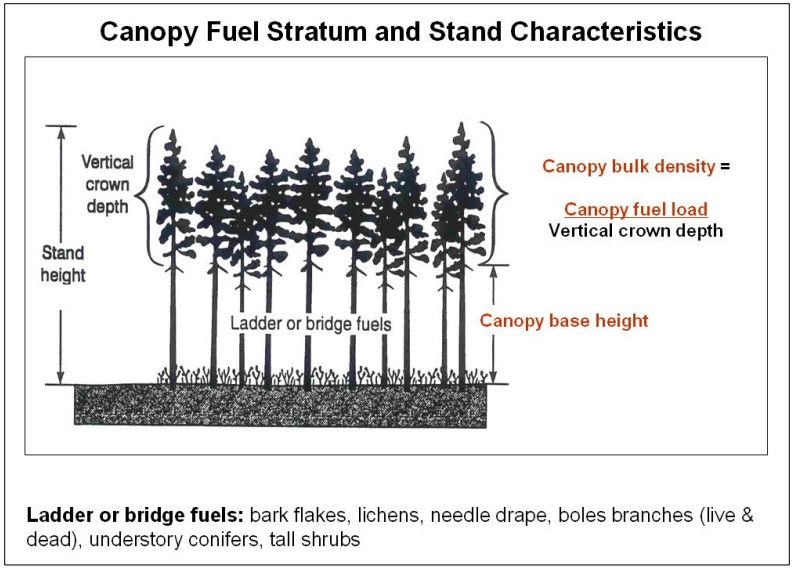
Introducing the *Canopy Fuel Stratum Characteristics Calculator*



Marty Alexander, University of Alberta

Miguel Cruz, CSIRO Bushfire Dynamics & Applications

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
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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 have 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

 10.1071/WF02024 1049-8001/03/010039

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)

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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]:

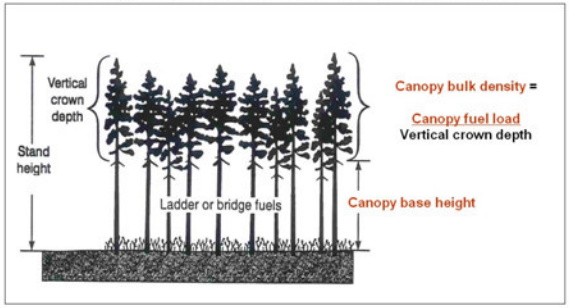
- Canopy base height (CBH)
- Canopy fuel load (CFL)
- Canopy bulk density (CBD)

