Evaluating fuels treatments using fire behavior modeling

Monique Rocca
Colorado State University

Manager's Workshop on Restoration of Ponderosa Pine Ecosystems, April 2006
Deckers, Colorado

Overview

- Evaluating fuel treatments
- Tools: Fire behavior modeling 101
- Example with real data
- Model Limitations

Overview

- Evaluating fuel treatments
- Tools: Fire behavior modeling 101
- Example with real data
- Model Limitations

Overview

- Evaluating fuel treatments
- Tools: Fire behavior modeling 101
- Example with real data
- Model Limitations

Evaluating Fuel Treatments

- What do we hope to achieve?
  - Ecological goals
    - stand structure
    - T & E
    - biodiversity
    - ecosystem services
  - Fire behavior goals
    - desired ecological outcome
    - suppression/fire mitigation

Fire Behavior Objectives

1. What kind of fire behavior would we like to achieve?
2. Under what weather conditions is the treatment effective at achieving goal #1?

Concept of Percentile Weather

Cheesman RAWS station, May 1-Oct31

percentile weather	1 hr FM%	10 hr FM%	100 hr FM%	Herb FM%	Live Woody FM%
8	11	20	15	57	107
10	9	18	15	57	111
30	7	11	13	50	104
50	6	8	11	45	97
60	6	8	11	48	96
80	4	6	8	33	81
94	3	4	7	34	70
99	3	3	5	27	60

*(percentiles based on ERC)

Overview

- Evaluating fuel treatments
- Tools: Fire behavior modeling 101
- Example with real data
- Model Limitations

Overview

- Evaluating fuel treatments
- Tools: Fire behavior modeling 101
- Example with real data
- Model Limitations

Will our fire behavior objectives be met?

- Ideal: observe fire behavior through a variety of fuels treatments under different weather scenarios
- A less-than-ideal guidleine: fire behavior modeling

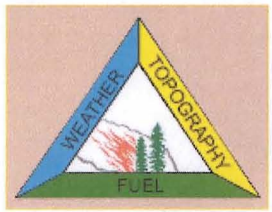
Fire behavior modeling

Models can help to answer these types of questions… using these approaches:

Question:	Stand-scale approach	Landscape-scale approach
How fast will fire spread?	BehavePlus/NEXUS	Farsite
How intense will fire be?	BehavePlus/NEXUS	Farsite
How severe will fire effects be?	FOFEM	Forest simulation models

Inputs into models

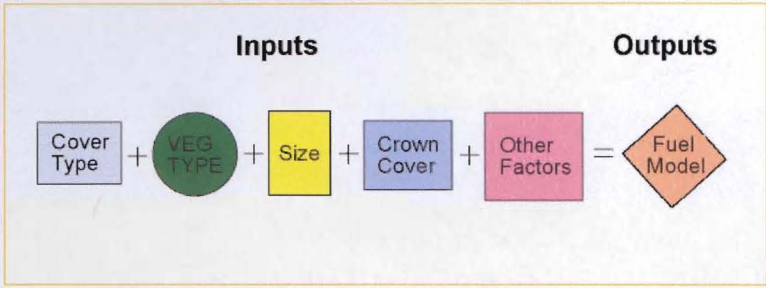
- Fuels
  - Fuel model
- Weather
  - Wind
  - Fuel moisture
- Topography
  - Slope



