ESTABLISHING FIRE INTENSITY AND DURATION ON SMALL RESEARCH PLOTS USING A THERMAL IMAGING CAMERA

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Extended abstract—To study the effects of fire on red maple (*Acer rubrum*) seedlings, an experimental plantation was established. Fuels were needed to create fires of low and high intensity to reproduce conditions of wildfires in upland hardwood forests with a high red maple component. Because the amount of natural fuel needed to produce fires of low and high intensities was unknown, the purpose of this research was to study the type and amount of fuel that resulted in low and high intensity fires and fires of differing duration. This research was a pilot study and the experiment was not replicated at this time. This research was conducted at the University of Tennessee, Forest Resources AgResearch and Education Center, Cumberland Forest Unit (N 36º 3.045', W 84º 28.905') in Oliver Springs, TN.

The experiment was conducted in part in an open field where there was ample space. A total of four plots were established, each with a different fuel type and arrangement. Three plots with simulated fuels were located on a mown grass surface. One natural plot located in a forest was utilized as a control to provide a comparison. The natural plot (Natural) was located on a southeast aspect of minimal slope with a red maple overstory. The three field plots were situated on the ground with no duff or leaf litter layers and were directly exposed to sunlight. To simulate hardwood forest fuels, red maple leaves and loblolly pine (*Pinus taeda*) needles (1-hour fuels) and 1 inch by 1 inch by 12 foot white pine (*Pinus strobus*) furring strips (10-hour fuels) were used. Leaves and pine straw were gathered several months in advance and air dried on tarps in a pole barn. Fuel amounts were measured using a 1 cubic foot cardboard box which was pre-weighed. To ensure uniformity, leaves and pine straw were measured separately by hand-filling and weighing the boxes. The average dry weights of 1 cubic foot of leaves (11.0 ± 1.7 (standard deviation) ounces) and pine straw (10.7 ± 2.5 ounces) were similar. Three 14 foot by 14 foot square plots were loaded with fuels. Fuels were loosely spread across the area with no trampling. The three fuel loads that were used included leaves only (LO), leaves and pine straw (LP), and leaves, pine straw, and wood (LPW). To create a low fire intensity, Plot LO was loaded with 24 cubic feet of leaves spread throughout the plot with 6 cubic feet on the 1-foot-edge buffer and 18 cubic feet spread evenly within the inner 12-foot by 12-foot area. To create a medium intensity fire burn, Plot LP was loaded with 24 cubic feet of fuel; 12 cubic feet of pine straw was spread as a bottom layer and 12 cubic feet of red maple leaves on top of the pine straw. To create a high fire intensity, the final plot LPW was loaded with leaves, pine straw, and the 1 inch by 1 inch by 12 foot wood strips. Plot LPW was loaded with three layers: 12 cubic feet of pine straw spread as the base layer, 24 cubic feet of red maple leaves in the middle, and 24 12-foot-long wood strips added as the top layer. To simulate a 2 x 2 plant spacing grid, each set of two strips were placed one foot apart in each row in a double cross hatch pattern. The strips were elevated on 2-inch blocks above the fine fuels to prevent compaction and another 12 strips were layered perpendicularly across the first layer in the same fashion.

Ignition of the plot fires was conducted using a 1.25-gallon drip torch. The torch fuel consisted of three parts of diesel and one part gasoline. Plot fires were set by running a single line of fire along the plot perimeter. Plots were burned on March 14, 2018. Plot LO was the first plot burned at 13:43 followed by Plot LP, Plot LPW, and Plot Natural at 14:18, 15:37, and 17:16, respectively. Fire weather was recorded and winds during burning were from variable directions but remained light ranging from 4.9 to 6.0 mph. Temperatures were cool on the day of the burn, reading 38 °F during the first burn and reaching 41 °F during the final burn. Relative humidity values remained consistent throughout the burning of all plots, ranging from 25.9 to 33.0 percent. The temperatures of the fires were recorded using a Micro-Epsilon thermoIMAGER ® Infra-red TIM 400 camera. The Micro-Epsilon thermoIMAGER and associated TIMCONNECT software provided a platform for the accurate measurement and digital documentation of fire temperatures that is compatible with mainstream software programs. According to the manufacturer, a thermoIMAGER detects emissivity and converts it into temperatures using special sensor technology (Micro-Epsilon 2018). The camera used non-contact technology and recorded in real time at 80 Hz. The camera was outfitted with a 30° lens to increase the field of view. The camera resolution was 382 x 288 pixels with a sensitivity of 32.1 °F, accuracy of ±2%, and a temperature range from –4 °F to 2732 °F. The camera

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recorded temperatures in the 7.5 and 13 µm wavelengths and was calibrated to 0.95 emissivity (Micro-Epsilon, 2018). The camera was placed on a tripod 3.5 feet high, and 10 feet from plot edge to allow for a full view of the plot. Recording was stopped when temperatures had cooled to 392 °F.

