JFSP Crown Fire Behavior Synthesis Project

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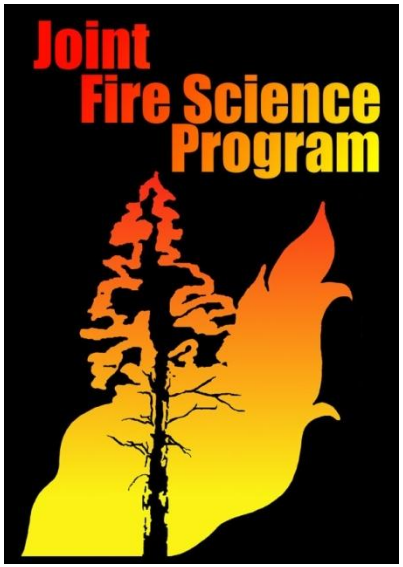
PNW Fire Behavior Workshop – January 17-20, 2012, Vancouver, WA

As for big fires in the early history of the Forest Service, a young ranger made himself famous by answering the big question on an exam, "What would you do to control a crown fire?" with the one-liner, "Get out of the way and pray like hell for rain."

Maclean (1992)

In October 2009, a 3-year project supported by the Joint Fire Science Program was initiated that aims to synthesize the currently available information on crown fire behavior in conifer forests (e.g., the onset of crowning, type of crown fire and the associated spread rate and fireline intensity).



Project Team Members

Marty Alexander, University of Alberta, Edmonton, Alberta

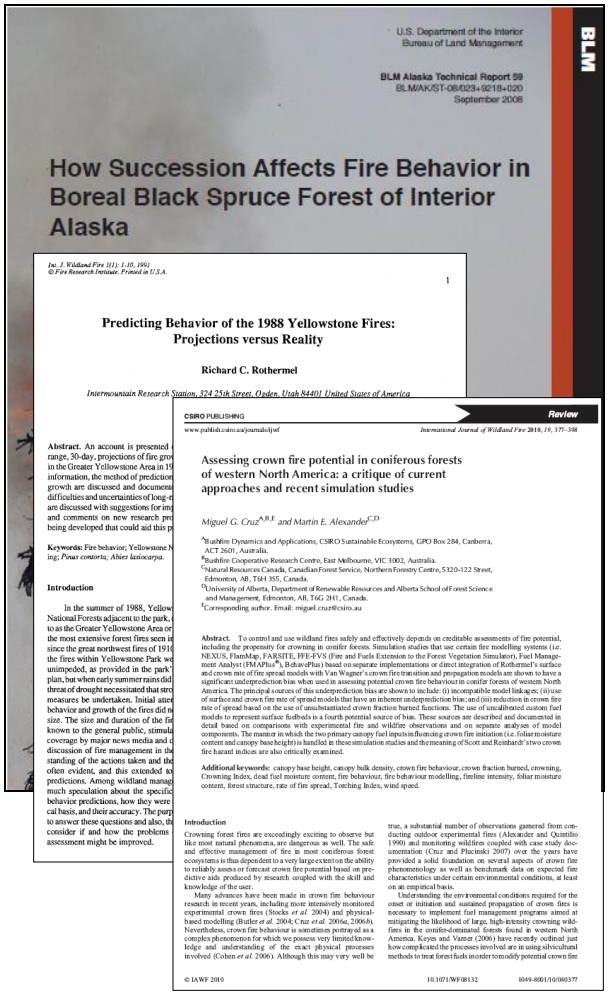
Miguel Cruz, CSIRO Bushfire Dynamics & Applications, Canberra, Australia

Nicole Vaillant, USDA Forest Service, Western Wildland Environmental Threat Assessment Center, Sparks, Nevada

Dave Peterson, USDA Forest Service, Pacific Wildland Fire Sciences Laboratory, Seattle, Washington

A critical synthesis on crown fire behavior must rest upon as solid a foundation of knowledge as is possible at this time.

A sufficient body of scientific, peer-reviewed and technical literature of a practical nature does in fact presently exist to be able undertake a synthesis on crown fire behavior.



U.S. Department of the Interior
Bureau of Land Management

BLM Alaska Technical Report 59
BLM/AK/ST-08/023+9218+020
September 2008

BLM

How Succession Affects Fire Behavior in Boreal Black Spruce Forest of Interior Alaska

Int. J. Wildland Fire 1(1): 1-10, 1991
© *Fire Research Institute. Printed in U.S.A.*

1

Predicting Behavior of the 1988 Yellowstone Fires: Projections versus Reality

Richard C. Rothermel

Intermountain Research Station, 324 25th Street, Ogden, Utah 84401 United States of America

Abstract. An account is presented
range, 30-day, projections of fire gro
in the Greater Yellowstone Area in 19
information, the method of prediction
growth are discussed and documente
difficulties and uncertainties of long-r
are discussed with suggestions for im
and comments on new research pro
being developed that could aid this p

Keywords: Fire behavior; Yellowstone N
ing; *Pinus contorta; Abies lasiocarpa.*

Introduction

In the summer of 1988, Yellow
National Forests adjacent to the park,
to as the Greater Yellowstone Area or
the most extensive forest fires seen in
since the great northwest fires of 191
the fires within Yellowstone Park we
unimpeded, as provided in the park'
plan, but when early summer rains did
threat of drought necessitated that stro
measures be undertaken. Initial aner
behavior and growth of the fires did n
size. The size and duration of the fir
known to the general public, stimula
coverage by major news media and
discussion of fire management in th
standing of the actions taken and the
often evident, and this extended to
predictions. Among wildland manag
much speculation about the specific
behavior predictions, how they were
cal basis, and their accuracy. The purp
to answer these questions and also, th
consider if and how the problems
assessment might be improved.

CSIRO PUBLISHING
www.publish.csiro.au/journals/ijwf

Review

International Journal of Wildland Fire 2010, *19*, 377–398

Assessing crown fire potential in coniferous forests of western North America: a critique of current approaches and recent simulation studies

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[B]Bushfire Cooperative Research Centre, East Melbourne, VIC 3002, Australia.
[C]Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, 5320-122 Street, Edmonton, AB, T6H 3S5, Canada.
[D]University of Alberta, Department of Renewable Resources and Alberta School of Forest Science and Management, Edmonton, AB, T6G 2H1, Canada.
[E]Corresponding author. Email: miguel.cruz@csiro.au

Abstract. To control and use wildland fires safely and effectively depends on creditable assessments of fire potential, including the propensity for crowning in conifer forests. Simulation studies that use certain fire modelling systems (i.e. NEXUS, FlamMap, FARSITE, IFE-FVS (Fire and Fuels Extension to the Forest Vegetation Simulator), Fuel Management Analyst (FMAPlus®), BehavePlus) based on separate implementations or direct integration of Rothermel's surface and crown rate of fire spread models with Van Wagner's crown fire transition and propagation models are shown to have a significant underprediction bias when used in assessing potential crown fire behaviour in conifer forests of western North America. The principal sources of this underprediction bias are shown to include: (i) incompatible model linkages; (ii) use of surface and crown fire rate of spread models that have an inherent underprediction bias; and (iii) reduction in crown fire rate of spread based on the use of unsubstantiated crown fraction burned functions. The use of uncalibrated custom fuel models to represent surface fuelbeds is a fourth potential source of bias. These sources are described and documented in detail based on comparisons with experimental fire and wildfire observations and on separate analyses of model components. The manner in which the two primary canopy fuel inputs influencing crown fire initiation (i.e. foliar moisture content and canopy base height) is handled in these simulation studies and the meaning of Scott and Reinhardt's two crown fire hazard indices are also critically examined.