fire environment triangle

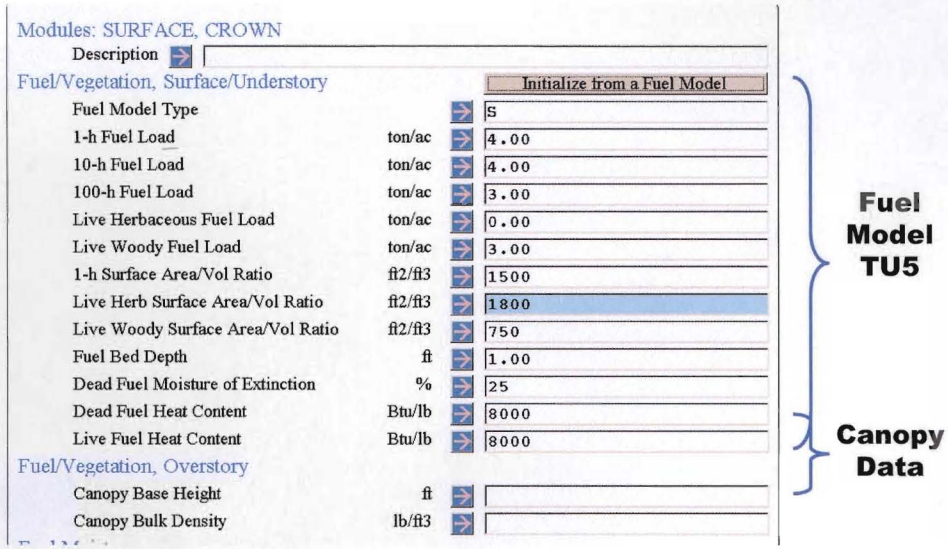
Fuel model 10

More about fuel models

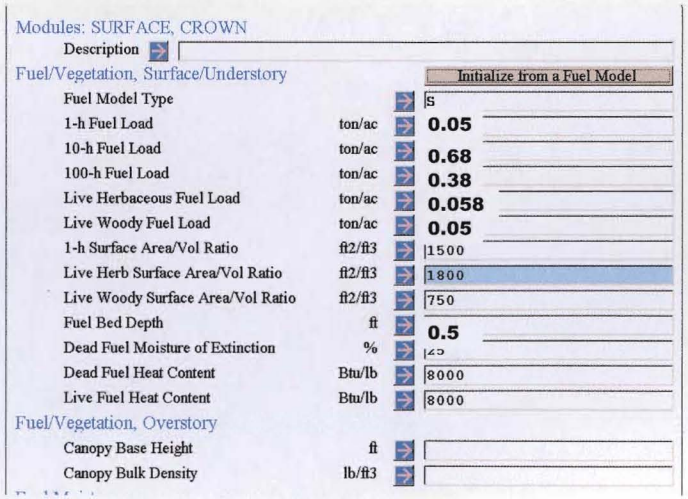


- Fuel models can be customized
- Restoration treatments cause a reduction or rearrangement of fuels; require a new, "custom" fuel model

Developing custom fuel models



Developing custom fuel models



Models discussed here based on an old set of equations:

- Rate of Spread (Rothermel)
- Fireline intensity (Byram)
- Crown fire initiation (Van Wagner)
- Crown fire spread (Rothermel)

Surface fire spread

Rothermel's fire spread equation (with no slope or wind):

$$R = \frac{I_R \xi}{\rho_b \varepsilon Q_{ig}} = \frac{(H\frac{dw}{dt})e^{[(0.793+3.7\sigma\text{^}0.5)(\beta+0.7)]}}{\rho Q_{ig}(192+7.894\sigma)}$$

σ,ρ,β are properties of the fuel

σ is the fine particle surface area to volume ratio (cm^{-1})

ρ is the fuel density (kg/m^3)

β is the fuel array bulk density/fuel particle density (also known as the packing ratio)(dimensionless)

Rothermel's fire spread equation

$$R = \frac{I_R \xi (1+\phi_w+\phi_s)}{\rho_b \varepsilon Q_{ig}}$$

- to add slope and wind effects, we multiply R by $(1 + \Phi_w + \Phi_s)$

$$\phi_w = C_w U_{10}^{B_w} \left(\frac{\beta}{\beta_o}\right)^{-E_w}$$

- Φ_w = wind effect
- Φ_s = slope effect

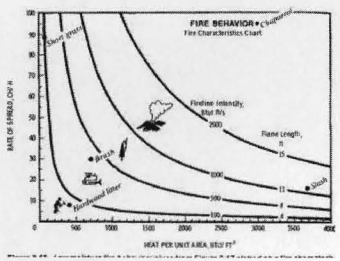
$$\phi_s = 5.275\beta^{-0.3}\tan^2\theta$$

Byram's Fireline Intensity

- Fireline Intensity (I_B) is the <u>rate</u> of heat released per linear distance on fire perimeter (kW/m)
- I_B related to flame length (L):

