Spotfires have and always will be a problem that burn bosses and fire crews will have to contend with on prescribed burns. Spotfires can cause mental and physical stress on burn bosses and crews if they occur or not. If a spotfire does take place it can cause injury to personnel or even loss of life, as well as monetary damages and loss of public support for the prescribed burning program. From interviewing many private and public land managers in Oklahoma, spotfires or risk of escape (liability) is the main reason many of them do not conduct prescribed fires. Many of these land managers have the personnel and equipment needed to conduct prescribed fires, but lack the experience or knowledge to deal with spotfires. So any type of simple guideline or rule-of-thumb is always needed to assist these people with their prescribed fires.

Temperature, wind speed, and relative humidity are the most important weather factors that burn bosses can use to predict and monitor prescribed fire behavior. Bunting and Wright (1974) determined that danger from firebrands was lower if the ambient air temperature was below 60ºF (15ºC) when conducting prescribed burns. Burning above 40 percent relative humidity has been shown to slow rates of spread significantly (Lindenmuth and Davis 1973) and reduce danger from firebrands (Green 1977). Wind speeds of 8 mph (13 km/h) are needed to ignite and burn standing fuels (Britton and Wright 1971), but with winds over 20 mph (32 km/h) firebrands and other debris become problems (Wright and Bailey 1982). As indicated from the research, there are several weather related thresholds that influence the occurrence of spotfires. So if spotfire causes can be narrowed down to one key weather factor, this will help burn bosses to focus on that single variable, possibly reducing the likelihood of spotfires.

Methods

At the Oklahoma State University Research Range (OSURR) prescribed burns are conducted during different seasons of the year and in different fuel types all over the state of Oklahoma. These burns are conducted in a wide variety of fuels: Tallgrass Prairie (NFES fuel models 1, 3), Postoak-Blackjack Oak (NFES fuel models 3, 8, 9), Eroded Mixed Prairie (NFES fuel models 1, 3), Sandsage Grassland (NFES fuel model 4), and Oak-Pine Forest (NFES fuel models 3, 8, 9, 11) (NFES fuel models from Anderson 1982). Since 1996, records have been kept to track spotfires that occur on these prescribed burns. For this study, a spotfire is considered any fire that occurs outside the burn unit no matter what size it is or what caused it. The size of a spotfire is relative to fuel loads outside of the burn unit, crew size, crew experience, equipment present, equipment dependability, firebreak type and size, and weather conditions. The spotfires during this study ranged in size from less than 1 ft^2 (.09-m^2) to 120 acres (264 ha). Most of these spotfires were due to firebrands caused by crowning eastern redcedar (*Juniperus virginiana*), while leaves from

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Figure 1. Fire whirls and ignition by other volatile fuels can cause spotfires on prescribed burns. The probability of a spotfire occurring is considerably less when the burn is conducted when the relative humidity is over 40 percent.

oak (*Quercus* spp.) trees or tallgrasses floating or blowing across the fireline and smoke or fire whirls were responsible for most of the other spotfires (fig. 1).

When prescribed fires are conducted by the OSURR crew, weather is recorded on site before, during and after the burn. This weather data consists of dry bulb and wet bulb temperature, wind speed and direction, and relative humidity, which is calculated from the dry and wet bulb temperatures. Information is also recorded about spotfires, such as if one occurred and time it occurred.

Results and Conclusions

When the burn data was reviewed, one weather variable stood out as the main cause of spotfires – low relative humidity. Of the 99 burns conducted, there were 21 spotfires, with 19 of the spotfires occurring at or below 40 percent relative humidity (fig. 2). Research has shown that below 40 percent relative humidity fine fuels ignite and burn easily, while above 40 percent ignition slows (Britton and Wright 1971; Lindenmuth and Davis 1973; Green 1977). This research validates that the threshold value of 40 percent relative humidity is an excellent rule-of-thumb to follow when conducting prescribed burns. This does not mean that there should be no prescribed burns conducted below 40 percent relative humidity. There are many regions of the US and certain burn units that require low relative humidity to allow for the goals and objectives of that specific burn to be met. But it should be imprinted in the burn boss' mind that there is an excellent probability for a spotfire to occur if the burn is conducted below 40 percent relative humidity. In the same instant burn bosses should be ready for spotfires on all prescribed burns no matter what the relative humidity values are. For example, we recorded one spotfire when the relative humidity was at 73 percent, which was caused by crowning eastern redcedar throwing firebrands across the firebreak into heavy fuels. This proves spotfires can occur at higher relative humidity values.

Since most spotfires occur at or below 40 percent relative humidity, then what is the probability of a spotfire occurring at the 40 percent threshold value or any other relative humidity value? This information would be important for burn bosses to know as they prepare for and conduct prescribed burns to help reduce the risk to personnel and property. The information from the 99 prescribed burns was used to develop a set of probabilities for a spotfire occurring at a certain relative humidity. To determine this probability the following formula was used (Steele and Torrie 1980):

$$P = \frac{\text{number of successes (spotfires)}}{\text{total number of events (successes + failures) (fires)}}$$

From the data collected at the OSURR, the probability of a spotfire occurring on any prescribed burn with the relative humidity is between 20 and 80 percent was determined to be 21.2 percent, so approximately one out of five burns could be a spotfire. The data was then tested for the probability of spotfires above and below the 40 percent relative humidity threshold. There was a 41.3 percent probability for a spotfire occurring when the relative humidity was below

