Stand Structure Modification to Reduce Fire Potential: Simulation vs. Reality

Marty Alexander, PhD, RPF
Senior Researcher
Wildland Fire Operations Research Group
Forest Engineering Research Institute of Canada – Western Division

Is the English translation of the title of a paper (Cruz, Alexander and Viegas 2005) presented at the 5th National Forestry Congress sponsored by the Portugese Society of Forestry Sciences (http://www.spcf.pt) held in Viseu, Portugal, May 16-19, 2005.

This presentation was co-authored by Dr. Marty Alexander, a Senior Researcher with the FERIC Wildland Fire Operations Research Group, and two Portuguese wildland fire research scientists, Drs. Miguel Cruz and Domingos Viegas. Dr. Cruz is a Researcher at the Center of Forest Fire Studies with the Associação para o Desenvolvimento da Aerodinâmica Industrial (ADAI) located in Coimbra. Dr. Viegas is a professor in the Department of Mechanical Engineering at the University of Coimbra. ADAI is a private non-profit research organization linked to the Department of Mechanical Engineering, University of Coimbra. The original abstract (in Portuguese) of their presentation from the conference proceedings is presented below along with the English translation.

Modificação da Estrutura de Povoamentos Florestais para Redução do Potencial do Comportamento do Fogo: Modelação vs. Realidade

[1]**Miguel G. Cruz,** [2]**Martin E. Alexander e** [3]**Domingos X. Viegas**
[1]Associação para o Desenvolvimento da Aerodinâmica Industrial, Apartado 10131, 3031 – 601 COIMBRA, Portugal.
E-mail: miguel.cruz@adai.pt
[2]Forest Engineering Research Institute of Canada, Wildland Fire Operations Research Group, 1176 Switzer Drive, HINTON, AB T7V 1V3, Canada
[3]Universidade de Coimbra, Depto. de Eng. Mecânica, Apartado 10131, 3031 – 601 COIMBRA, Portugal

A alteração da estrutura dos povoamentos florestais provocada por actividades silviculturais induz alterações no microclima do sub-bosque e na estrutura do complexo combustível que afectam o comportamento do fogo. A complexidade dos processos que determinam o comportamento fogo leva à necessidade da utilização de modelos para integrar os diversos componentes do sistema ecossistema – meteorologia – fogo e produzir descrições quantitativas do potencial do comportamento do fogo, nomeadamente a probabilidade de ignição de fogos secundários, o potencial de ocorrência de fogos de copas, velocidade de propagação e intensidade frontal da frente de chamas. A utilização destes modelos é essencial para uma gestão do fogo pró-activa permitindo responder a questões como "Quais as modificações ao estrato de combustível de superfície são necessárias para reduzir a probabilidade de ocorrência de fogos de copas?", "Para um determinado regime silvicultural qual a redução da taxa de coberto arbóreo necessária para evitar o desenvolvimento de fogos de copas activos?" e "Em que condições um povoamento considerado como uma barreira à propagação do fogo se torna susceptível à iniciação de fogos de copas e sua propagação sustentada?". No entanto, a complexidade do ambiente do fogo e as limitações inerentes aos sistemas de simulação do comportamento do fogo podem levar à tomada de opções silviculturais que induzam resultados opostos aos obtidos na simulação. No presente trabalho são descritos vários casos de estudo de aplicação de modelos de comportamento para avaliar o efeito de tratamentos silviculturais no potencial do comportamento do fogo e como a monitorização do ambiente e comportamento do fogo em fogos experimentais revelaram resultados distintos dos esperados.