Additional keywords: canopy base height, canopy bulk density, crown fire behaviour, crown fraction burned, crowning, Crowning Index, dead fuel moisture content, fire behaviour, fire behaviour modelling, fireline intensity, foliar moisture content, forest structure, rate of fire spread, Torching Index, wind speed.

Introduction

Crowning forest fires are exceedingly exciting to observe but like most natural phenomena, are dangerous as well. The safe and effective management of fire in most coniferous forest ecosystems is thus dependent to a very large extent on the ability to reliably assess or forecast crown fire potential based on predictive aids produced by research coupled with the skill and knowledge of the user.

Many advances have been made in crown fire behaviour research in recent years, including more intensively monitored experimental crown fires (Stocks *et al.* 2004) and physical-based modelling (Butler *et al.* 2004; Cruz *et al.* 2006*a*, 2006*b*). Nevertheless, crown fire behaviour is sometimes portrayed as a complex phenomenon for which we possess very limited knowledge and understanding of the exact physical processes involved (Cohen *et al.* 2006). Although this may very well be true, a substantial number of observations garnered from conducting outdoor experimental fires (Alexander and Quintilio 1990) and monitoring wildfires coupled with case study documentation (Cruz and Plucinski 2007) over the years have provided a solid foundation on several aspects of crown fire phenomenology as well as benchmark data on expected fire characteristics under certain environmental conditions, at least on an empirical basis.

Understanding the environmental conditions required for the onset or initiation and sustained propagation of crown fires is necessary to implement fuel management programs aimed at mitigating the likelihood of large, high-intensity crowning wildfires in the conifer-dominated forests found in western North America. Keyes and Varner (2006) have recently outlined just how complicated the processes involved are in using silvicultural methods to treat forest fuels in order to modify potential crown fire

10.1071/WF08132 1049-8001/10/060377

Getting the word out

A Synthesis on Crown Fires in Conifer Forests is Underway

Martin E. Alexander

The Joint Fire Science Program (JFSP) has elected to support a project aimed at synthesizing the currently available information on the characteristics and prediction of crown fire behavior in conifer forests (Alexander and others 2010). This would include such facets of crown fire behavior as the onset of crowning and the type of crown fire (passive, active, independent) and the associated spread rate and fireline intensity in relation to the wildland fire environment (i.e., fuels, weather, and topography).

While the focus is on North American forests, the synthesis is intended to be global in nature and is intended for multiple audiences ranging from the general public to college students, fire and land managers, university professors, and other researchers.

In addition to summarizing the existing scientific and technical literature on the subject, project members are also actively seeking assistance from individuals in the form of field observations of crown fires and related experiences as well as still pictures and video footage.

We are interested in hearing from you, the wildland fire community, as to your opinions on the subject of crown fires and any specific questions, research needs, or knowledge gaps that you would like to see addressed or discussed in this crown fire synthesis project. Feel free to contact any project team member.

Rapelje Lake Fire burning in Subalpine fir at about 9,000 feet (2,000 m) elevation near the Continental Divide on the Jim Bridger Wilderness, Bridger-Teton National Forest, WY. Photo: Richard Clappole, Forest Service, Klamath National Forest, Happy Camp Ranger District, CA, 1988.

To learn more about JFSP Project 09-S-03-1 and ensuing developments, visit the crown fire synthesis project Web site at <http://www.fs.fed.us/wwetac/projects/alexander.html>.

Reference

Alexander, M.E.; Cruz, M.G.; Vaillant, N.M.; Peterson, D.L. 2010. Towards a crown fire synthesis: what would you like to know and what might you be able to contribute? In: Proceedings of 3rd Fire Behavior and Fuels Conference, 25–29 October 2010, Spokane, WA. Birmingham, AL: International Association of Wildland Fire. CD-ROM.

JFSP Crown Fire Synthesis Project Team Members

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Dr. Miguel G. Cruz, Research Scientist, CSIRO Ecosystem Sciences and Climate Adaptation Flagship—Bushfire Dynamics and Applications, Canberra, Australian Capital Territory, Australia (miguel.cruz@csiro.au).

Dr. Nicole M. Vaillant, Fire Ecologist, Forest Service, Pacific Northwest Research Station, Western Wildland Environmental Threat Assessment Center, Sparks, NV (nvaillant@fs.fed.us).

Dr. David L. Peterson, Biological Scientist, Forest Service, Pacific Northwest Research Station, Wildland Fire Sciences Laboratory, Seattle, WA (peterson@fs.fed.us).

Dr. Marty Alexander is an adjunct professor of wildland fire science and management to the Department of Renewable Resources and Alberta School of Forest Science and Management at the University of Alberta in Edmonton, Alberta, Canada.

Proceedings of 3rd Fire Behavior and Fuels Conference, October 25-29, 2010, Spokane, Washington, USA
Published by the International Association of Wildland Fire, Birmingham, Alabama, USA

**Towards a crown fire synthesis:
what would you like to know and what might you be able to contribute?**

Martin E. Alexander[A,E], Miguel G. Cruz[B], Nicole M. Vaillant[C], and David L. Peterson[D]

[A]University of Alberta, Department of Renewable Resources and Alberta School of Forest Science and Management, Edmonton, AB, T6G 2H1, Canada.
[B]CSIRO Ecosystem Sciences and CSIRO Climate Adaptation Flagship - Bushfire Dynamics and Applications, GPO Box 284, Canberra, ACT 2601, Australia.
[C]USDA Forest Service, Pacific Northwest Station, Western Wildland Environmental Threat Assessment Center, 1200 Franklin Way, Sparks, NV, 89431, USA.
[D]USDA Forest Service, Pacific Northwest Station, Pacific Wildland Fire Sciences Laboratory, 400 N 34th Street, Suite 201, Seattle, WA, 98103, USA.
[E]Corresponding author. Email: mea2@telus.net

…am associated with the Joint Fire Science Program (JFSP) …wn Fire Behavior Characteristics and Prediction in Conifer …esis" are actively seeking help and input from members of …orm of photo documentation of crown fires and suggestions …itten product.

…havior, crown fire initiation, crown fire propagation, crown

…am (JFSP) elected to support a project to undertake a state …ct of crown fire behavior characteristics and prediction in …ed to be completed by October 2012. The purpose of this …ckground information on the project and at the same time …l fire community for their input and assistance.

…l is on synthesizing the currently available information on …er forests (e.g. onset of crowning, type of crown fire and …tensity) in relation to the wildland fire environment (i.e. …rmation on crown fire behavior is available from several …ding the seminal articles by Van Wagner (1977, 1993) on … 1989) on fire behavior in immature and mature jack pine …*f Forest Research* as well as the special issue on the …Experiment (Butler *et al.* 2004*a*, 2004*b*; Stocks *et al.* 2004; …ecently developed and tested models for predicting passive …l (Cruz *et al.* 2005; Alexander and Cruz 2006). Additional …avior can be found in *Forest Science* (Cruz et al. 2004), *International Journal of Wildland Fire* (Cruz *et al.* 2003*c*, 2006*a*, 2006*b*; Cruz and Alexander 2010), *Forestry Chronicle* (Cruz *et al.* 2003*b*), and *Australian Forestry* (Cruz *et al.* 2008).

CROWN FIRES IN CONIFER FORESTS OF THE WORLD: Do you have something to contribute or would like to know about something?

M.G. Cruz, M.E. Alexander, N.M. Vaillant & D.L. Peterson

In October 2009, a 3-year project supported by the Joint Fire Science Program was initiated that aims to synthesize the currently available information on crown fire behavior in conifer forests.

While the focus is on the coniferious forests of the United States and adjacent areas of Canada, the synthesis is intended to be global in nature and is intended for multiple audiences ranging from the general public to college students to fire and land managers to university professors and other researchers.

Information from all regions of the world would be appreciated, including Mexico, South Africa, Australasia, Euope, Central and South America, Europe and Asia.

