Using Handheld Weather Monitors to Estimate Prescribed Burning Parameters

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Prescribed burning is one of the most cost effective forest management tools available to landowners. Prescribed burning reduces hazardous fuels, enhances wildlife habitat, opens up the woods, and improves aesthetics. To be done safely and effectively, the burn manager needs accurate local weather information before, during, and after the burn.

During the planning stage (the "prescribed" part of prescribed burn), the burner needs to "select" what weather conditions will be best for the planned burn. How dry should the fuel be? What wind direction and speed is needed to blow the smoke away from sensitive areas, such as highways, schools, and hospitals? Fuel dryness is critical to the success of the burn. If the understory fuels are too dry, the fire will be too "hot," resulting in scorching and damage to the overstory trees. If the fuels are too damp, the fire will not burn. For a site preparation or windrow burn, the drier the fuel, the more complete the burn, with less residual smoldering and smoke.

The two key parameters for how well a fire behaves are how hot or intense the fire will be and how fast the fire will spread across the stand. Intensity is directly related to fuel type and dryness. Fuel moisture, especially "fine fuels" such as dead grass and pine straw, is closely tied to relative humidity. Fire spread is directly related to wind speed.

When planning a prescribed burn, the burner must forecast the relative humidity as well wind speed and direction. The USDA Forest Service and other large landowners monitor permanent weather stations to track weather trends and develop forecasts. In recent years, television weather forecasts have become more accurate. The Weather Channel gives up-to-the minute weather conditions and forecasts on a continuous basis. There are also internet sites that give localized weather forecasts for any specific latitude and longitude. Many of these sites are sponsored by local TV stations and rely on detailed National

Weather Service computer models and reports.

While broadcast reports and forecasts are good for planning, they may not be useful for a burner on the ground with a specific fire. The burner needs a method to monitor relative humidity and wind speed at the ground level in real time. There are several instruments available to help with these measurements.

The traditional instrument is a belt weather kit which includes, among other things, a wind gauge and sling psychronometer. A psychronometer uses two thermometers to measure a dry bulb temperature and a wet bulb temperature. These readings are compared using a slide rule or a look-up table to estimate relative humidity. While the technique can give a precise reading, the equipment is sensitive, time-consuming to use, and requires careful regular maintenance to ensure accuracy.

With computer chip technology, there are now on the market electronic weather monitors that are extremely useful to prescribed burn managers. These are readily available through forestry and environmental supply catalogs at prices ranging from about $90 to $150, depending on their features.

All handheld monitors measure several basic parameters. They all have a propeller anemometer to measure wind speed. They all measure temperature and have a moisture sensor, which is used to calculate relative humidity and dewpoint. From these measurements, other values such as wind chill and heat index are calculated. The units are all simple to use with a push button to scroll through measurements and LED display screens.

A comparison between the electronic monitors and belt weather kit instruments show that the monitors are relatively accurate, especially for wind speeds. The relative humidity calculations vary slightly between units, but all are within 2 to 5% of the psychronometer readings during normal Alabama weather. It has been reported that they are less accurate in drier conditions, such as occurs out West during summer droughts. In Alabama during normal prescribed burning season, the electronic monitors produce relative humidity readings with acceptable accuracy for a prescribed burn manager.

Estimating Fire Behavior from Weather Readings

Once a burn manager has a relative humidity reading, he or she can estimate fine fuel moisture levels. There are several 'rules of thumb" for doing this, but

the most accurate uses formulas based on research by Fosberg and Deeming. The formula uses relative humidity (Rh) and temperature (T) to estimate fine fuel moisture, as follows:

If RH < 50%,
FFM = 2.21819 + 0.16491(Rh) – 0.01522(T)

If RH > 50%,
FFM = 21.69242 + 0.00573(Rh)(Rh) – 0.00036(Rh)(T) – 0.4995(Rh)

These formulas are shown graphically in Figure 1. If the relative humidity is 40% and the temperature is 50°F, then the estimated fine fuel moisture would be roughly 8%. If the relative humidity is 80% and the temperature is 50°F, the fuel moisture would be 17%. In Alabama, fuels need to be in the 8 to 15% range for a good understory burn. Moistures higher than 15% will not allow enough fire spread, while fuel moistures below 8% may cause residual tree damage.