  $I = 259.833\ L^{2.174}$

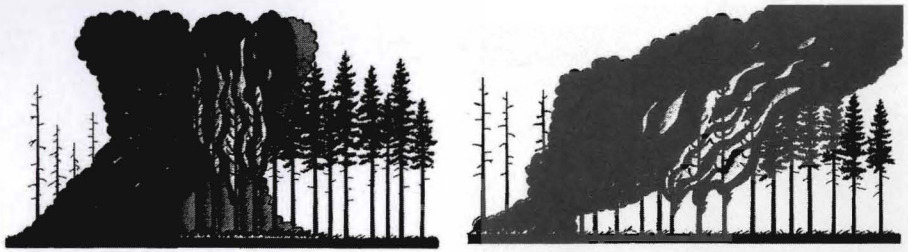
  $\approx 300\ L^{2}$ (20% accuracy)



Crown fire propagation

- Types of crown fire:

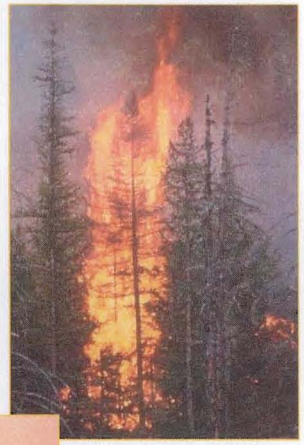
dependent (passive) **active** **independent**



from Cottrell 1989

Torching

- Also called:
  - candling
  - passive crown fire
  - "initiation" of crown fire



Running crown fire

- Also called:
  - active crown fire
  - continuous crown fire
  - "propagation" of crown fire

Crown fire

- initiation—when torching happens
- propagation—when active crown fire happens

Crown fire initiation

- Van Wagner's 1977 model of initiation
- define some new variables:
  - M = % crown foliar moisture content
  - CBH = crown base height (m)
  - I_0 = fireline intensity at which crownfire can initiate (KW/m)

Crown fire initiation, Van Wagner

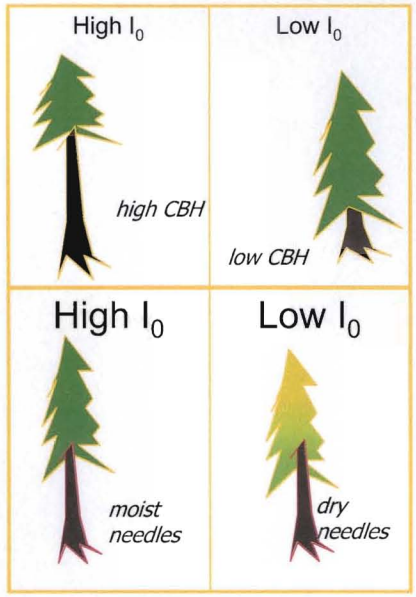
In other words…whether crown fire will initiate depends on:

1) how intense the surface fire is
2) how high the canopy is from the surface fire
3) how moist the canopy vegetation is (how much heat is required to ignite it?)

Review: how models handle crown fire

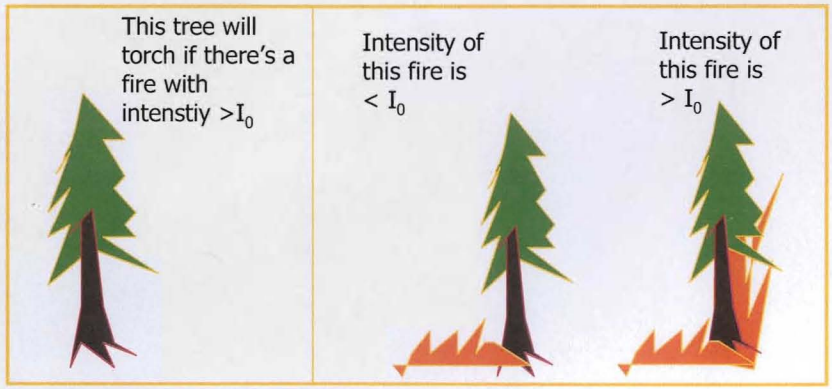
Initiation

1. Surface fire must be intense enough to heat crown fuels to ignition temperature
2. The critical surface intensity (I_0) depends on
   - crown base height (CBH)
   - crown foliar moisture content