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



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

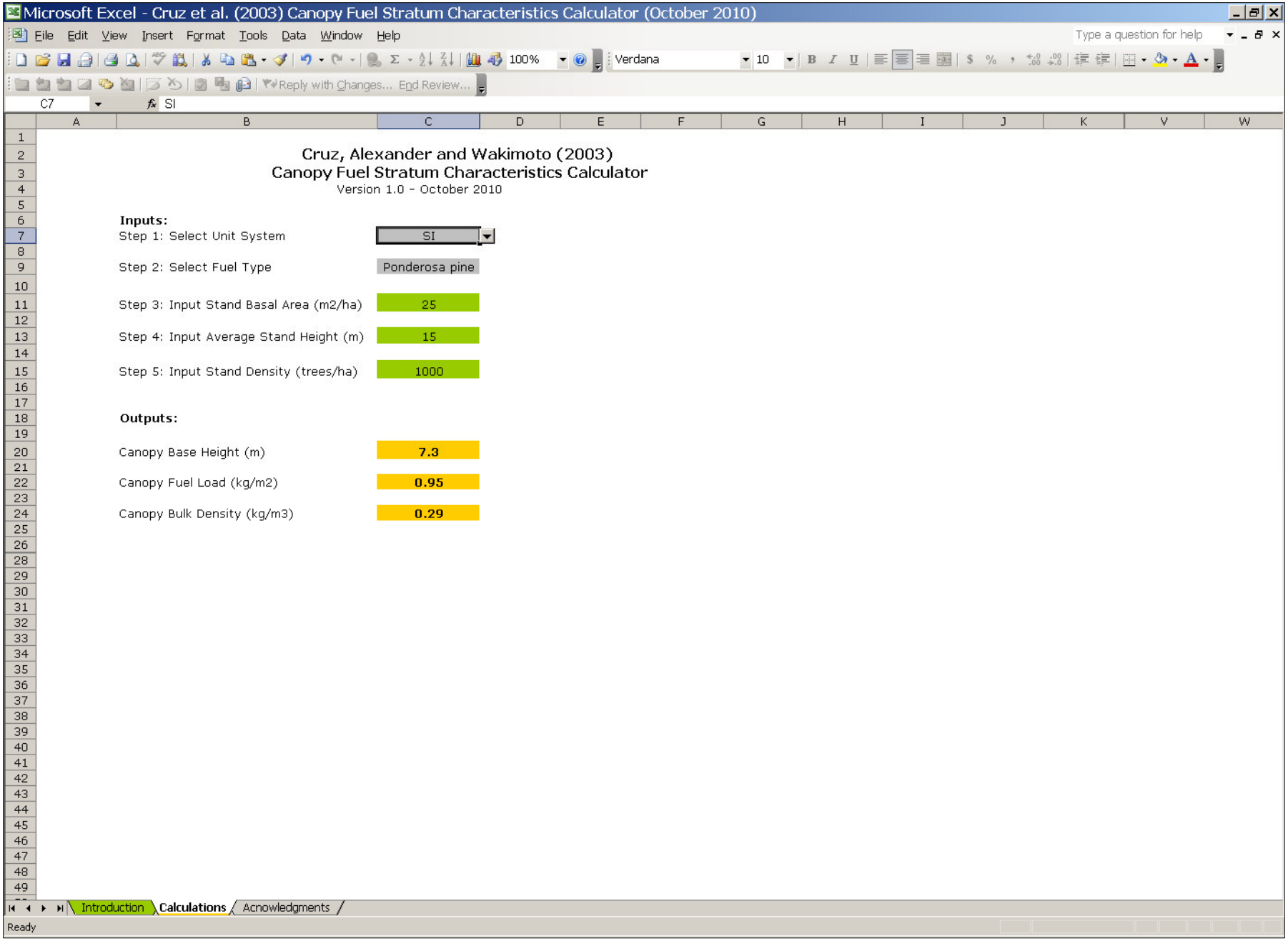
[1] Cruz, M.G.; Alexander, M.E.; Wakimoto, R.H. (2003) Assessing canopy fuel stratum characteristics