Once a prescribed burn manager has an estimated fuel moisture and ground level wind speed, he or she can estimate the rate of spread for the fire. Rate of spread is how fast the fire will move across the stand. This calculation tells the burner how long it will take to burn the targeted stand, so that the burn can be done within the allotted time. Rate of spread is very complex, however the Forest Service has published a series of tables that can be used to estimate spread rates. Figure 2 shows such a table for closed pine plantation or mature hardwood stands with little underbrush and little slopes (less than 45%). The table shows that with 12% fuel moisture and 4 mph surface wind, an understory head fire should travel at about 4 feet per minute.

Using another set of formulas, the burner can estimate the flame height, which is a measure of fire intensity and can be used to predict residual tree scorch or damage. A Forest Service table for pine hardwood litter is shown in Figure 3. It shows that with a 12% fuel moisture and 4 mph wind speed, an understory litter fire would have flames about 2 feet high.

These estimates are for a closed stand with no understory, just pine straw and hardwood leaves. Stands with understory brush will have a different rate of spread and flame length. The method used to estimate rate of spread and flame length is the same, but it uses different tables and factors.

These tables and formulas only give estimates on how the fire will behave, all things being equal (which they never are). Your fire will vary some from these values. But determining the fuel moisture, rate of spread, and flame length will give you a benchmark for your burn. Experience in managing prescribed burns will help you adapt these estimates to fit your forest situation.

Weather is a critical element in prescribed burning. Modern technology in weather forecasting and handheld electronic weather monitors make getting accurate weather information easily available. This small investment will pay out many benefits on your TREASURE Forest.

Figure 1

Fine Fuel Moisture
Pine and Hardwood Understory (Fuel Model 9)

Relative Humidity	Temperature (degrees F)						
	20	30	40	50	60	70	80
10%	4	3	3	3	3	3	3
20%	5	5	5	5	5	4	4
30%	7	7	7	6	6	6	6
40%	9	8	8	8	8	8	8
50%	10	10	10	10	10	9	9
60%	12	12	12	11	11	11	11
70%	14	14	14	14	13	13	13
80%	18	18	17	17	17	16	16
90%	23	22	2	22	21	21	21

Figure 2

Estimated Rate of Spread
Pine and Hardwood Understory (Fuel Model 9)

Fine Fuel Moisture	Midflame Wind (mph)						
	0	2	4	6	8	10	12
	Spread in Feet per Minute						
3%	1	3	9	18	28	40	54
6%	1	2	7	13	21	30	41
9%	1	2	6	11	17	24	33
12%	1	2	4	9	14	21	29
15%	1	2	4	8	13	19	25
18%	0	1	3	7	11	15	21
21%	0	1	2	4	8	11	14

Source: Fireline Handbook, Appendix B-Fire Behavior, Table 54, converted from chains/hour

Figure 3

Estimated Flame Length
Pine and Hardwood Understory (Fuel Model 9)

Fine Fuel Moisture	Midflame Wind (mph)						
	0	2	4	6	8	10	12
	Flame Length in Feet						
3%	1.3	2.1	3.2	4.2	5.2	6.2	7.1
6%	1.0	1.6	2.5	3.4	4.2	4.9	5.7
9%	0.9	1.4	2.2	2.9	3.6	4.3	5.0
12%	0.8	1.3	2.0	2.7	3.4	4.0	4.6
15%	0.8	1.2	1.9	2.5	3.1	3.7	4.3
18%	0.7	1.1	1.7	2.2	2.7	3.3	3.7
21%	0.5	0.8	1.2	1.6	2.0	2.4	2.7

Source: Fireline Handbook, Appendix B-Fire Behavior, Table 54