POST-FIRE TWIG TIP DIAMETERS AS A MEASURE OF FIRE INTENSITY

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ABSTRACT

Fire line intensity (kW/m) in woody vegetation crowns is one of the parameters useful in assessing many fire effects. However, crown fire intensity is very difficult to measure. Temperature and time can be measured with a variety of sensors such as thermistors and thermocouples, but this technology is expensive, difficult to deploy, and provides only point measurements. Many of these devices would be needed to get an estimate of the average fire intensity over a given area. Evaporative devices such as water-filled metal cans are less expensive and are able to estimate heat experienced by the device, but they too are difficult to deploy in tree crowns. Also, these measurements are obtainable only while the fire is ongoing. No post-fire method to collect such information is available.

The physics of burning wood and the geometry of twigs indicate the possibility of an inexpensive method of estimating crown fire intensity that would be available for a few years post-fire. Before wood can burn, all the moisture must be evaporated and the drying rate is directly related to diameter. The geometry of a twig is basically a long, thin cone. Thus the portion of the twig from the tip toward the base that is burned off in a crown fire would be proportional to the length of time the twig is exposed to flames. In theory, any twig could be used for this purpose, but dead twigs would most likely have a non-uniform fuel moisture distribution along the twig because the thinner tips would be drier than the thicker base. Dead twig fuel moisture could also vary spatially across the stand.

Live twigs, on the other hand, would have a fairly constant moisture content throughout the length of the twig and across the stand because of their water relationships. The moisture relationships within the live twigs would also work together to produce a burned surface that would be nearly perpendicular to the axis of the cone. After the thin layer of dry outer bark is consumed, the living phloem and cambium would provide a substantial barrier to the fire until it fails catastrophically. Thus the tip of the cone is consumed while the surface of the remaining cone is left essentially intact instead of the radius being partially consumed.

Diameter is easily and quickly measured with inexpensive calipers. Live twigs are always deployed throughout the stand and diameters can be easily measured post-fire. Even when moisture content at the time of the fire is not available, the minimum diameter could be used as an index of fire intensity differences between stands burned in similar phenological states.

The International Crown Fire Modelling Experiment, Northwest Territories, provided an excellent opportunity to test this hypothesis. Numerous measurements and observations were made that directly related to fire intensity. Environmental conditions were closely monitored, pre- and post-burn fuel loads were sampled, spread rate was closely timed, and several thermocouple arrays and heat flux monitors were deployed by the Canadian Forest Service and the U.S. Forest Service.

The mean of post-fire twig tip diameters (TTDs) for each plot was calculated from 12 trees randomly chosen from each of seven plots. These were measured and compared with several fire parameters. Highly significant linear regression was found between TTDs and rate of spread (ROS) that explained 63% of the variation. Energy released from crown fuels consumed (live fuels <0.5 cm + dead fuels <1cm), multiplied by the low heat of combustion of biological material (18700 kJ/kg), multiplied by ROS, gives fire line intensity. Regressing TTDs against this intensity increased the explained variation between all plots to 77%. The equation for the regression line was TTD (mm) = 3.271 (mm) – 0.000018 × Intensity (kW/m).

To determine whether TTDs were related to crown position, tips from five trees from one of the plots were measured by taking TTDs from 30 twigs in each vertical third (top, middle, bottom) of the crown. ANOVA showed significant differences in TTDs between thirds in three of the five trees with the middle third having the largest TTDs. The other two trees came from the fringe of an unburned area in the corner of the plot. This finding agrees with the higher heat production found in the middle of the crown layer.

From these data it appears that TTDs integrate the various factors that go into fire intensity and provide a usable indicator. The crown fire environment is a very complex, turbulent mixture of heated and flaming gasses, but the twig appears to provide a simple, easily measured property. However, the negative slope of the regression equation is counterintuitive—the greater the intensity, the smaller the diameter, i.e., the less twig wood is consumed. The twig is probably responding to the flame residence time. The negative slope of the regression line would indicate that the consumable fuel appears to burns faster at higher intensities. This study should be verified by measurements in other fuel types where ROS and fuel consumption can be measured.

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