in crown fire prone fuel types of western North America. International Journal of Wildland Fire 12: 39-50.

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

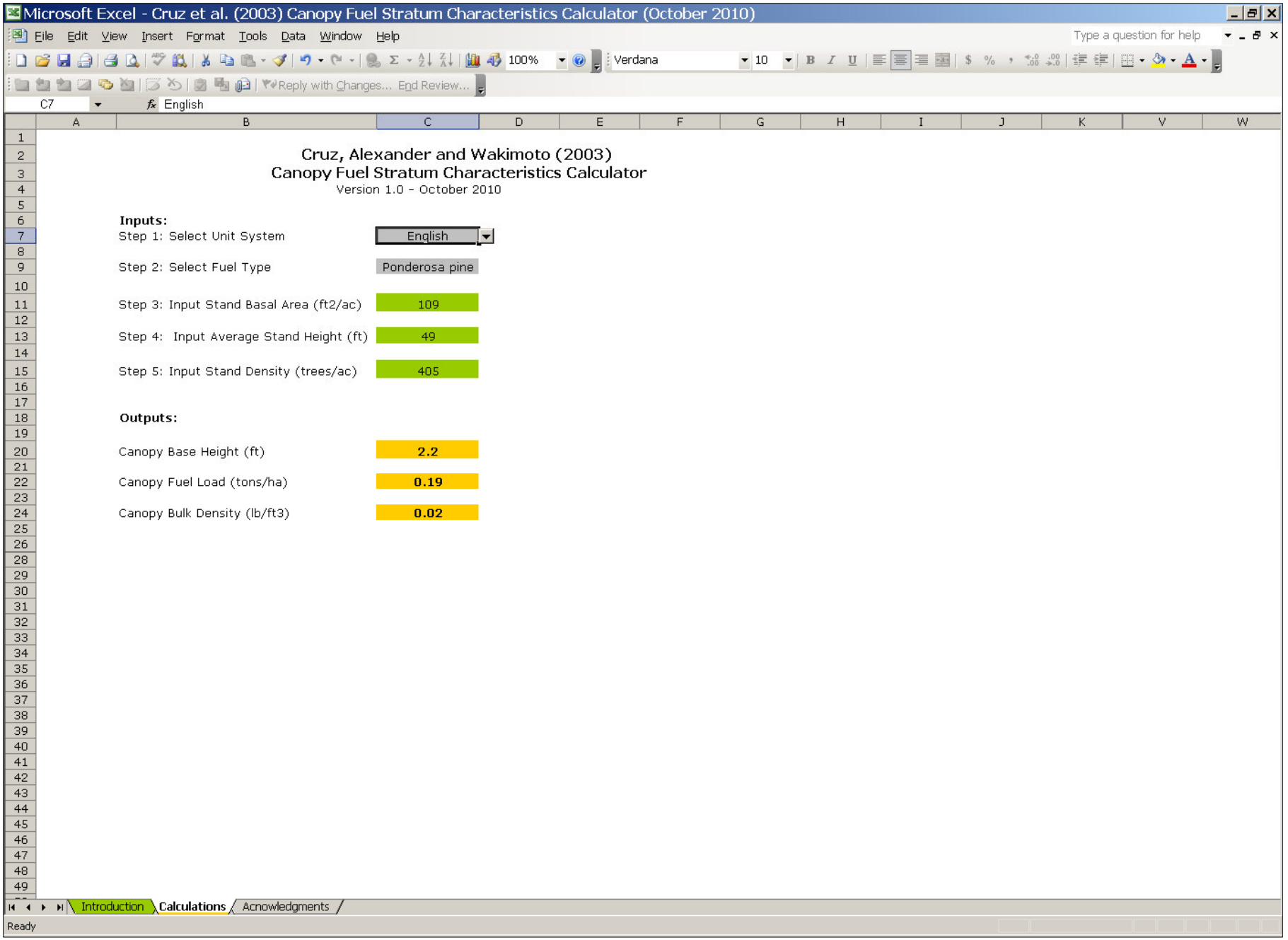
Introduction | Calculations | Acnowledgments

