

Exercises

1. Returning to the Crown Flame Length calculation, which variables is it more sensitive to: Canopy Bulk Density, 1-h Moisture, 20-ft Wind Speed, or Heat per Unit Area? The Worksheet we used on page 20 of the lesson is shown below to get you started. Use your experience to determine typical ranges of values to test the model.

The screenshot shows the BehavePlus 5.0.5 software interface. At the top, it says "BehavePlus 5.0.5", "Thu, Aug 11, 2011 at 15:33:41", and "Page 1". The main section is titled "Inputs: CROWN" and "Description: CROWN Module: Crown Flame Length". It is divided into several sections: "Fuel/Vegetation, Overstory" with inputs for Canopy Height (100 ft), Canopy Base Height (3, 6, 9, 12, 15, 18, 21 ft), and Canopy Bulk Density (0.006, 0.012, 0.019, 0.025, 0.031 lb/ft³); "Fuel Moisture" with inputs for 1-h Moisture (5%), 10-h Moisture (5%), 100-h Moisture (5%), and Live Woody Moisture (90%); "Weather" with input for 20-ft Wind Speed (upslope) (20 mi/h); "Fire" with input for Heat per Unit Area (760 Btu/ft²); "Run Option Notes" with "None"; and "Output Variables" with "Crown Fireline Intensity (Btu/ft/s) [CROWN]" and "Crown Flame Length (ft) [CROWN]".

To test the sensitivity of the model to various inputs, we used the following ranges of values. Your values may differ.

- Canopy Bulk Density = 0.006, 0.012, 0.019, 0.025, 0.031
- 1-h Moisture = 5, 10, 15
- 20-ft Wind Speed = 10, 20, 30, 40, 50
- Heat per Unit Area = 580, 760, 1050, 1325, 1570, 3430
 - Note: These are all of the values on the **Choices** menu.

In BehavePlus, we can look at ranges of values for any two variables at one time. So, when the values remained constant, we used the following

- Canopy Bulk Density = 0.025 lb/ft³

- 1-h Moisture = 5%
- 20-ft Wind Speed = 20 mi/h
- Heat per Unit Area = 760 Btu/ft²

First, let's look at Canopy Bulk Density and 1-h Moisture.

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Inputs: CROWN

Description ➡ CROWN Module: Crown Flame Length

Fuel/Vegetation, Overstory

Canopy Height	ft	➡	100
Canopy Base Height	ft	➡	10
Canopy Bulk Density	lb/ft ³	➡	0.006, 0.012, 0.019, 0.025, 0.031

Fuel Moisture

1-h Moisture	%	➡	5, 10, 15
10-h Moisture	%	➡	5
100-h Moisture	%	➡	5
Live Woody Moisture	%	➡	90

Weather

20-ft Wind Speed (upslope)	mi/h	➡	20
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Fire

Heat per Unit Area	Btu/ft ²	➡	760
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Run Option Notes

