Practical Tools for Assessing Potential Crown Fire Behavior and Canopy Fuel Characteristics

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Abstract—*This presentation recapitulates the main points made at a technology and information transfer workshop held in advance of the conference that provided overviews of two software applications, developed by the authors, for use in assessing crown fire behavior and canopy fuel characteristics. These are the Crown Fire Initiation and Spread (CFIS) software system and the Canopy Fuel Stratum Characteristics Calculator. Both of these application tools are based on model formulations and performance evaluations that have appeared in the scientific peer-reviewed literature. The software and publications associated with each are available for downloading at: http://frames.nbii.gov/cfis.*

CFIS incorporates several models designed to simulate certain characteristics of crown fire behavior in live, boreal and near-boreal like, conifer-dominated forests (Alexander and others 2006). The two main outputs are: (1) the likelihood of crown fire initiation or occurrence and (2) the type of crown fire (active vs. passive; Van Wagner 1977) and its rate of spread. A secondary output, the minimum spotting distance required to increase a fire's overall forward rate of spread, is also provided. The onset of crowning can be predicted through one of two distinct approaches. One approach relies on the knowledge of canopy base height and certain components of the Canadian Forest Fire Weather Index System and/or the 10-m open wind speed (Cruz and others 2003b). The other approach requires the 10-m open wind speed, the estimated fine fuel moisture (Rothermel 1983), fuel strata gap or canopy base height, and an estimate of surface fuel consumption as inputs (Cruz and others 2004). Required inputs to predict crown fire rate of spread are 10-m open wind speed, estimated fine fuel moisture, and canopy bulk density (Cruz and others 2005). The minimum spotting distance to affect overall crown fire rate of spread, which assumes a point ignition and subsequent fire acceleration to an equilibrium rate of spread, requires the predicted crown fire spread rate and an ignition delay as inputs (Alexander and Cruz 2006). This latter model should be considered as theoretical in nature at this time and lacks evaluation.

The primary models incorporated into CFIS have been evaluated against independent datasets involving both experimental fires (Cruz and others 2003b, 2005) and wildfire observations (Alexander and Cruz 2006) with good results. CFIS has applicability as a decision support aid in a wide variety of fire management activities ranging from near-real time prediction of fire behavior to analyzing the impacts of fuel treatments on potential crown fire behavior (Alexander 2007). All or parts of the system have to date been applied to situations in Australia, North America, and Europe (e.g., Cruz and others 2008, 2014; Smith 2011; Osiowy 2012; Fernández-Alonso and others 2013; Watt 2014; Bried and others 2015).

Presently, the main limitations of CFIS are as follows:

- *Ideally, CFIS is most appropriate for use in fuel types that mimic the original datasets (i.e., healthy, single-age and single stratum conifer forests). Thus, one should not expect accurate predictions in conifer forests with highly variable vertical complexity (e.g., old growth wet forests in Pacific Northwest), highly drought-stressed forests, and stands with a prominent medium or tall understory shrub layer.*
- *Not appropriate for use in "dead" conifer forest stands resulting from insects and disease (e.g., mountain pine beetle attacked lodgepole pine).*
- *Valid for free-burning fires that have reached a pseudo steady-state (i.e., a "line fire" as opposed to a point source fire); they are not considered applicable to prescribed fires or wildfires involving ignition patterns that deviate from this simplistic situation (e.g., spot grid, strip-head fires, backfiring, ring fire).*
- *They do not at present consider the mechanical effects of slope steepness on crown fire behavior.*

The other software application, the Canopy Fuel Stratum Characteristics Calculator, is based on the regression equations developed by Cruz and others (2003a) for estimating the canopy base height, canopy bulk density and canopy fuel load for four broad coniferous forest fuel types found in western North America

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based on three stand characteristics (i.e., average height, basal area and stand density). The regression equations have been programmed into an excel spreadsheet (Alexander and Cruz 2010). Tabular versions of the equations have also been prepared (Alexander and Cruz 2014). Three of the types involve relatively pure stands of Douglas-fir (Pseudotsuga menziesii), ponderosa pine (Pinus ponderosa) and lodgepole pine (P. contorta). A mixed-conifer type was also identified, which consisted of seven different forest cover types: Engelmann spruce (Picea engelmannii), Engelmann spruce–subalpine fir (Abies lasiocarpa), white fir (A. concolor) or grand fir (A. grandis), western red cedar (Thuja plicata), western hemlock (Tsuga heterophylla), mountain hemlock (T. mertensiana)–subalpine fir, and western larch (Larix occidentalis)–Douglas-fir.

Two evaluations have been undertaken of the Cruz and others (2003a) canopy fuel regression equations (Cruz and Alexander 2012). The first evaluation involved a random selection of 10 stands each from the four datasets used in the original study. These were in turn subjected to two simulated thinning regimes (i.e., 25 and 50% basal area removal). The second evaluation involved a completely independent dataset for ponderosa pine consisting of 16 stands sampled by Keyser and Smith (2010). The results of both evaluations clearly show that the stand-level models of Cruz and others (2003a) are, considering their simplicity, quite robust in nature.

The Cruz and others (2003a) regression equations have been used by investigators for over a decade now (e.g., Stevens-Rumann and others 2012).

Keywords: *canopy base height, canopy bulk density, canopy fuel load, onset of crowning, rate of fire spread, spot fire distance*

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