The highest maximum temperature recorded was 1628 °F in plot Natural, consistent with forest fire temperatures measured by others that ranged between 1616 °F and 2238 °F (Dupuy and others 2003, Van Wagner and Methven 1978). When compared to Natural, the LO and LPW plots displayed lower maximum temperatures and longer duration of increased temperatures. Plot LO had a maximum temperature of 1234 °F, and remained above 392 °F for 17 minutes, 8 seconds. Plot LO also exhibited a rapid rate of heating and a rapid rate of cooling (fig. 1). Plot LP had a maximum temperature of 1450 °F. The amount of time greater than 200 C (392 °F) for Plot LP was slightly less than that of Plot LO, measuring 15 minutes, 19 seconds. The time-temperature relationship of Plot LP was similar to Plot LO. The time-temperature diagram shows a short, rapid heating phase and a short, rapid cooling phase on either side of a sustained phase of high temperatures (fig. 1). Plot LPW sustained a maximum temperature of 1284 °F. This value was higher than that of Plot LO but was lower than that of Plot LP. Plot LPW had the most time greater than 392 °F. for a total of 49 minutes, 29 seconds. Plot LPW exhibited a rapid heating phase and maintained high temperatures with a slow, gradual cooling (fig. 1). Plot Natural sustained the highest maximum temperature of all plots (1628 °F) and the least amount of time greater than 392 °F. The temperature remained above 392 °F for 5 minutes, 51 seconds. Plot Natural had the fastest heating rate and a very short duration of sustained high temperatures. Additionally, Plot Natural showed the fastest cooling time of all plots (fig. 1).

The different fuel types produced two distinct fire intensities. The short duration and low maximum temperature of Plot LO made it suitable as a low fire intensity fuel load. The long duration of sustained high temperatures of Plot LPW made it suitable for the high fire intensity fuel load. This may emulate more intense forest fires that burn dead tree stumps and root systems, creating increased temperatures within the root zones of adjacent trees. Fires of different intensity can be created using artificially arranged natural fuels outside of the forest environment. Use of red maple leaves only (LO) yielded fire intensity metrics that made it suitable for a low fire intensity fuel. A combination of leaves, pine straw, and wood strips (LPW) created high fire intensity with an extended duration that made it suitable as a high fire intensity fuel. The fire intensities in the artificially arranged fuel beds (LO and LP) were similar to the natural fire in that fire temperatures peaked and declined rapidly as fine fuels were consumed. The addition of 10-hour fuels in LPW increased the duration of higher temperatures.

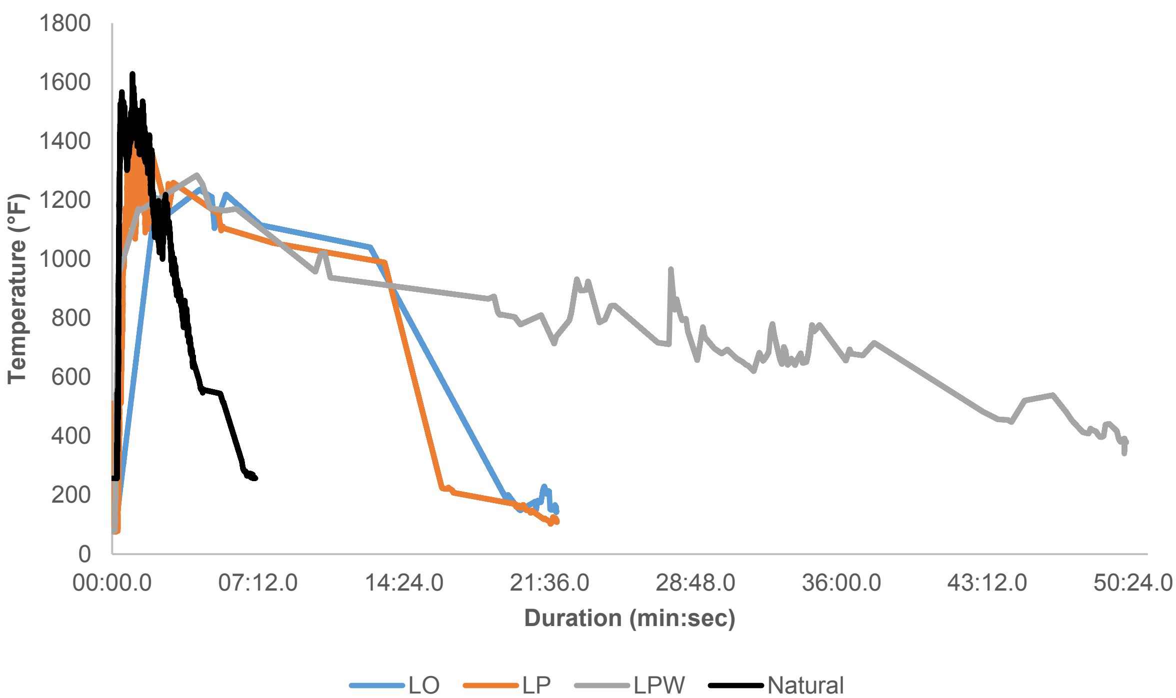

Figure 1—Time-temperature relationship comparison between plots LO (red maple leaves), LP (red maple leaves and pine straw), LPW (red maple leaves, pine straw, and wood strips), and Natural.

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