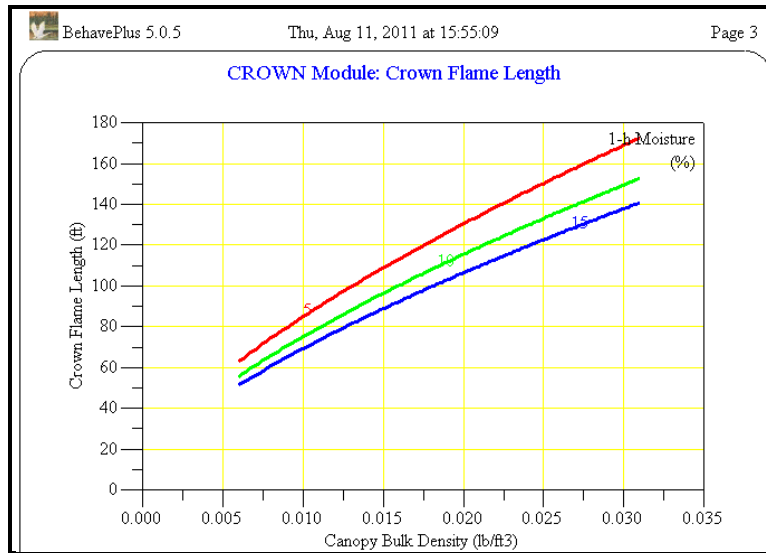
None

Output Variables

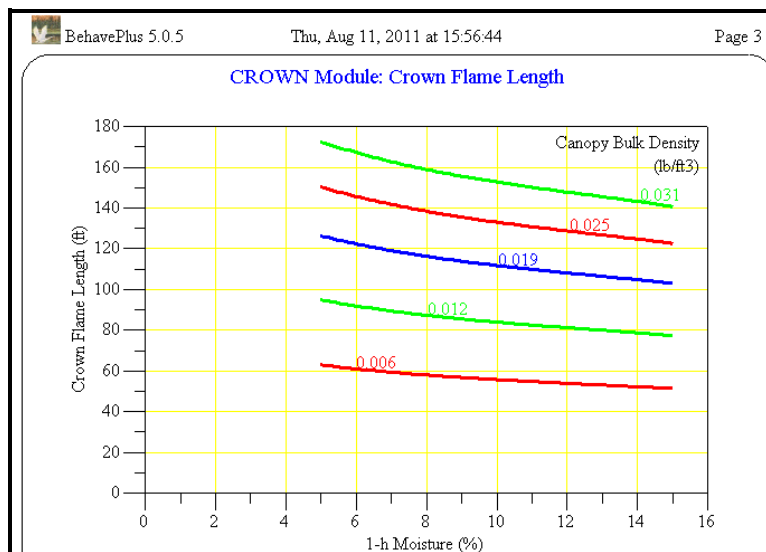
Crown Flame Length (ft) [CROWN]

Notice that Crown Flame Length is the only output in our example. You may have different outputs.

In this case, it seems that Crown Flame Length is more sensitive to Canopy Bulk Density than to 1-h Moisture. In the top graph, Canopy Bulk Density is the X-Axis Variable. The Crown Flame Length varies by about 100 ft across the range of Canopy Bulk Density.



➤ **Calculate** the Run using 1-h Moisture as the X-Axis Variable.




Crown Flame Length changes only slightly (10-20 ft or 10-15%) with 1-h Moisture.


Next, let's look at 20-ft Wind Speed and Heat per Unit Area.


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Inputs: CROWN

Description  CROWN Module: Crown Flame Length


Fuel/Vegetation, Overstory


Canopy Height ft  100


Canopy Base Height ft  10


Canopy Bulk Density lb/ft³  0.025

Fuel Moisture


1-h Moisture %  5

10-h Moisture %  5


100-h Moisture %  5

Live Woody Moisture %  90

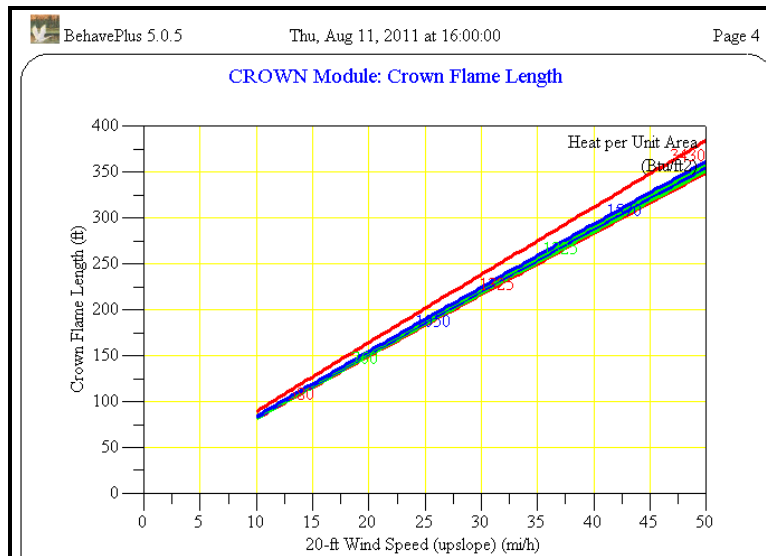
Weather

20-ft Wind Speed (upslope) mi/h  10, 20, 30, 40, 50

Fire

Heat per Unit Area Btu/ft²  580, 760, 1050, 1325, 1570, 3430

- **Calculate** the Run using 20-ft Wind Speed (upslope) as the X-Axis Variable.