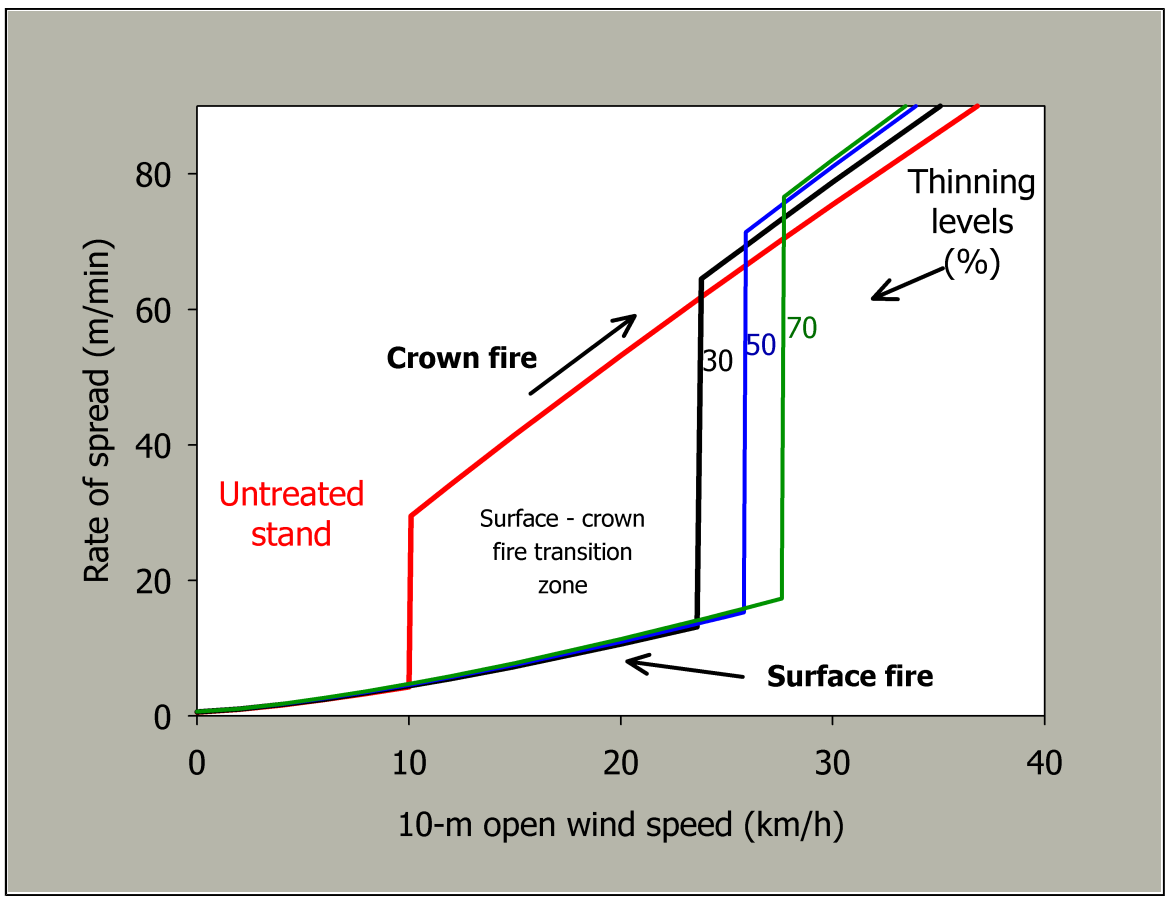
English Translation of Cruz, Alexander and Viegas (2005) Abstract

The use of fire behavior models is an essential element in the development of proactive fire management systems. Silvicultural activities and the associated changes in stand structure in turn affect in-stand microclimate processes and fuel complex characteristics that influence fire behavior. The complexity of the processes that determine fire behavior makes it necessary to use models that integrate the various variables controlling fire behavior that in turn

produce quantitative descriptions of potential fire behavior, namely probability of ignition, fire spread and intensity, and the likelihood of crown fire development. The use of models allows one to address questions like: "What levels do surface fuel loads need to be maintained at in order to reduce the likelihood of crown fire initiation?", "For a given silvicultural system, what is the target canopy cover in avoid the possibility of active crown fires?", and "Under what conditions is a stand considered largely a barrier to surface fire propagation but yet could allow for the development of active crown fires?". The complexity involved in assessing the fire environment coupled with the inherent limitations of fire behavior simulation systems can lead to erroneous results that might induce mismanagement with long-term, unwanted consequences. In the present work we describe several case studies of the application of crown fire behavior models to evaluate the effects of silvicultural treatments on fire potential and discuss the main limitations of this approach. We also argue for the need to monitor microclimate processes (e.g., wind and fuel moisture) and determine their effect on fire potential.