Active crown fire in Pinus radiata New South Wales

Active crown fire in Pinus pinaster, Portugal

In addition to summarizing the existing scientific and technical literature on crown fires, project members are also seeking assistance from individuals in the form of field observations of crown fires and related experiences as well as still pictures and video footage in both natural forest stands and industrial plantations.

Finally, we are interested in hearing from you -- the "**end user**" -- as to your opinions on the subject of crown fires and any specific questions and/or research needs/knowledge gaps that you would like to see addressed in this crown fire synthesis project.

To keep up to date on the crown fire synthesis project periodically visit our website:

http://www.fs.fed.us/wwetac/projects/alexander.html

miguel.cruz@csiro.au

Throughout the process there has been liaison and dialogue with:

Fire Behavior Subcommittee

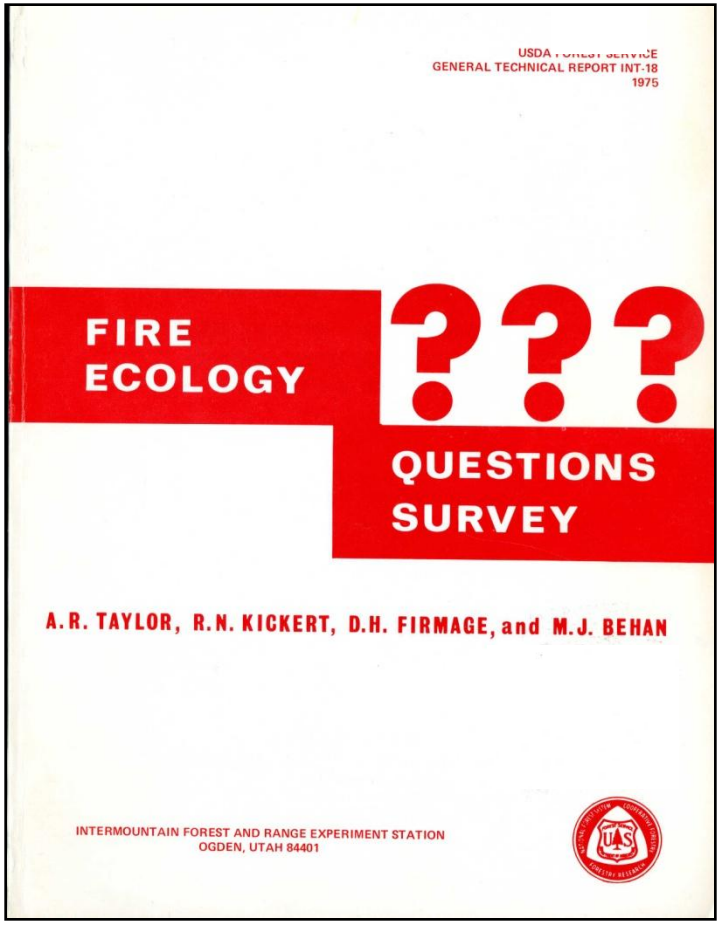
Conference calls and a in person meeting. Progress reports and provided documents. E-mails. Reviews by FBSC members.

In addition to summarizing the existing scientific and technical literature on crown fires, project members are also seeking assistance from individuals in the form of field observations of crown fires and related experiences as well as still pictures and video footage.

Finally, we are interested in hearing from you -- the "end user" -- as to your opinions on the subject of crown fires and any specific questions and/or research needs/knowledge gaps that you would like to see addressed in this crown fire synthesis project. For example:

What fuel-weather combinations are required to produce a propagating crown fire in northern flatwood forests? – Rodney W. Sando *et al.* (1970)

Another example: In a fire ecology survey of land managers and environmental scientists in western North America conducted in the early 70s, several questions were raised that dealt with aspects of crown fire potential:

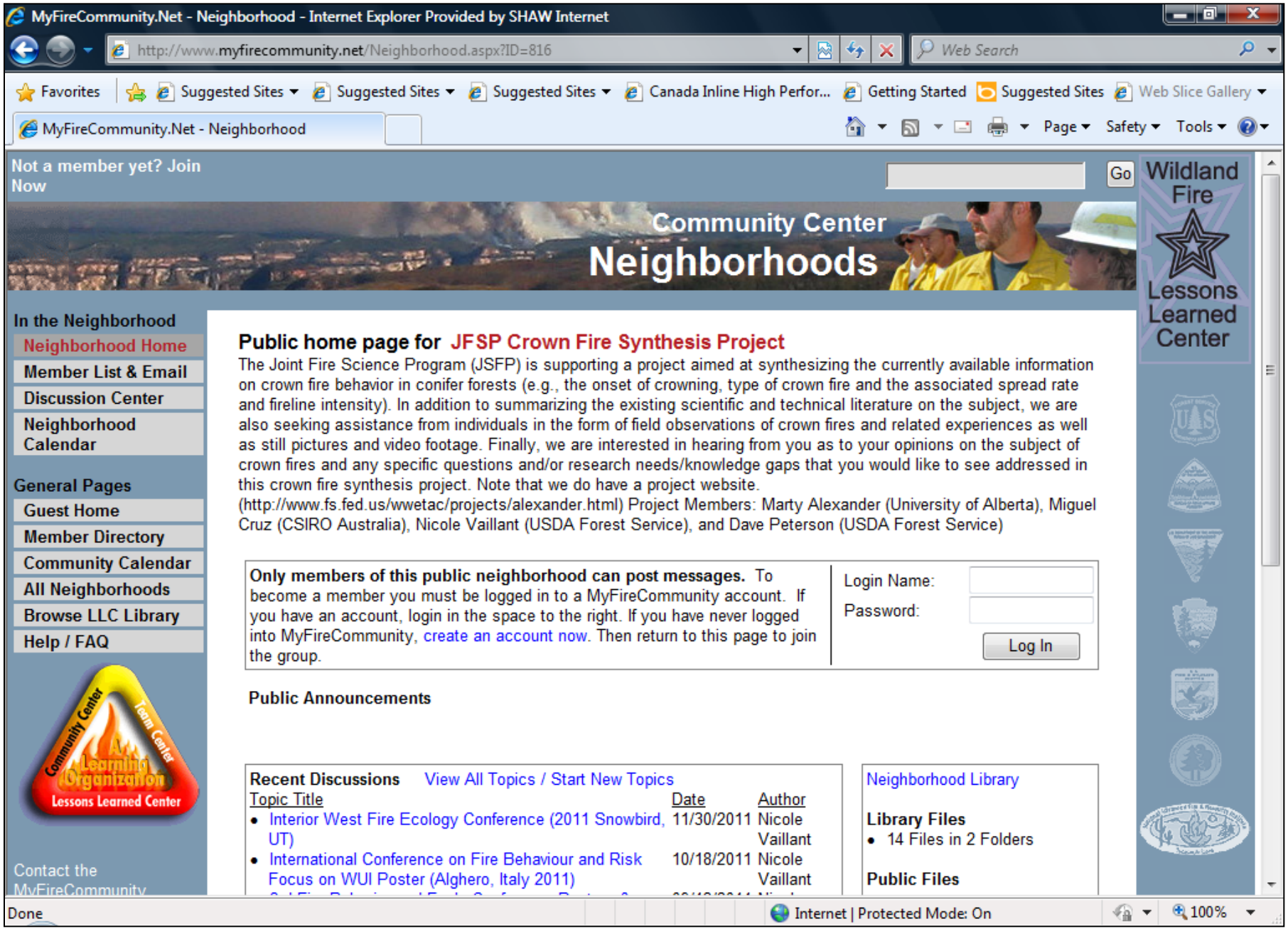


Will fire in a thinned stand tend to stay on the ground as opposed to crowning? What are the effects of various spacings? What spacing inhibits spread of [crown] fire?