Ready

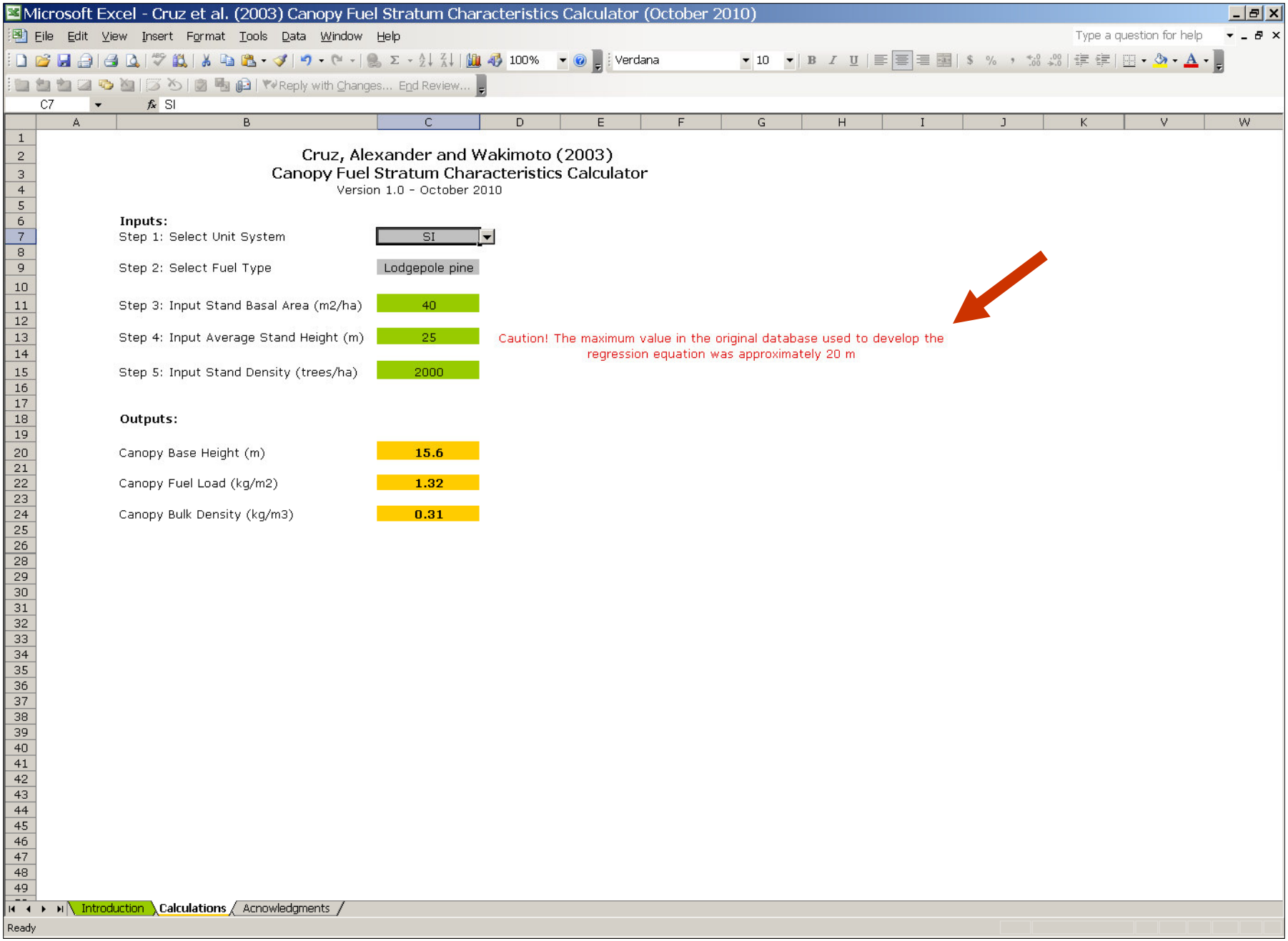
SI or Metric Unit Input/Output Example



English Unit Input/Output Example



Example of a CAUTION Message for Exceeding Reliable Input Value

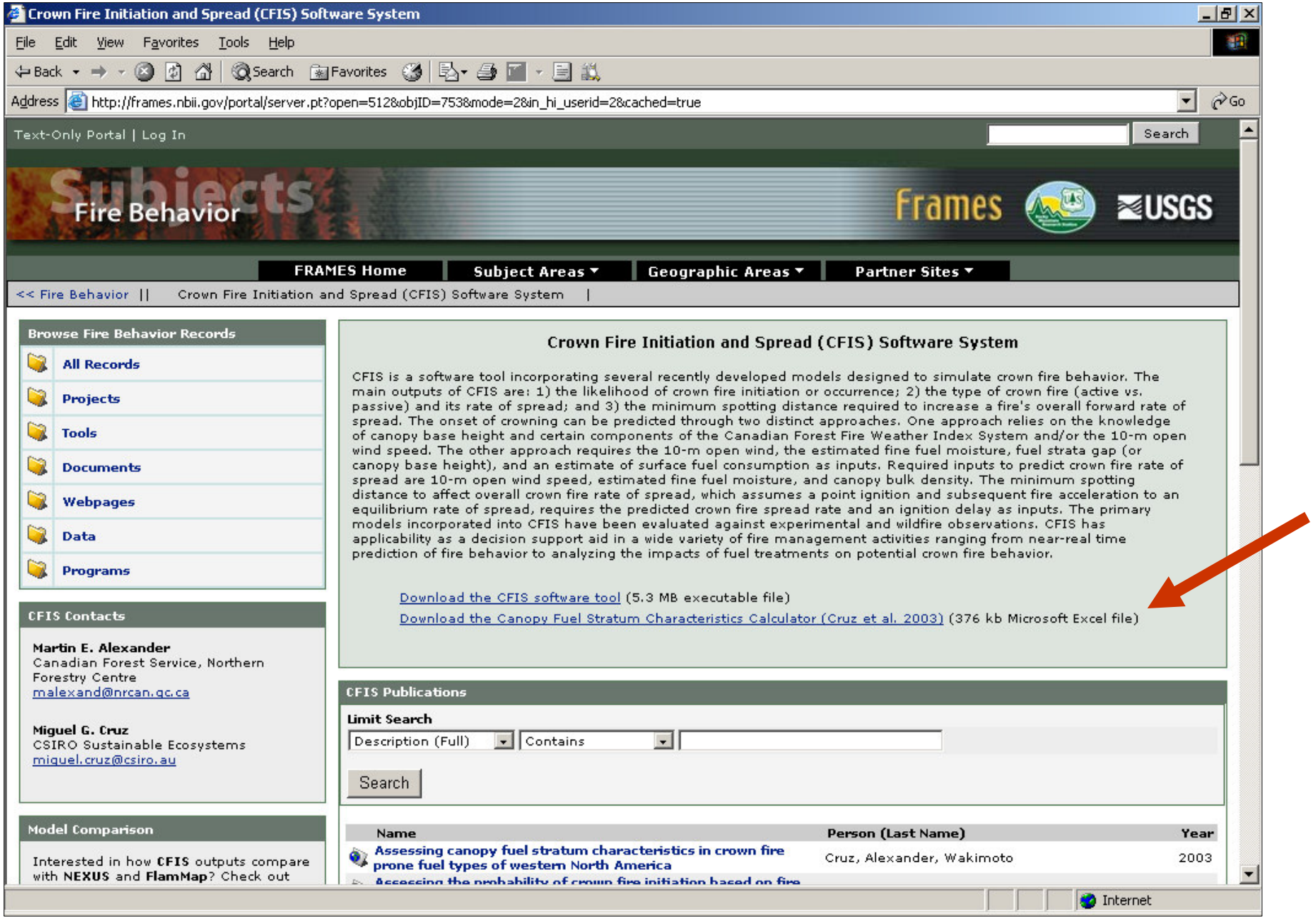


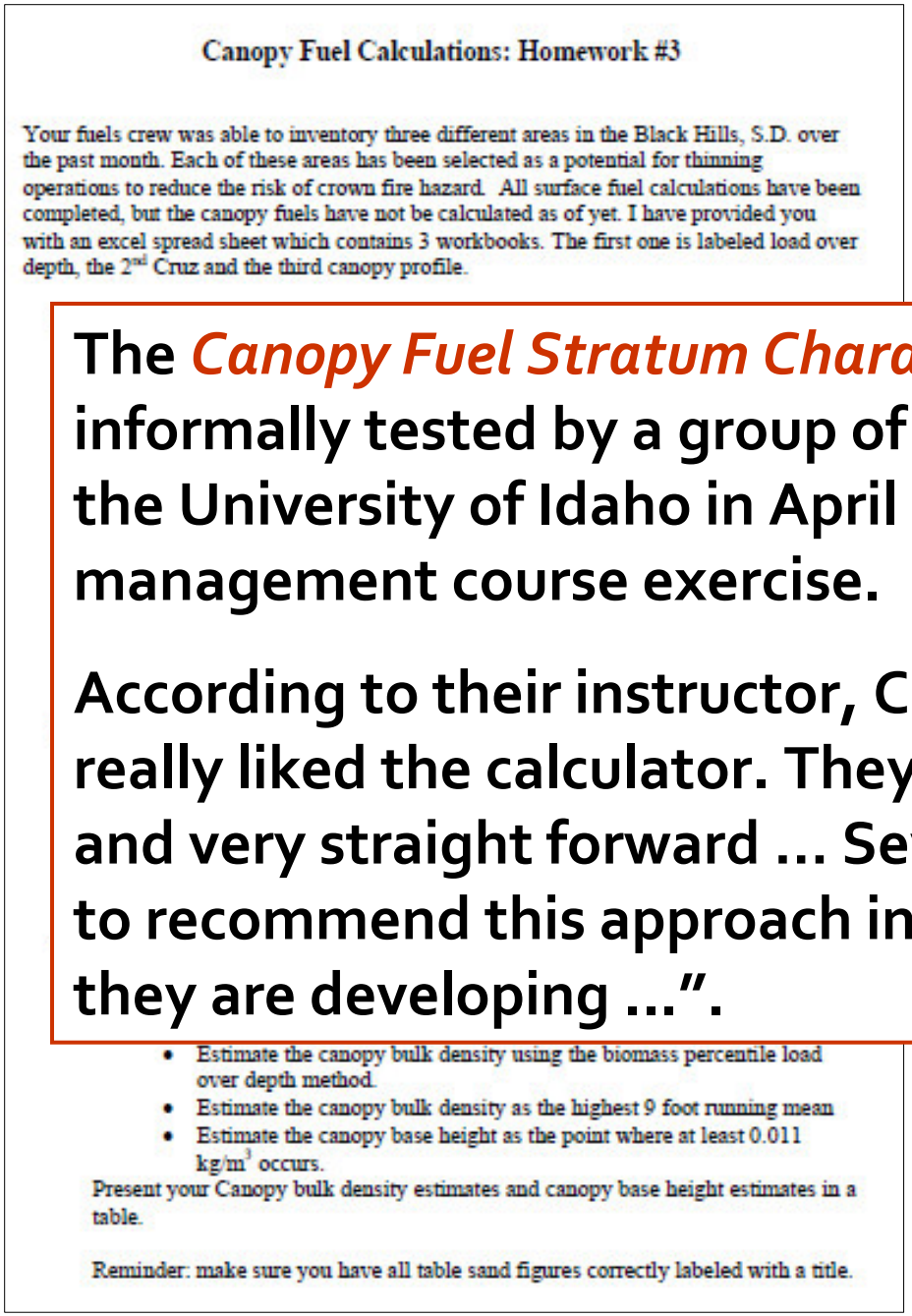
Maximum Reliable Input Values in the *Canopy Fuel Stratum Characteristics Calculator*

Conifer fuel type	Basal area (m^2/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 (ft^2/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





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 be 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.

- 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/m^3 occurs.

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

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

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 …".

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

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- 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