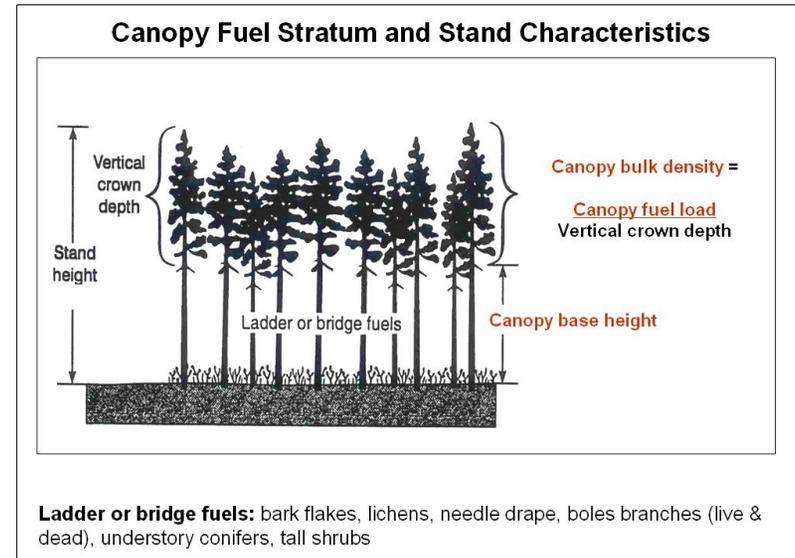


Introducing the *Canopy Fuel Stratum* *Characteristics Calculator*

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3rd Fire Behavior and Fuels Conference – October 25-29, 2010 – Spokane, WA

Cruz *et al.* (2003) developed regression equations for estimating canopy base height (CBH), canopy fuel load (CFL) and canopy bulk density (CBD) for use in assessing crown fire potential in four broad coniferous forest fuel types found in western North America.

CSIRO PUBLISHING
www.publish.csiro.au/journals/ijwf International Journal of Wildland Fire, 2003, 12, 39–50

Assessing canopy fuel stratum characteristics in crown fire prone fuel types of western North America

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Abstract. Application of crown fire behavior models in fire management decision-making has been limited by the difficulty of quantitatively describing fuel complexes, specifically characteristics of the canopy fuel stratum. To estimate canopy fuel stratum characteristics of four broad fuel types found in the western United States and adjacent areas of Canada, namely Douglas-fir, ponderosa pine, mixed conifer, and lodgepole pine forest stands, data from the USDA Forest Service's Forest Inventory and Analysis (FIA) database were analysed and linked with tree-level foliage dry weight equations. Models to predict canopy base height (CBH), canopy fuel load (CFL) and canopy bulk density (CBD) were developed through linear regression analysis and using common stand descriptors (e.g. stand density, basal area, stand height) as explanatory variables. The models developed were fuel type specific and coefficients of determination ranged from 0.90 to 0.95 for CFL, between 0.84 and 0.92 for CBD and from 0.64 to 0.88 for CBH. Although not formally evaluated, the models seem to give a reasonable characterization of the canopy fuel stratum for use in fire management applications.

Additional keywords: canopy base height; canopy bulk density; canopy fuel load; crown fire behavior; crown fuel dynamics.

Introduction

The growing complexity of deterministic fire behavior models implemented in fire management decision support systems requires that descriptions of fuel complex characteristics should be as accurate as possible given the existing resource and knowledge constraints. Until recently in the U.S. fuel complex characterization has been limited to surface fuel beds (e.g. Brown and See 1981; Brown and Bevins 1986) due to the restricted applicability of fire behavior models such as the BEHAVE system (Burgan and Rothermel 1984; Andrews 1986) to this fuel stratum. The development of fire behavior models and systems designed to predict crown fire behavior (Albini 1979, 1996; Van Wagner 1977, 1989; Forestry Canada Fire Danger Group 1992; Call and Albini 1997; Alexander 1998; Finney 1998; Scott and Reinhardt 2001) point out the need to describe the canopy fuel stratum. Based on an analysis of existing fire behavior models and physical reasoning, it is possible to isolate the relevant canopy fuel stratum characteristics that determine crown fire behavior. The canopy structural properties of a stand (e.g. cover, depth, shape, leaf area and leaf distribution) influence understory micrometeorology, and therefore influence certain factors of the fire environment such as subcanopy wind flow (Meyers and Paw U 1987; Amiro 1990) and seasonal and diurnal fuel moisture dynamics (Rothermel *et al.* 1986).

Since canopy fuels are the main fuel layer supporting crown fire spread, canopy structure largely determines combustion requirements and outputs, and consequently important fire behavior descriptors such as rate of fire spread and fire intensity (Byram 1959). With Finney's (1998) implementation of Van Wagner's (1977) crown fire initiation and spread models into the FARSITE fire growth simulator, information on CBD and CBH have become essential for fire management planning (Keane *et al.* 1998), although no method of easily quantifying these parameters is directly available to fire managers. Such information is needed for other crown fire potential assessment schemes (Alexander 1988; Graham *et al.* 1999; Keyes and O'Hara 2002).

