RECENT ADVANCES IN MODELING THE ONSET OF CROWNING AND CROWN FIRE RATE OF SPREAD

Martin E. Alexander[1]* and Miguel G. Cruz[2]

[1] University of Alberta, Department of Renewable Resources, Edmonton, AB T6G 2H1, Canada. Full-time affiliation: Canadian Forest Service, Northern Forestry Centre, 5320-122 Street, Edmonton, AB T6H 3S5, Canada. *Corresponding author (mea2@telus.net)

[2] CSIRO Sustainable Ecosystems, Bushfire Dynamics and Applications, P.O. Box E4008, Kingston, ACT 2604, and Bushfire Cooperative Research Centre, East Melbourne, VIC 3002, Australia

ABSTRACT

This presentation will provide an overview of several models and modeling systems developed by the authors over the past 10 years for simulating certain aspects of crown fire behavior. Based on a wealth of high-quality fire behavior data collected over some three decades of experimental burning principally in Canada, the authors have developed and tested several empirical and semi-physically-based models aimed at predicting the onset of crowning, the type of crown fire (i.e., passive or active) and the associated rate of spread.

Three broad types of models were developed to describe the onset of crowning. Four empirical-based models describing the probability of crown fire initiation were developed based on logistic regression analysis; these models require canopy base height, certain components of the Canadian Forest Fire Weather Index System and/or wind speed as input variables. Another logistic regression model that provides an estimate of the likelihood of crown fire occurrence relies on wind speed, fine dead fuel moisture, canopy base height, and surface fuel consumption as input variables. Fine dead fuel moisture is estimated from Rothermel's 1983 "how to" fire behavior prediction manual procedure (using the >51% degree of shading option).

To overcome some of the perceived limitations of the fully empirical models, we also developed a semi-physically-based crown fuel ignition model (CFIM). CFIM relies upon fluid dynamics and heat transfer principles coupled with some empiricism as necessary in order to predict the ignition temperature of canopy fuels above a spreading surface fire.

Models to predict the rate of spread of crown fires, spreading either by active or passive crowning regime, were developed through nonlinear regression analysis encompassing the effects of wind speed, fine dead fuel moisture, and canopy bulk density. Van Wagner's criterion for active crowning based on canopy bulk density is utilized in the passive crown fire rate of spread model and in determining when the conditions for active crown fire spread are met.

Both the onset of crowning and crown fire rate of spread models have been evaluated against experimental fire observations, including data from the International Crown Fire Modelling Experiment, and wildfire observations with favorable results, although additional research is needed in predicting passive crown fire rate of spread. Comparisons with other similar predictive models have also revealed the relative robustness of the models.

The models developed for predicting the onset of crowning and crown fire rate of spread have been integrated into two different fire behavior modeling systems. The Crown Fire Initiation and Spread (CFIS) software system comprises the empirical-based models for predicting the likelihood or probability of the onset of crowning, type of fire (i.e., surface, passive crown, or active crown), and crown fire rate of spread. It also includes a simplistic model for estimating the minimum spotting distance required to increase a fire's overall forward rate of spread, assuming a point ignition and subsequent fire acceleration to an equilibrium rate of spread based on the predicted crown fire rate of spread and ignition delay as inputs.

CFIS is considered most applicable to free-burning fires that have reached a pseudo–steady state, burning in live, boreal, or boreal-like conifer forests found in western and northern North America (i.e., they are not applicable to insect-killed or otherwise "dead" stands). Furthermore, the models underlying CFIS are not applicable to prescribed fire or wildfire situations that involve strong convection activity as a result of the ignition pattern. Level terrain is assumed, as the CFIS does not presently consider the mechanical effects of slope steepness on crown fire behavior, although this is being planned for in a future version of the system.

Pine Plantation Pyrometrics (PPPY) is a modeling system developed to predict fire behavior in exotic pine plantations found in Australasia over the full range of burning conditions in relation to proposed changes in fuel complex structure from fuel treatments. The system comprises a series of sub-models, including CFIM and elements of CFIS, that describe surface fire characteristics and crown fire potential in relation to the surface and crown fuel structures, fuel moisture contents, and wind speed. A case study application of the PPPY modeling system has highlighted the complex interactions associated with fuel treatments such as pruning and thinning have on surface and crown fire behavior potential.

The models comprising CFIS, CFIM, and PPPY and the evaluation results have been published in various scientific and technical peer-reviewed journals (e.g., *Forest Science, Canadian Journal of Forest Research, International Journal of Wildland Fire, Australian Forestry, Forestry Chronicle*). Publications describing CFIS, CFIM, and PPPY, including the CFIS software, are available for downloading from the *FIREHouse—The Northwest and Alaska Fire Research Clearinghouse* Web site (http://www.fs.fed.us/pnw/fera/firehouse).

The authors are willing to work with individuals and organizations interested in implementing and evaluating the performance of crown fire behavior models and modeling systems for use at the local level.

keywords: crown fire initiation, crown fire occurrence, extreme fire behavior, fire behavior, fire dynamics, fire potential, modeling systems, models, rate of fire spread, spotting.

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