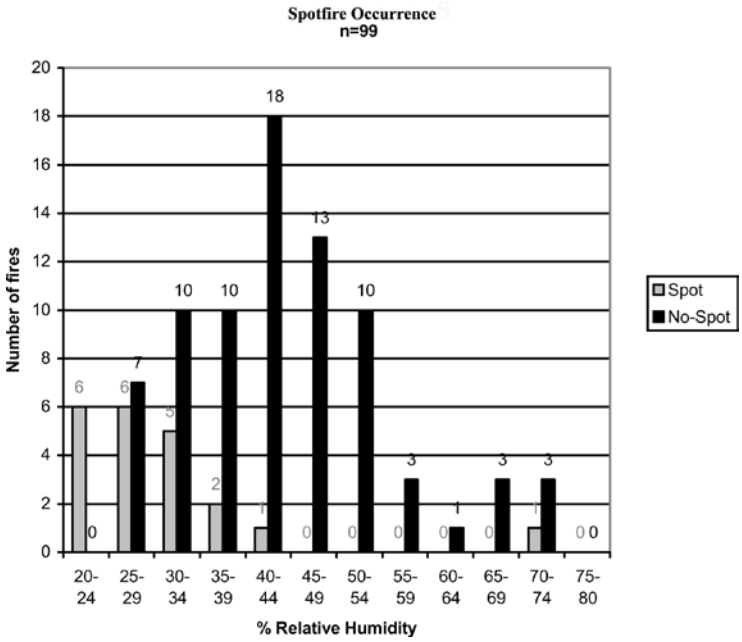

Figure 2. Of the 99 prescribed fires conducted from 1996 to 2002, 21 burns had spotfires. Only two spotfires occurred when relative humidity was greater than 40 percent.

40 percent and only a 3.8 percent probability when the relative humidity was above 40 percent. This is a large difference and the 40 percent threshold should be considered when inexperienced personnel are conducting prescribed burns or when heavy fuel loads are adjacent to the burn unit or if escape could bring possible public scrutiny or litigation. Again this is not condemning prescribed burning below 40 percent relative humidity.

If burns are conducted under 40 percent relative humidity, does the probability of spotfires change at lower relative humidity values? As figure 3 shows, there is a difference in probability at each 5 percent drop in humidity below 40 percent. There also appears to be another threshold at less than 25 percent relative humidity. At this point, there is a 100 percent probability of a spotfire occurring. So below 25 percent relative humidity, burn bosses should be prepared for a spotfire. The spotfire probability drops to 46.2 percent in the 25 to 29 percent relative humidity range, which reduces spotfire risk over half with just a couple of percentage point increase in relative humidity. When the relative humidity is between 30 and 34 percent, only one out of three prescribed burns is likely to have a spotfire. So even within the range of 20 to 40 percent relative humidity there is a large difference in the probability of a spotfire occurring.

With this information, burn bosses can determine spotfire potential when considering burn units or burn days. It can also assist when considering crew size; equipment needed and possibly reduce anxiety when burning below 40 percent relative humidity. Most of all inexperienced burn bosses can use this to help reduce risk (liability) and increase safety for their crews. The main item to remember is to burn when conditions are safest for the crew and surrounding neighbors.

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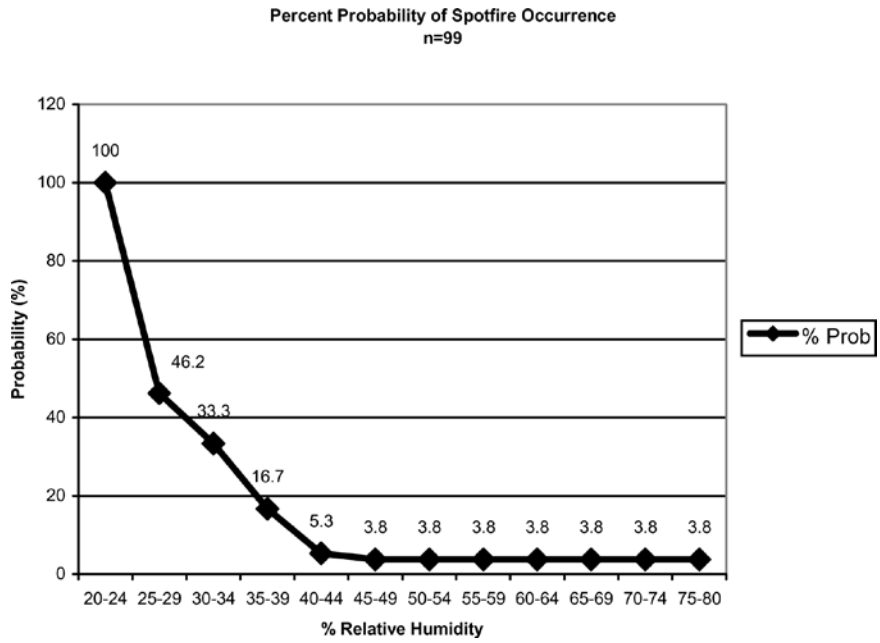

Figure 3. The percent probability of spotfires as a function of relative humidity determined from 99 prescribed fires conducted across Oklahoma from 1996 to 2002.

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