How many tons/acre of fuel are required to support a crown fire in ponderosa pine and in mixed conifer forest in the Southwest?

What stand and crown density is required to carry a fire in standing pinon-juniper stands?

Over 6,000 invitations sent out to join the *Neighborhood*

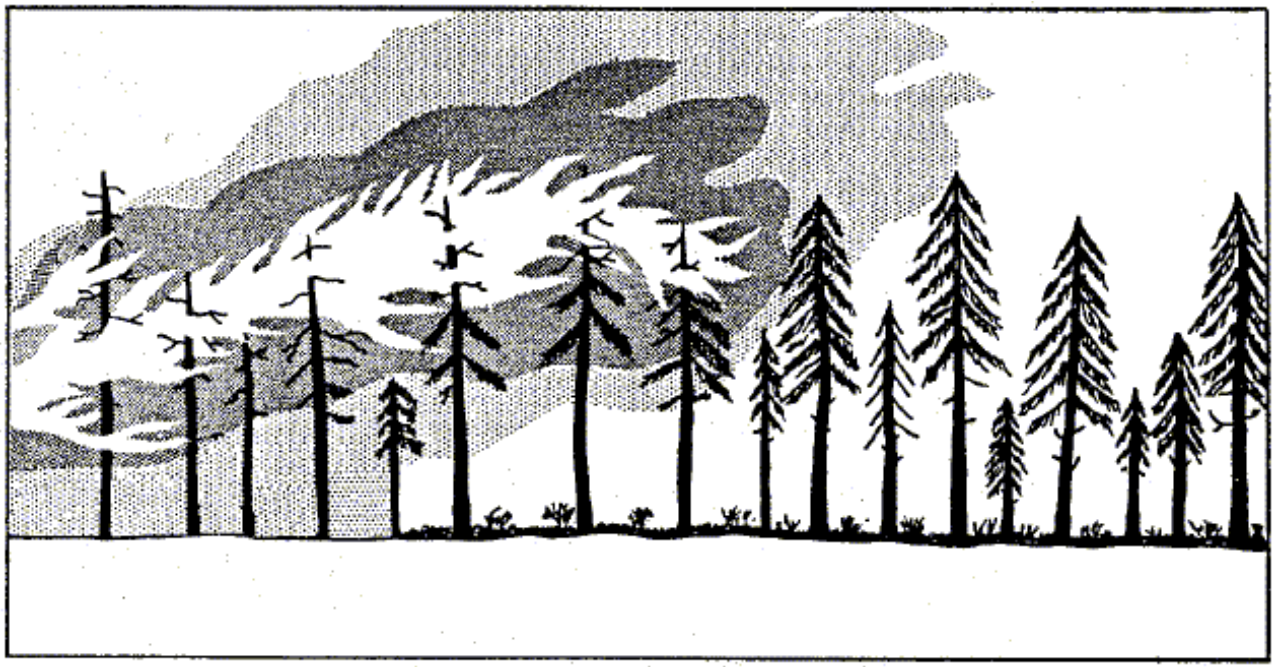


Topical Issue #1

Independent Crown Fire

"The crown phase will ... No longer depend in any way on the surface phase and can run ahead on its own." – Van Wagner (1977)

- **Is this possible, have you seen it?**
- **Long term or short term phenomena?**
- **Crowning over snow or rock slide**



Adapted from Brown and Davis (1973)

Topical Issue #2

Conditional Crown Fire

The possibility exists for a stand to support an active crown fire that would otherwise not initiate a crown fire (Scott and Reinhardt 2001).

- Relatively high CBH and CBD where CI < TI.
- More extreme conditions (of wind and fuel moisture) are required to initiate crown fire than to maintain active crown fire.

Fire Type		Active crown fire?	
		No	Yes
Transition to crown fire?	No	Surface Fire	Conditional Crown Fire
	Yes	Passive Crown Fire	Active Crown Fire

Topical Issue #3

Crown Fire Cessation

What causes crown fires to stop?

- Major change in fuel type,
- Wind changes (speed or direction),
- Moisture differential,
- Combination,
- Other factors ??

Topical Issue #4

Spot Fire Distances
> 2 miles from Active Crown Fires

Open Discussion

#1 Independent Crown Fire

#2 Conditional Crown Fire

#3 Crown Fire Cessation

#4 Spot Fire Distances
> 2 miles from Active Crown Fires

Interim Products:
Review of "Crown Fire" Content in 'S' Fire Behavior Courses (190, 290, 390 & 490)

Introduction to Wildland Fire Behavior
S-190

NFES 2900

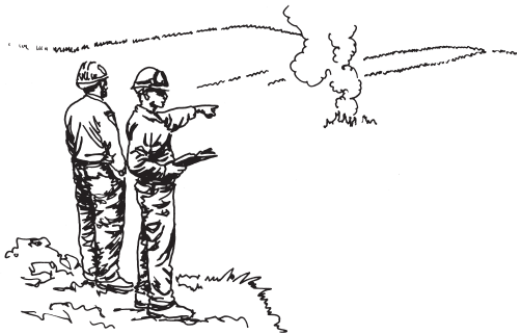
Intermediate Wildland Fire Behavior
S-290

DRAFT

NFES 0000

Instructor Guide
MONTH 200?

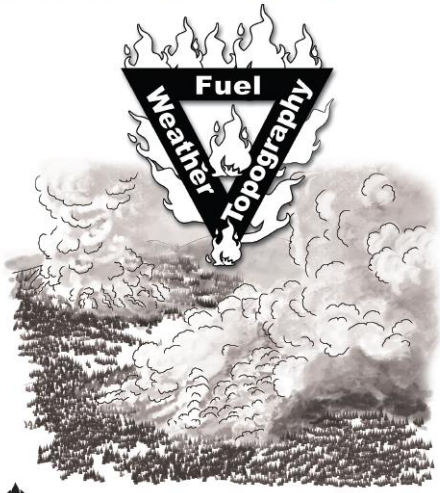
Introduction to Wildland Fire Behavior Calculations
S-390



NFES 2930

Instructor Guid
SEPTEMBER 200

S-490
Advanced Wildland Fire Behavior Calculations



NFES 001770

Instructor Guide
AUGUST 2010

Interim Products (cont.): Software

File Edit View Insert Format Tools Data Window Help

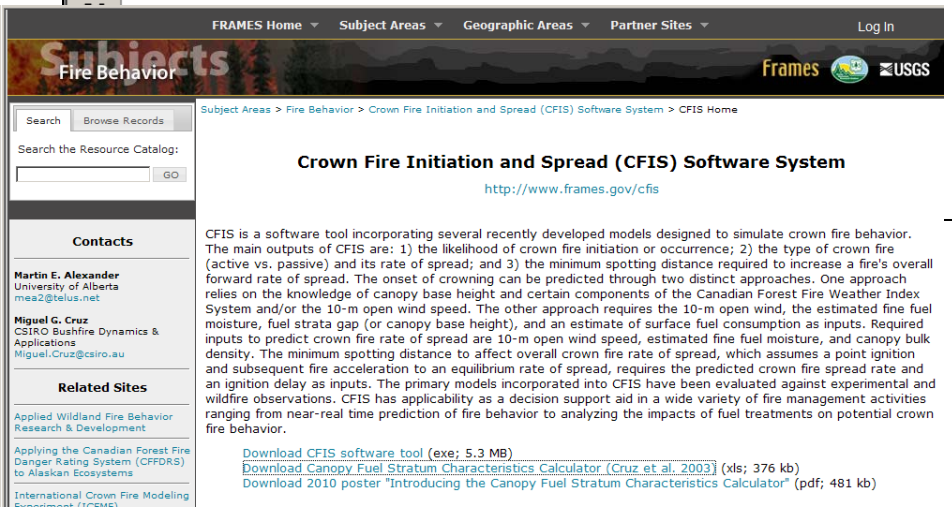
Cruz, Alexander and Wakimoto (2003)
Canopy Fuel Stratum Characteristics Calculator
Version 1.0 - February 2010