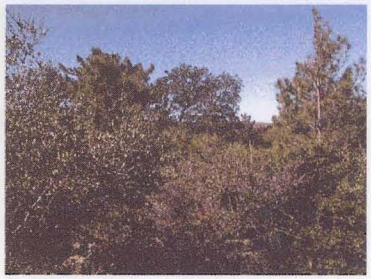


Review: how models handle crown fire

- Initiation



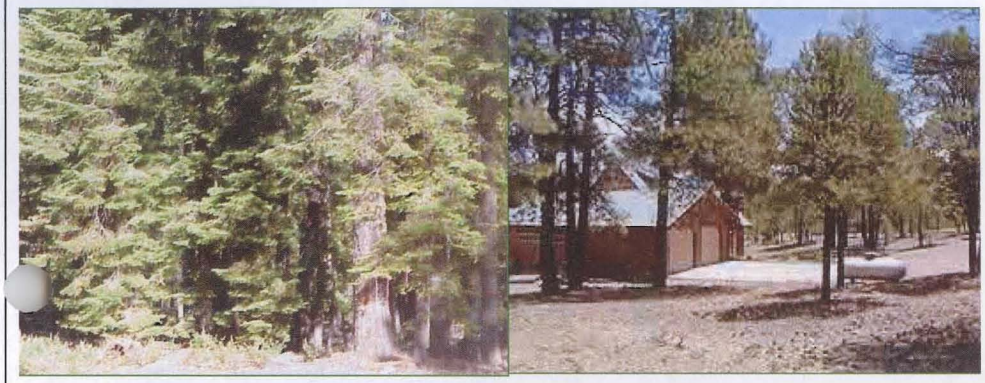
What is the CBH?



2

Managing CBH

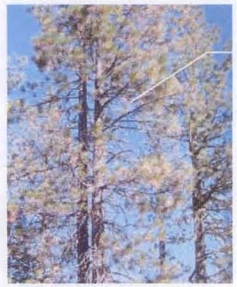
pruned



Crown fire propagation—Active crown fire

Will fire spread from one tree's crown to the next? depends on:

- available canopy bulk density (CBD or ACBD)
  - mass of "available" fuel per volume of canopy (kg/m^3)
  - a measure of how close branches and needles are to one another
- how fast the fire is going, ROS_{active} (or simply R_{active})



low CBD

high CBD

How models handle crown fire

Propagation

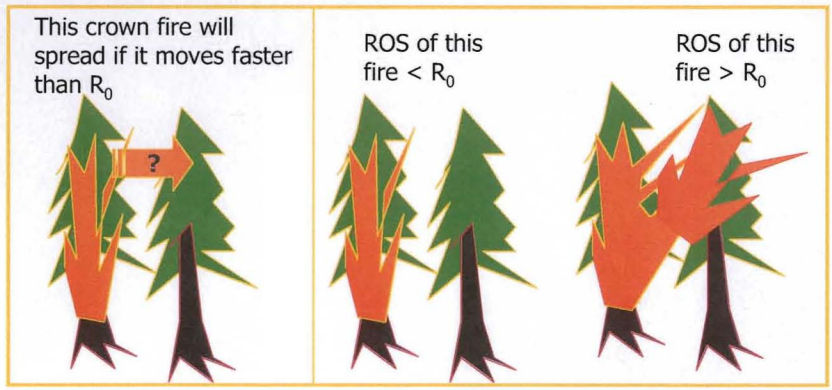
1. canopy fire must move fast enough to overcome the distance between fuel particles
2. the critical ROS depends on the available canopy bull density (CBD)
   - CBD= mass of available fuel/unit volume of canopy
   - not usually uniform, very difficult number to estimate
3. $R_0 = 3.0/CBD$ (CBD in kg/m^3 and ROS in m/min)

Low CBD

High CBD

Review: how models handle crown fire

- Propagation



Crown fire propagation

- Criterion for active canopy fire:
  - Basically, whether fire spreads from crown to crown depends on fire ROS and Canopy Bulk Density

Torching index

With increasing windspeed…

…the surface fire increases in intensity….

until its intense enough to ignite the canopy!

- This windspeed is called the "torching index"
- The torching index is the windspeed at which $I_B = I_0$

Crowning index

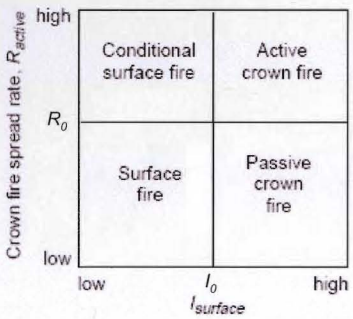
With increasing windspeed…

…the canopy fire's ROS increases….