Fuel complex characteristics commonly accepted as controlling crown fire spread are CFL, canopy fuel bulk density and CBH. When describing aerial fuels the term crown and canopy have often been used interchangeably without formal

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The Cruz *et al.* (2003) regressions for estimating the CBH, CFL and CBD of these fuel types have recently been evaluated for their performance*.

A simple software application (i.e., an excel spreadsheet) of the Cruz *et al.* (2003) equations has recently been developed.

* Cruz, M.G.; Alexander, M.E. Evaluating regression model estimates of canopy fuel stratum characteristics in four fuel types in western North America. Accepted for publication in the *International Journal of Wildland Fire* (subject to revision) 6 October 2010.

The main features of the *Canopy Fuel Stratum Characteristics Calculator* are:

- Provides for both SI or metric and English unit inputs/outputs.
- Given three user inputs (i.e., stand area basal area, average stand height and stand density), CBH, CFL and CBD are automatically calculated for one of the four fuel types.
- Cautionary “pop-up” messages for input values that exceed a maximum reliable value.

The *Canopy Fuel Stratum Characteristics Calculator* Introduction

Microsoft Excel - Cruz et al. (2003) Canopy Fuel Stratum Characteristics Calculator (October 2010)

File Edit View Insert Format Tools Data Window Help

Type a question for help

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

Canopy fuel stratum characteristics determine to a large extent the behavior of crown fires. By linking an extensive forest stand database with foliage dry weight allometric equations, we developed regression equations to estimate the following canopy fuel stratum characteristics[1]:

- Canopy base height (CBH)
- Canopy fuel load (CFL)
- Canopy bulk density (CBD)

Equations are available for the following fuel types that commonly occur in western North America:

- Ponderosa Pine
- Lodgepole Pine
- Douglas-fir
- Mixed Conifer

The Cruz et al. (2003) regressions for estimating the CBH, CFL and CBD of these four fuel types are included within the present software. The outputs will serve as inputs in predicting crown fire behavior potential using, for example, the Crown Fire Initiation and Spread (CFIS) software[2].

Canopy Fuel Stratum and Stand Characteristics

Vertical crown depth

Stand height

Ladder or bridge fuels

Canopy base height

Canopy bulk density =
Canopy fuel load
Vertical crown depth

Ladder or bridge fuels: bark flakes, lichens, needle drape, boles branches (live & dead), understory conifers, tall shrubs

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

[2] *Crown Fire Initiation and Spread (CFIS) Software System is available for downloading at the FRAMES website*

Introduction Calculations Acknowledgments

Ready

SI or Metric Unit Input/Output Example

Microsoft Excel - Cruz et al. (2003) Canopy Fuel Stratum Characteristics Calculator (October 2010)

File Edit View Insert Format Tools Data Window Help

Type a question for help

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C7 SI

Cruz, Alexander and Wakimoto (2003)
Canopy Fuel Stratum Characteristics Calculator
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Inputs:

Step 1: Select Unit System

Step 2: Select Fuel Type

Step 3: Input Stand Basal Area (m²/ha)

Step 4: Input Average Stand Height (m)

Step 5: Input Stand Density (trees/ha)

Outputs:

Canopy Base Height (m)

Canopy Fuel Load (kg/m²)

Canopy Bulk Density (kg/m³)

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Ready

English Unit Input/Output Example

The screenshot shows a Microsoft Excel spreadsheet with the following content:

Microsoft Excel - Cruz et al. (2003) Canopy Fuel Stratum Characteristics Calculator (October 2010)

File Edit View Insert Format Tools Data Window Help

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C7 English

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

Inputs:

Step 1: Select Unit System English

Step 2: Select Fuel Type Ponderosa pine

Step 3: Input Stand Basal Area (ft²/ac) 109

Step 4: Input Average Stand Height (ft) 49

Step 5: Input Stand Density (trees/ac) 405

Outputs:

Canopy Base Height (ft) 2.2

Canopy Fuel Load (tons/ha) 0.19

Canopy Bulk Density (lb/ft³) 0.02

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Ready

Example of a CAUTION Message for Exceeding Reliable Input Value

Microsoft Excel - Cruz et al. (2003) Canopy Fuel Stratum Characteristics Calculator (October 2010)

File Edit View Insert Format Tools Data Window Help

Type a question for help

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

Inputs:

Step 1: Select Unit System

Step 2: Select Fuel Type

Step 3: Input Stand Basal Area (m²/ha)

Step 4: Input Average Stand Height (m) **Caution! The maximum value in the original database used to develop the regression equation was approximately 20 m**

Step 5: Input Stand Density (trees/ha)

Outputs:

Canopy Base Height (m)

Canopy Fuel Load (kg/m²)

Canopy Bulk Density (kg/m³)