The presentation made by Cruz, Alexander and Viegas (2005) is based in large part on field experiments (Alexander and Lanoville 2004) and the recent development of empirically-based models for predicting selected aspects of crown fire behavior (Cruz, Alexander and Wakimoto 2003b, 2004, 2005, Cruz et al. 2006)[1], including a semi-physical based for crown fire initiation (Cruz 2004; Cruz et al. 2006).

One of the objectives of the International Crown Fire Modelling Experiment (ICFME) was the testing of a physically-based model for predicting crown fire rate of spread developed by the late Dr. Frank A. Albini (Alexander 2005; Stocks, Lanoville and Alexander 2005). While his model accurately predicted the relative response of fire spread rate to fuel and environment variables it overpredicted the magnitude of the spread rates observed on the ICFME crown fires (Butler et al. 2004). As a result there is still the necessity for empirically-based models for predicting crown fire rate of spread such as developed by Cruz, Alexander and Wakimoto (2005).



A simulation of the impacts of fuel treatments on the type of fire and rate of fire spread in relation to increasing wind speed for three different levels of thinning (i.e., 30, 50 and 70% of the original stand basal area) in a maritime pine stand (characteristics in control or untreated stand: average DBH 15 cm; average height 11.7 m; basal area 41 m^2/ha; average crown base height 7.1 m; canopy bulk density 0.48 kg/m^3) under relative severe

fire weather conditions (air temperature - 35°C and relative humidity - 27%) assuming a surface fuel consumption of 0.8 kg/m^{2}. The Estimated Fine Fuel Moisture (EFFM) in the control or untreated stand was set at 5.5% and was varied from 4 (70% of basal area), to 4.5 (50% of basal area) to 5% (30% of basal area) in the three thinning treatments. The basal area reductions were accomplished by successively removing the smallest stems in the stand first which resulted in lowering the crown fuel load, increasing the live crown base height, and decreasing the canopy bulk density. This simulation utilized a customized fuel model (described by Cruz, Alexander and Wakimoto 2004) in the BehavePlus system (Andrews, Bevins and Seli 2003) for surface fire rate of spread, the Cruz et al. (2006) model for crown fire initiation, and the Cruz, Alexander and Wakimoto (2005) model for active crown fire rate of spread.

The active crown fire rate of spread (Cruz, Alexander and Wakimoto 2005) has undergone extensive testing using wildfire observations (Alexander and Cruz 2005). The Cruz et al. (2006) crown fire initiation model has received limited testing to date (Cruz, Butler and Alexander 2006).

These models have permitted an objective basis for evaluating the impacts of fuel treatments on fire behavior potential as illustrated in the example presented above based on the ability to manipulate three characteristics of a fuel complex by silvicultural and other vegetation management techniques:

- available surface fuel load;
- crown base height, and
- canopy bulk density

The later quantity is a function of the available crown fuel load (e.g., needle foliage and small branchwood) and the depth of the crown fuel layer which is the difference between the stand height and crown base height (Cruz, Alexander and Wakimoto 2003a).

Case study knowledge (Alexander and Thomas 2003a, 2003b, 2006), coupled with experience judgment and fire behavior modeling is considered an effective operational technique for appraising fire potential in regards to fuels management (Brown 1978). FERIC in collaboration with ADAI have now developed a user-oriented modeling tool (Cruz, Lopes, Alexander 2005), for fire/fuel managers and planners which incorporates some of the models mentioned here thereby permitting them the ability to readily gauge the impacts of proposed fuel treatments on crown fire potential.

References Cited

Alexander, M.E. 2005. Long-term experiment takes some of the mystery out of crown fires. Fire Management Today 65(3): 36-37.

Alexander, M.E.; Cruz, M.G. 2005. Evaluating a model for predicting active crown fire rate of spread in conifer forest stands using wildfire observations. Submitted for publication.

Alexander, M.E.; Lanoville, R.A. 2004. The International Crown Fire Modelling Experiment fuel treatment trials. Pages 222 *in* R.T. Engstrom, K.E.M. Galley and W.J. de Groot (editors). Proceedings of the 22nd Tall Timbers Fire Ecology Conference: Fire in Temperate, Boreal, and Montane Ecosystems. Tall Timbers Research Station, Tallahassee, Florida.

Alexander, M.E.; Thomas, D.A. (Issue Coordinators). 2003a. Wildland Fire Behavior Case Studies and Analyses: Part 1. Fire Management Today 63(3): 1-95.