It is very clear that Heat per Unit Area has very little impact on Crown Flame Length. However, 20-ft Wind Speed has a huge impact on Crown Flame Length.

Therefore, we can say that Crown Flame Length is most sensitive to Canopy Bulk Density and 20-ft Wind Speed under the conditions we examined. Feel free to look at a larger range of values or other input variables.

2. Given the following conditions, what 20-ft Wind Speed is required to produce a wind-driven crown fire in a mixed Douglas fir/lodgepole pine stand? Calculate the Heat per Unit Area using the SURFACE Module.

- **Fuel Model TU1 (Moderate load conifer litter)**
- **Canopy Height = 60 ft**
- **Canopy Base Height = 5 ft**
- **Canopy Bulk Density = 0.0161 lb/ft³**
- **1-h Moisture = 5%**
- **10-h Moisture = 6%**
- **100-h Moisture = 7%**
- **Live Fuel Moistures = 100% (both Herbaceous and Woody)**
- **20-ft Wind Speed = ???**

Here is how we set it up. Notice that while the SURFACE Module is selected, there are no SURFACE module outputs. We must interpret all of our outputs as if a crown fire were occurring.

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Inputs: SURFACE, CROWN

Description CROWN Module: Wind-Driven Fire?

Fuel/Vegetation, Surface/Understory

Fuel Model tu1

Fuel/Vegetation, Overstory

Canopy Height ft 60

Canopy Base Height ft 5

Canopy Bulk Density lb/ft3 0.0161

Fuel Moisture

1-h Moisture % 5

10-h Moisture % 6

100-h Moisture % 7

Live Herbaceous Moisture % 100

Live Woody Moisture % 100

Weather

20-ft Wind Speed (upslope) mi/h 10, 20, 30, 40, 50

Run Option Notes

None

Output Variables

Power of the Fire (ft-lb/s/ft2) [CROWN]

Power of the Wind (ft-lb/s/ft2) [CROWN]

Power Ratio [CROWN]

Wind-driven Fire? [CROWN]

➤ **Calculate the Run.**

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CROWN Module: Wind-Driven Fire?

20-ft Wind mi/h	Power of the Fire ft-lb/s/ft2	Power of the Wind ft-lb/s/ft2	Power Ratio	Wind Driven?
10	23	3	7.62	No
20	58	24	2.42	No
30	102	80	1.28	No
40	152	186	0.82	Yes
50	208	359	0.58	Yes

The transition occurs somewhere between 30 and 40 mi/h. Given the uncertainties in the models, you probably don't want to be any more specific than that.

But, just for fun, let's see whether it is closer to 30 mi/h or closer to 40 mi/h.

- Change the range of 20-ft Wind Speed values to range from 30 to 40 in steps of 1.

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Inputs: SURFACE, CROWN

Description [CROWN Module: Wind-Driven Fire?]

Fuel/Vegetation, Surface/Understory

Fuel Model [tu1]

Fuel/Vegetation, Overstory

Canopy Height ft [60]

Canopy Base Height ft [5]

Canopy Bulk Density lb/ft3 [0.0161]

Fuel Moisture

1-h Moisture % [5]

10-h Moisture % [6]

100-h Moisture % [7]

Live Herbaceous Moisture % [100]

Live Woody Moisture % [100]

Weather

20-ft Wind Speed (upslope) mi/h [30, 31, 32, 33, 34, 35, 36, 37, 38, 39]

Run Option Notes

None

Output Variables

Power of the Fire (ft-lb/s/ft2) [CROWN]

Power of the Wind (ft-lb/s/ft2) [CROWN]

Power Ratio [CROWN]

Wind-driven Fire? [CROWN]

- **Calculate the Run.**

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CROWN Module: Wind-Driven Fire?

20-ft Wind mi/h	Power of the Fire ft-lb/s/ft2	Power of the Wind ft-lb/s/ft2	Power Ratio	Wind Driven?
30	102	80	1.28	No
31	106	88	1.21	No
32	111	96	1.15	No
33	116	106	1.10	No
34	121	115	1.05	No
35	126	126	1.00	No
36	131	137	0.96	Yes
37	136	148	0.92	Yes
38	141	160	0.88	Yes
39	147	173	0.85	Yes
40	152	186	0.82	Yes

The results suggest the fire changes to a wind-driven crown fire at 36 mi/h.