…until it moves fast enough to spread between crowns!

- This windspeed is called the "crowning index"
- The torching index is the windspeed at which $R_{active} = R_0$

Determining fire type



- What if the crowning index is lower than the torching index?

Application to fuels treatments

- To prevent canopy fire behavior, you might want to
  - raise the torching index
  - raise the crowning index

Main point of this modeling whirlwind:

- Models are relatively simple
- Lots of assumptions
- Lots of potential limitations

- But they're all we've got to work with

Overview

- Evaluating fuel treatments
- Tools: Fire behavior modeling 101
- Example with real data
- Model Limitations

South Platte Forest Restoration

- Data from two sites in the Pike-San Isabel National Forest, *collected and generously contributed by Paula Fornwalt, USFS, RMRS.*

Sugar Creek--Untreated

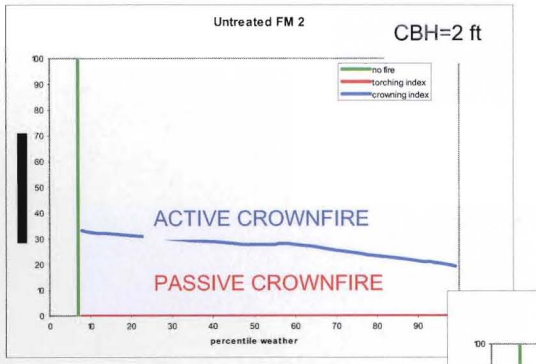
Trumbull--Post-treatment

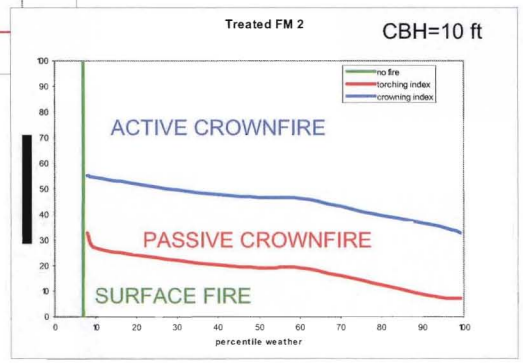
Stand Data

	Sugar Creek	Trumbull (vs. pre-treatment)
Avg BA (m2/ha)	16	8 (21)
Avg density (trees/ha)	57	10 (101)
Avg canopy cover%	54	31