Alexander, M.E.; Thomas, D.A. (Issue Coordinators). 2003b. Wildland Fire Behavior Case Studies and Analyses: Part 2. Fire Management Today 63(4): 1-91.

Alexander, M.E.; Thomas, D.A. (Issue Coordinators). 2006. Prescribed Fire Case Studies, Decision Aids, and Planning Guides. Fire Management Today 66(1): 1-99. [*in press.*]

Andrews, P.L.; Bevins, C.D.; Seli, R.C. 2003. BehavePlus fire modeling system, version 2.0: user's guide. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado. General Technical Rep RMRS-GTR-106WWW. 132 pp.

Brown, J.K. 1978. Appraisal of fuels and fire potential. USDA Forest Service, Intermountain Forest and Range Experiment Station, Northern Forest Fire Laboratory, Missoula, Montana. 15 pp.

Butler, B.W.; Finney, M.A.; Andrews, P.L.; Albini, F.A. 2004. A radiation-driven model for crown fire spread. Canadian Journal of Forest Research 34: 1588-1599.

Cruz, M.G. 2004. Ignition of crown fuels above a spreading surface fire. Ph.D. Thesis, University of Montana, Missoula, MT. 240 pp.

Cruz, M.G.; Alexander, M.E.; Viegas, D.X. 2005. Modificação da estrutura de povoamentos florestais para redução do potencial do comportamento do fogo: modelação vs. realidade. Page 237 *in* Silva, R.; Pascoa, F., eds. A Florest e as Gentes - Resumo das Comunicacoes Apresentadas ao 5 Congresso Florestal Nacional (May 16-19, 2005, Viseu, Portugal). Sociedade Portuguesa de ciencias florestais, Lisbon, Portugal.

Cruz, M.G.; Alexander, M.E.; Wakimoto, R.H. 2003a. Assessing canopy fuel stratum characteristics in crown fire prone fuel types of western North America. International Journal of Wildland Fire 12: 39-50.

Cruz, M.G.; Alexander, M.E.; Wakimoto, R.H. 2003b. Assessing the probability of crown fire initiation based on fire danger indices. Forestry Chronicle 79: 976-983.

Cruz, M.G.; Alexander, M.E.; Wakimoto, R.H. 2004. Modeling the likelihood of crown fire occurrence in conifer forest stands. Forest Science 50: 640-658.

Cruz, M.G.; Alexander, M.E.; Wakimoto, R.H. 2005. Development and testing of models for predicting crown fire rate of spread in conifer forest stands. Canadian Journal of Forest Research 35: 1626-1639.

Cruz, M.G.; Butler, B.W.; Alexander, M.E.; Forthofer, J.M.; Wakimoto, R.H. 2006. Predicting the ignition of crown fuels above a spreading surface fire. Part I: Model idealization. International Journal of Wildland Fire 15: [*in press.*]

Cruz, M.G.; Butler, B.W.; Alexander, M.E. 2006. Predicting the ignition of crown fuels above a spreading surface fire. Part II: Model behavior and evaluation. International Journal of Wildland Fire 15: [*in press.*]

Cruz, M.G.; Lopes, A.M.G.; Alexander, M.E. 2005. CFIS: Simulation of crown fire initiation and spread. Version 2.0. Associação para o Desenvolvimento da Aerodinâmica Industrial, Coimbra, Portugal and Forest Engineering Research Institute, Hinton, Alberta. Visual Basic Software. (**http://www2.dem.uc.pt/antonio.gameiro/ficheiros/CFIS.exe**)

Stocks, B.J.; Alexander, M.E.; Lanoville, R.A. 2004. Overview of the International Crown Fire Modelling Experiment (ICFME). Canadian Journal of Forest Research 34: 1543-1547.

---

[1] Dr. Alexander recently made a presentation entitled "Latest Developments in Crown Fire Behavior Prediction" at the Interior West Fire Council Annual Meeting in Canmore, AB, October 25-27, 2005, were he outlined the development of a user-friendly computer program called "Crown Fire Initiation and Spread" (CFIS) based on these models. Copies of the current version of the CFIS software (Cruz, Lopes, Alexander 2005).

Home