Inputs:

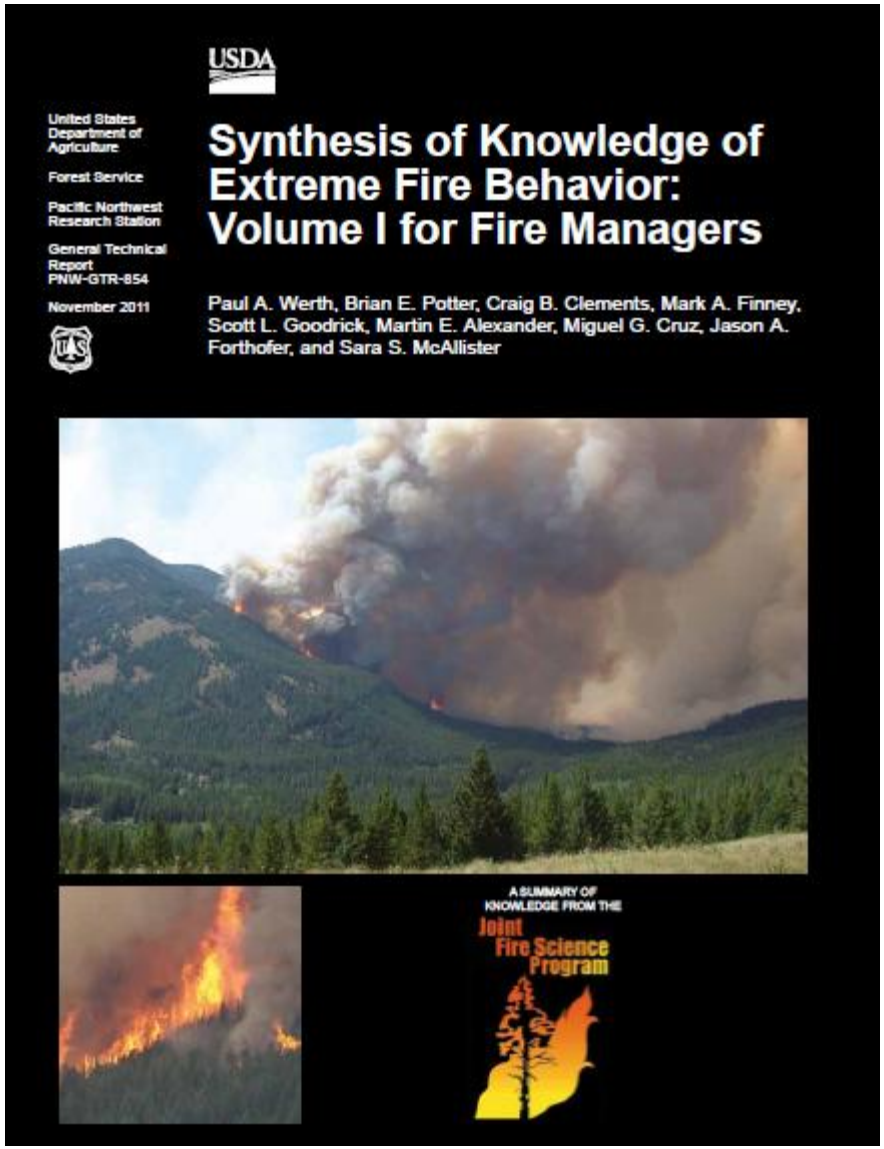
Step 1: Select Unit System	SI
Step 2: Select Fuel Type	Ponderosa pine
Step 3: Input Stand Basal Area (m2/ha)	25
Step 4: Input Average Stand Height (m)	15
Step 5: Input Stand Density (trees/ha)	1000

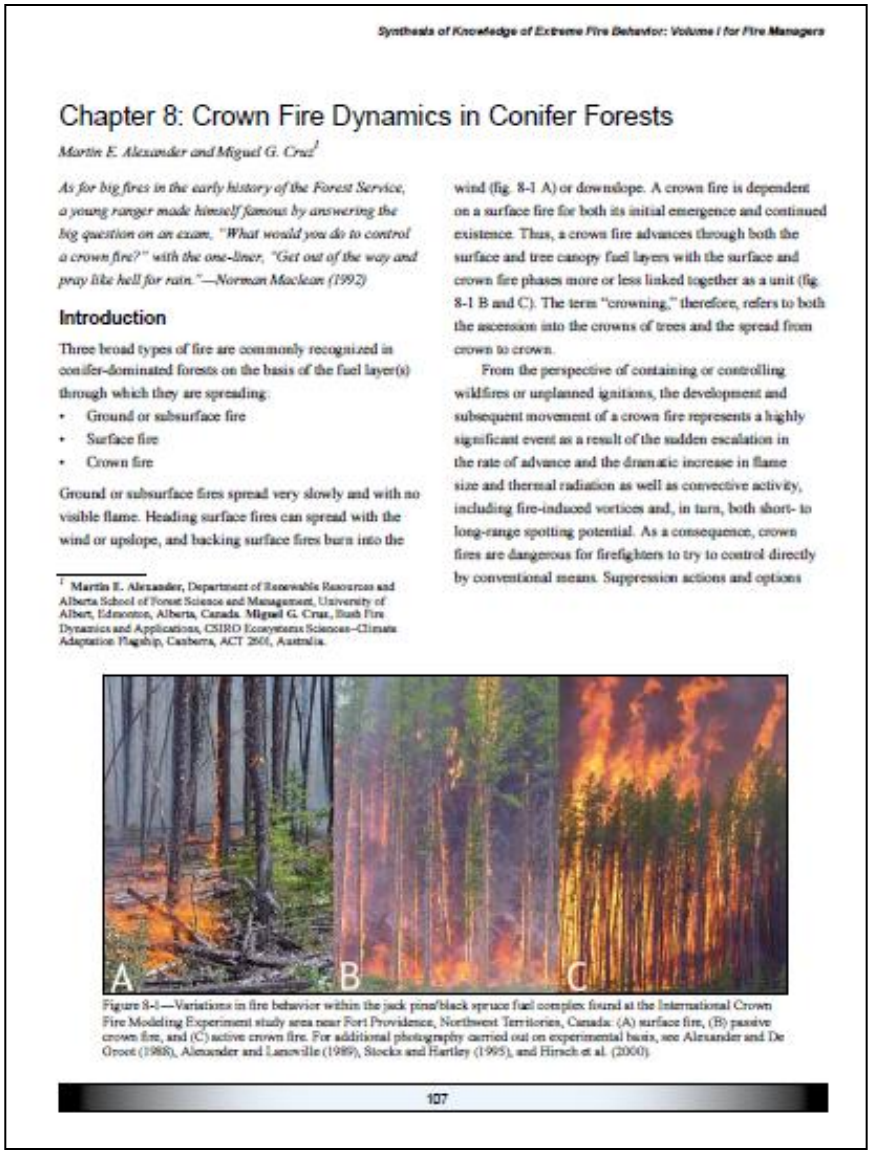
Outputs:

Canopy Base Height (m)	7.3
Canopy Fuel Load (kg/m2)	0.95
Canopy Bulk Density (kg/m3)	0.29



Interim Products (cont.)