Introduction Calculations Acknowledgments

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Maximum Reliable Input Values in the
Canopy Fuel Stratum Characteristics Calculator

Conifer fuel type	Basal area (m²/ha)	Stand height (m)	Stand density (no./ha)
Ponderosa pine	40	1- 20	3000
Lodgepole pine	50	3-20	4000
Douglas-fir	55	2-25	3000
Mixed conifer	70	3-25	4000

Conifer fuel type	Basal area (ft²/acre)	Stand height (ft)	Stand density (no./acre)
Ponderosa pine	175	60	1200
Lodgepole pine	220	80	1200
Douglas-fir	240	80	1200
Mixed conifer	300	80	1600

The *Canopy Fuel Stratum Characteristics Calculator* can be download from the *FRAMES* website

The screenshot shows a web browser window titled "Crown Fire Initiation and Spread (CFIS) Software System". The address bar shows the URL: http://frames.nbii.gov/portal/server.pt?open=512&objID=753&mode=2&in_hi_userid=2&cached=true. The page features a navigation menu with "FRAMES Home", "Subject Areas", "Geographic Areas", and "Partner Sites". The main content area is titled "Crown Fire Initiation and Spread (CFIS) Software System" and contains a detailed description of the software tool. Below the description, there are two download links: "Download the CFIS software tool (5.3 MB executable file)" and "Download the Canopy Fuel Stratum Characteristics Calculator (Cruz et al. 2003) (376 kb Microsoft Excel file)". An orange arrow points to the second link. The left sidebar includes sections for "Browse Fire Behavior Records", "CFIS Contacts" (listing Martin E. Alexander and Miguel G. Cruz), and "Model Comparison". The bottom of the page shows a "CFIS Publications" section with a search form and a table of publications.

Browse Fire Behavior Records

- All Records
- Projects
- Tools
- Documents
- Webpages
- Data
- Programs

CFIS Contacts

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Model Comparison

Interested in how **CFIS** outputs compare with **NEXUS** and **FlamMap**? Check out

Crown Fire Initiation and Spread (CFIS) Software System

CFIS is a software tool incorporating several recently developed models designed to simulate crown fire behavior. The main outputs of CFIS are: 1) the likelihood of crown fire initiation or occurrence; 2) the type of crown fire (active vs. passive) and its rate of spread; and 3) the minimum spotting distance required to increase a fire's overall forward rate of spread. The onset of crowning can be predicted through 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. The other approach requires the 10-m open wind, the estimated fine fuel moisture, fuel strata gap (or canopy base height), and an estimate of surface fuel consumption as inputs. Required inputs to predict crown fire rate of spread are 10-m open wind speed, estimated fine fuel moisture, and canopy bulk density. 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. The primary models incorporated into CFIS have been evaluated against experimental and wildfire observations. 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.

[Download the CFIS software tool](#) (5.3 MB executable file)

[Download the Canopy Fuel Stratum Characteristics Calculator \(Cruz et al. 2003\)](#) (376 kb Microsoft Excel file)

CFIS Publications

Limit Search

Description (Full) Contains

Search

Name	Person (Last Name)	Year
Assessing canopy fuel stratum characteristics in crown fire prone fuel types of western North America	Cruz, Alexander, Wakimoto	2003
Assessing the probability of crown fire initiation based on fire		

Canopy Fuel Calculations: Homework #3

Your fuels crew was able to inventory three different areas in the Black Hills, S.D. over the past month. Each of these areas has been selected as a potential for thinning operations to reduce the risk of crown fire hazard. All surface fuel calculations have been completed, but the canopy fuels have not been calculated as of yet. I have provided you with an excel spread sheet which contains 3 workbooks. The first one is labeled load over depth, the 2nd Cruz and the third canopy profile.

The *Canopy Fuel Stratum Characteristics Calculator* was informally tested by a group of undergraduate students at the University of Idaho in April 2010 as part of a fire management course exercise.

According to their instructor, Chad Hoffman, “The class really liked the calculator. They thought it was easy to use and very straight forward ... Several of the students decided to recommend this approach in the fuels inventory plan they are developing ...”.

- Estimate the canopy bulk density using the biomass percentile load over depth method.
- Estimate the canopy bulk density as the highest 9 foot running mean
- Estimate the canopy base height as the point where at least 0.011 kg/m³ occurs.

Present your Canopy bulk density estimates and canopy base height estimates in a table.

Reminder: make sure you have all table and figures correctly labeled with a title.

For further information or questions about the *Canopy Fuel Stratum Characteristics Calculator* contact:

☐ Martin E. Alexander, University of Alberta, Edmonton, Alberta: meaz@telus.net or

☐ Miguel G. Cruz, CSIRO Bushfire Dynamics and Applications, Canberra, Australia: Miguel.Cruz@csiro.au

The *Canopy Fuel Stratum Characteristics Calculator* is a product in part of the Joint Fire Science Program Project JFSP 09-S-03-1