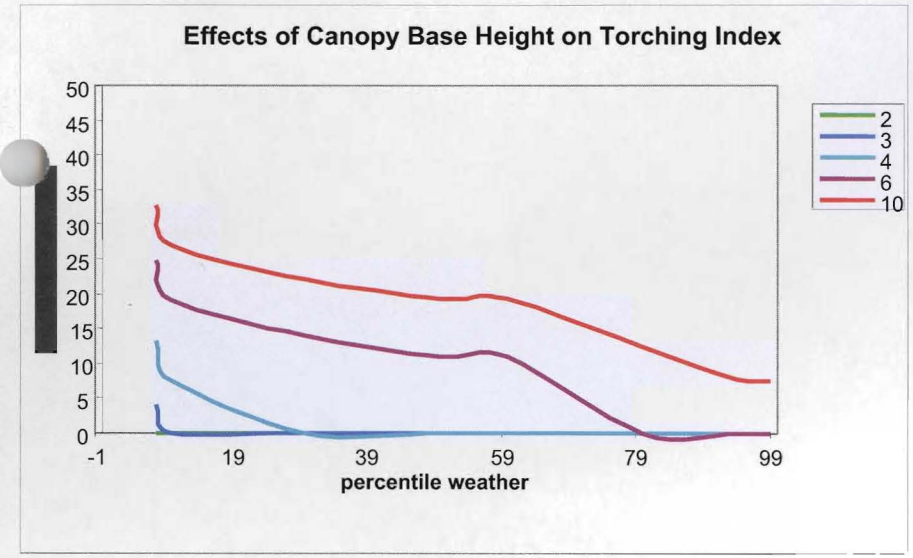
but high variability between samples…

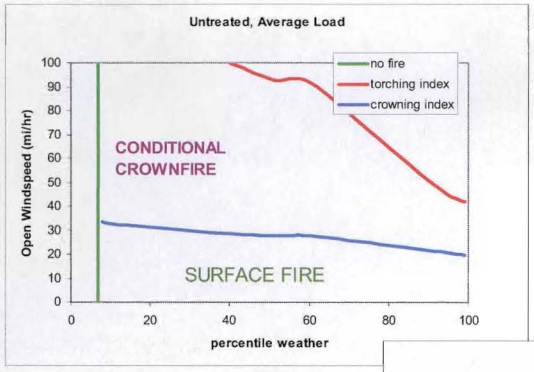
Results based on surface Fuel model 2

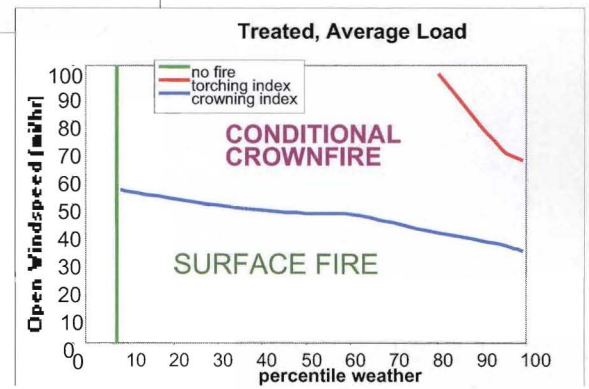




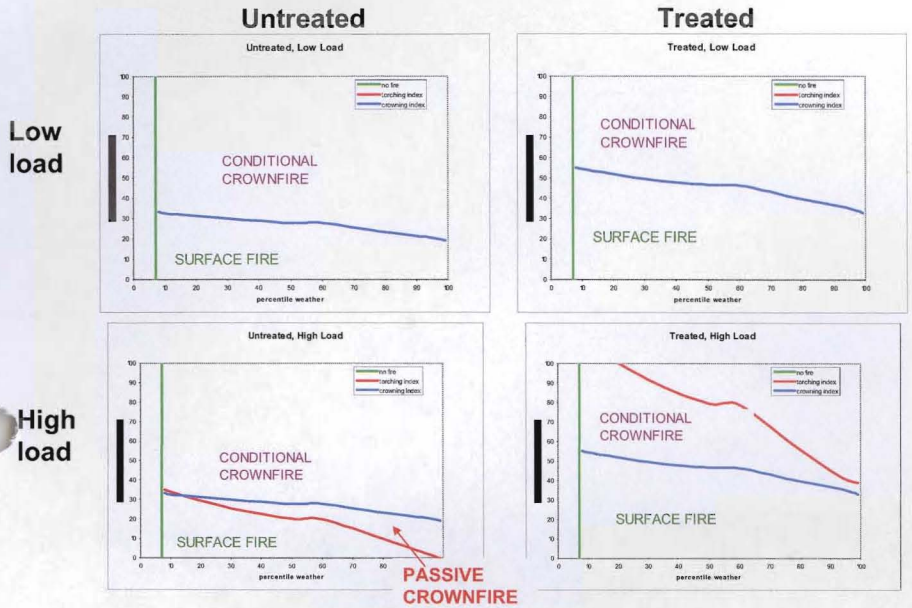
Model "sensitive" to Canopy Base Height (CBH)







Results of Treatment (Range)

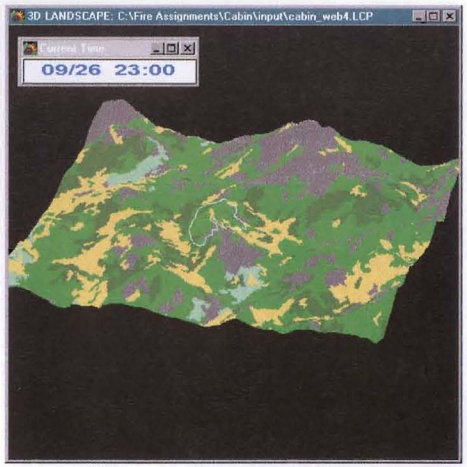


Overview

- Evaluating fuel treatments
- Tools: Fire behavior modeling 101
- Example with real data
- Model Limitations

Current Limitations

- Data hard to come by, data quality
- Spatial heterogeneity in fuels and forest structure
- Model sensitivities
  - surface fuel bed depth
  - canopy base height
- Still useful?

Landscape scale modeling

- Do stand-level models lots of times