Synthesis of Knowledge of Extreme Fire Behavior: Volume I for Fire Managers

Chapter 8: Crown Fire Dynamics in Conifer Forests

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

As for big fires in the early history of the Forest Service, a young ranger made himself famous by answering the big question on an exam, "What would you do to control a crown fire?" with the one-liner, "Get out of the way and pray like hell for rain."—Norman Maclean (1992)

Introduction

Three broad types of fire are commonly recognized in conifer-dominated forests on the basis of the fuel layer(s) through which they are spreading:

- Ground or subsurface fire
- Surface fire
- Crown fire

Ground or subsurface fires spread very slowly and with no visible flame. Heading surface fires can spread with the wind or upslope, and backing surface fires burn into the wind (fig. 8-1 A) or downslope. A crown fire is dependent on a surface fire for both its initial emergence and continued existence. Thus, a crown fire advances through both the surface and tree canopy fuel layers with the surface and crown fire phases more or less linked together as a unit (fig. 8-1 B and C). The term "crowning," therefore, refers to both the ascension into the crowns of trees and the spread from crown to crown.

From the perspective of containing or controlling wildfires or unplanned ignitions, the development and subsequent movement of a crown fire represents a highly significant event as a result of the sudden escalation in the rate of advance and the dramatic increase in flame size and thermal radiation as well as convective activity, including fire-induced vortices and, in turn, both short- to long-range spotting potential. As a consequence, crown fires are dangerous for firefighters to try to control directly by conventional means. Suppression actions and options

[1] Martin E. Alexander, Department of Renewable Resources and Alberta School of Forest Science and Management, University of Albert, Edmonton, Alberta, Canada. Miguel G. Cruz, Bush Fire Dynamics and Applications, CSIRO Ecosystems Sciences–Climate Adaptation Flagship, Canberra, ACT 2601, Australia.

Figure 8-1—Variations in fire behavior within the jack pine/black spruce fuel complex found at the International Crown Fire Modeling Experiment study area near Fort Providence, Northwest Territories, Canada: (A) surface fire, (B) passive crown fire, and (C) active crown fire. For additional photography carried out on experimental burns, see Alexander and De Groot (1988), Alexander and Lanoville (1989), Stocks and Hartley (1995), and Hirsch et al. (2000).

Volume II chapter on crown fires has been completed and reviewed

Interim Products (cont.): Peer-reviewed publications

•Cruz MG & Alexander ME. 2012. Evaluating regression model estimates of canopy fuel stratum characteristics in four crown fire-prone fuel types in western North America. Int. J. Wildland Fire - available online

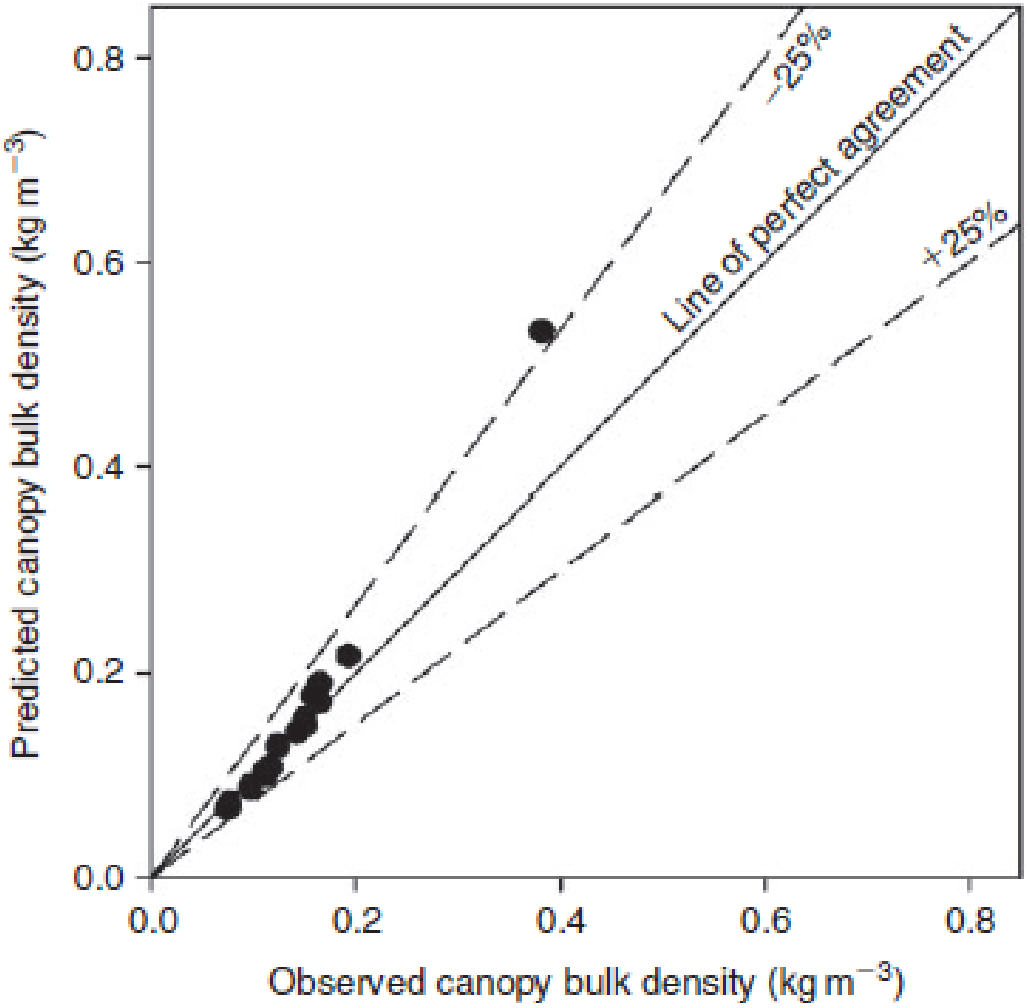
•Alexander ME & Cruz MG. 2012. Interdependencies between flame length and fireline intensity in predicting crown fire initiation and crown scorch height. Int. J. Wildland Fire - available online

•Albini FA, Alexander ME & Cruz MG. In press. A mathematical model for predicting the maximum potential spotting distance from a crown fire. Int. J. Wildland Fire - accepted, not available yet

•Alexander ME & Cruz MG. In press. Modelling the impacts of surface and crown fire behavior on serotinous cone opening in jack pine and lodgepole pine forests. Int. J. Wildland Fire - accepted, not available yet

•Alexander ME & Cruz MG. Assessing the effect of foliar moisture on the spread rate of crown fires. Submitted to the Int. J. Wildland Fire, Jan. 2012

Evaluating regression model estimates of canopy fuel stratum characteristics in four crown fire-prone fuel types in western North America.

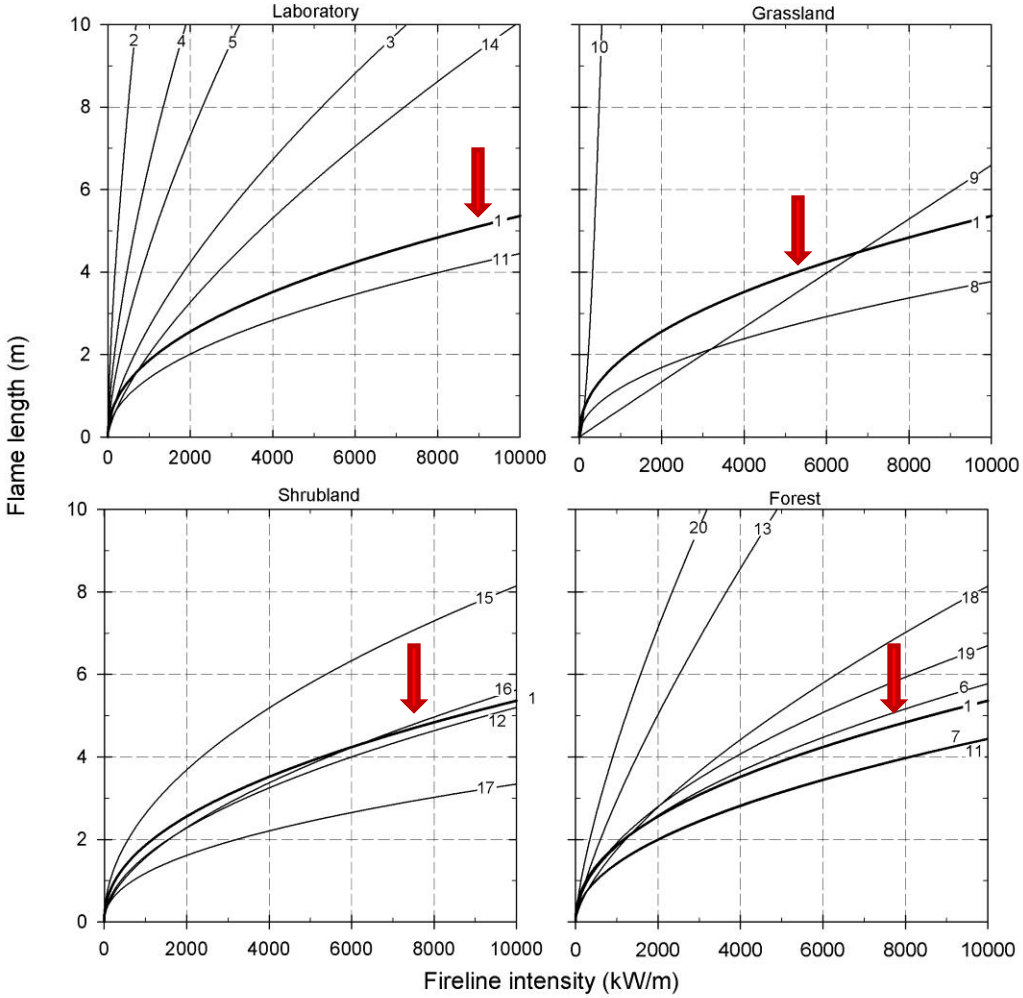


Observed vs. expected CBD for 16 PP stands in the Black Hills, SD

Evaluation of the Cruz et al. 2003 regression equations to predict CBH, CBD & CFL from stand characteristics

Comparison to original data treated and independent PP data set

Interdependencies between flame length and fireline intensity in predicting crown fire initiation and crown scorch height.



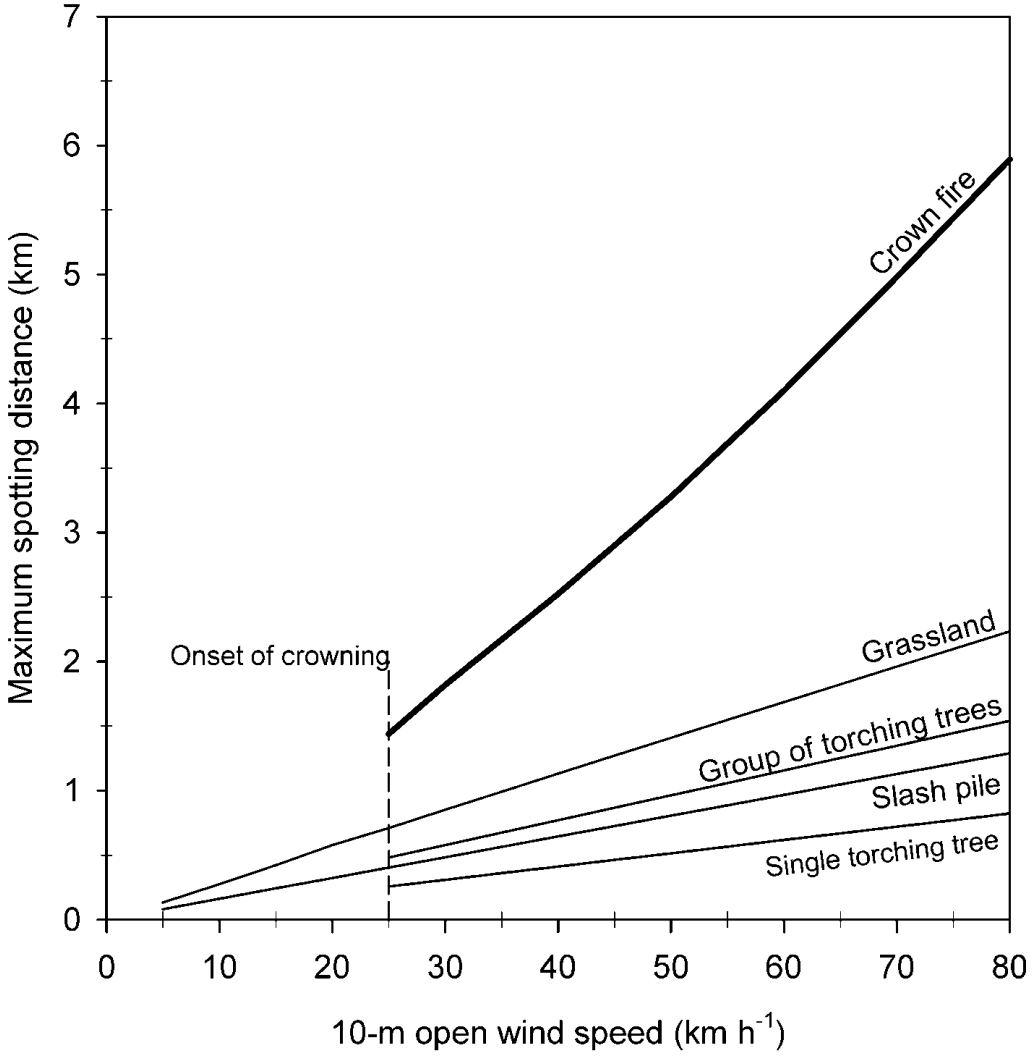
Comparison of FI – FL relationships for various models and fuel types

State-of-knowledge review of the assumptions and limitations associated with

- fireline intensity,
- flame length,
- char height, and
- crown scorch height

relationships.

A mathematical model for predicting the maximum potential spotting distance from a crown fire.



Spotting distances for different fuel types under specific conditions

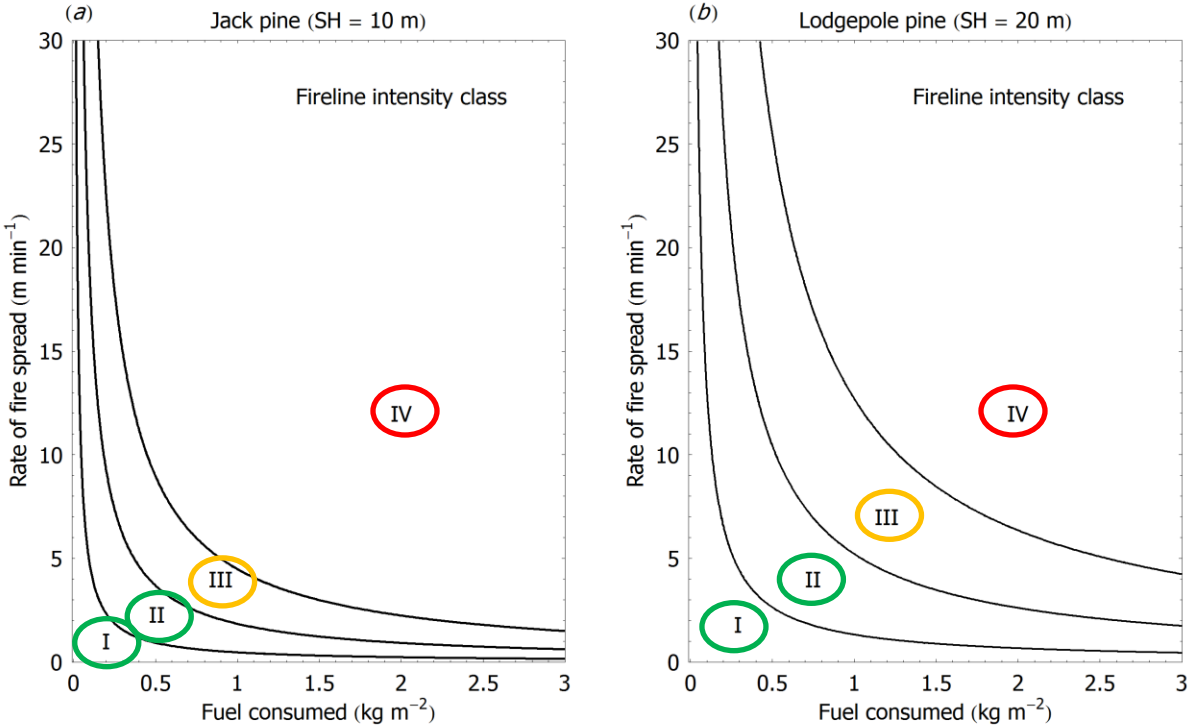
A mathematical model for predicting maximum spotting distance

- Multiple sub-models

Model inputs

- Flame height above canopy
- Windspeed at top of canopy
- Firebrand size

Modelling the impacts of surface and crown fire behavior on serotinous cone opening in jack pine and lodgepole pine forests.



Rate of spread, fuel consumption and fireline intensity can be used to define thresholds for opening serotinous cones and release of seed in JP & LP.

Fireline intensity class

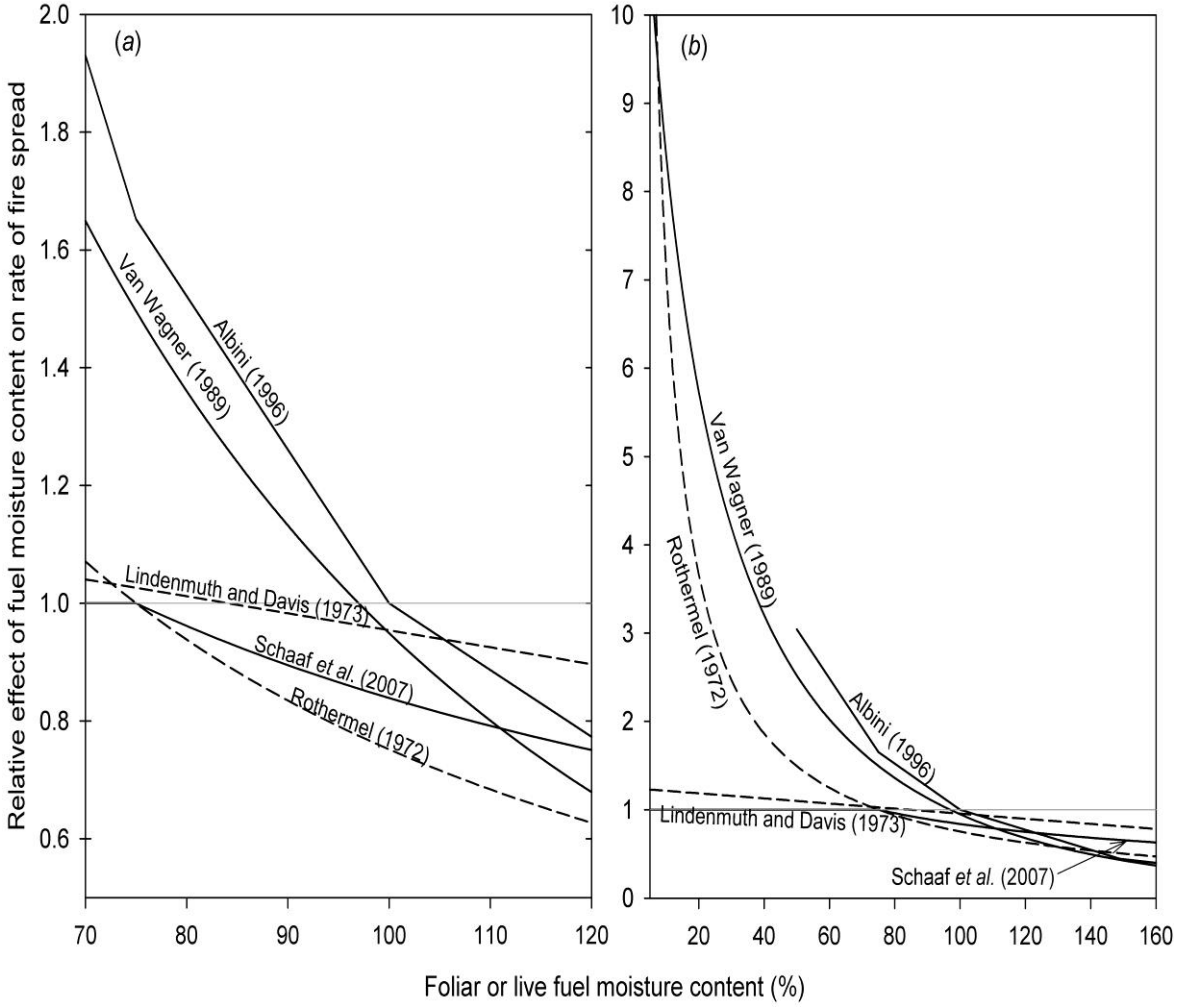
I – low intensity surface fire, no crown scorch, no cone opening

II – mod intensity surface fire, part to full crown scorch , no cone opening

III – high intesnity surface fire, full crown scorch, cone opening via convective & radiative heating

IV – crown fire, defoliation of crown, cone opening & charring via flame contact

Assessing the effect of foliar moisture on the spread rate of crown fires.



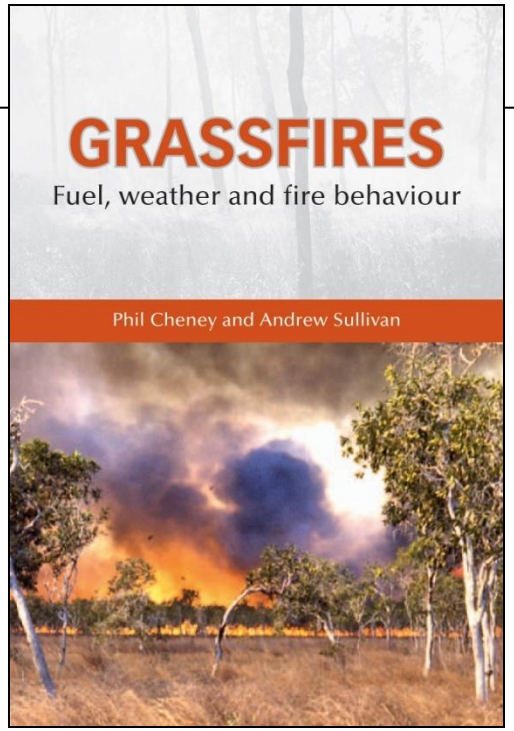
Digest and analysis of existing lab work, theories and experimental data related to the influence of live fuels/ foliar moisture on rate of spread of active crown fires for different spread models.

Relative effects of moisture on rate of spread for a) normal and b) extreme range of moisture

End Products

- ❑ Book (including a multi-media DVD featuring video imagery and other supporting documentation) pattern after "Grassfires"

- Text to be completed fall of 2012.
- Publication of book not likely until late 2013.
- Patterned after Australian grass fire behavior book.



End Products (cont.)

- Special issue of *Fire Management Today that will summarize the content of the book.*

Looking at early 2013 for publication.

Crown Fire Behavior Synthesis Project website