Fire behavior and fuel treatment effectiveness: Theory and current knowledge

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What is fire?

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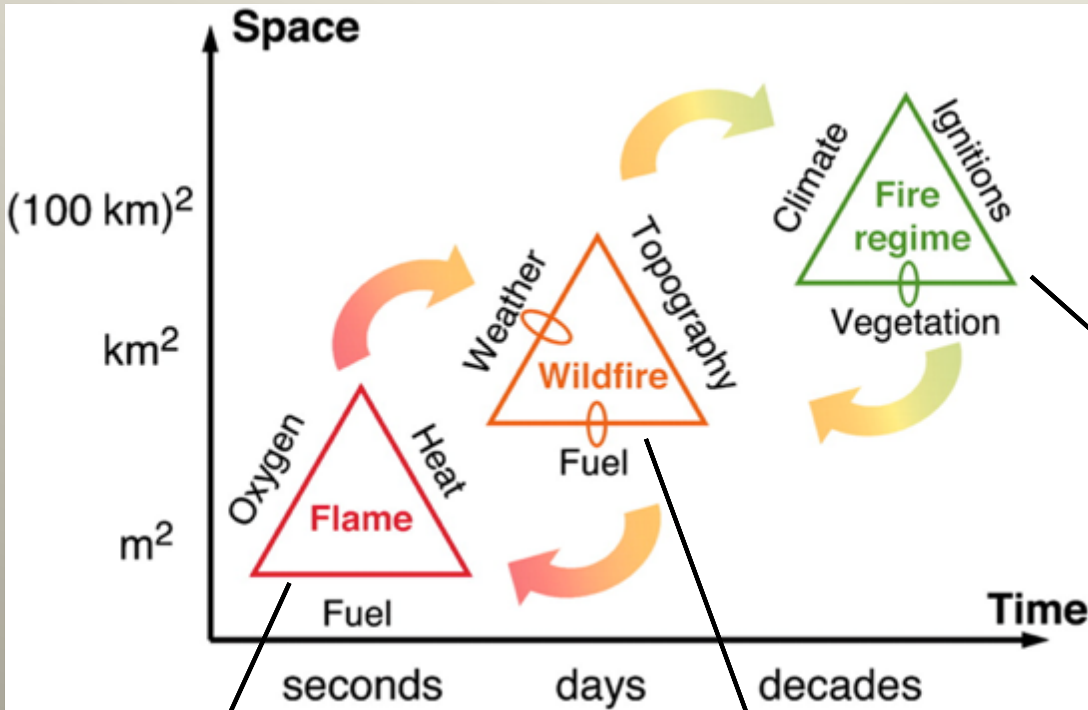
  - “the fire descended like a dragon from hell on the foothill neighbor hoods and laid them to waste” -San Bernardino Sun 1985
    - (no scientific evidence to support this viewpoint)
  - fire is a rapid chemical reaction between fuel and oxygen in the presence of heat resulting in the evolution of light, heat and emission products.
    - “wildfires spread, consume fuel and produce heat (Van Wagner 1970)” therefore the science of fire behavior seeks to understand how fast a fire spreads, how it consumes fuel and how it produces heat

What is fire behavior

- The term fire behavior is used to describe the physical measures related to how a fire starts, spreads and develops over space and time
  - the science of fire behavior seeks to understand how fast a fire spreads, how it consumes fuel and how it produces heat

Controls of fire over space and time



Fire regime triangle – the occurrence and severity of wildfires overtime is controlled by interactions among the vegetation, ignition sources and climate

Fire triangle – states that combustion depends upon the interactions between Oxygen, Heat and Fuel

Fire behavior triangle – states that fire behavior is controlled by the interactions among weather, fuel, topography and fire itself

Fire behavior and fuels

- In general, fuel treatments are designed to alter fuel conditions so that wildfire is less difficult, disruptive, and destructive.
  - Management focuses on fuels since it is the only factor that can be easily manipulated by human intervention

Describing wildland fuels

The fuelbed – a general term for the complex array of biomass types for a given area (this is a coarse descriptor of fuels)

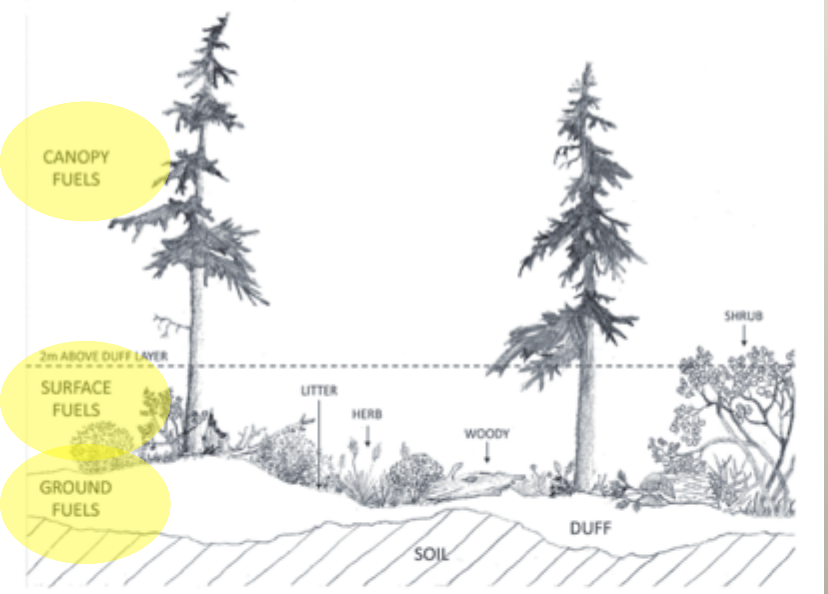
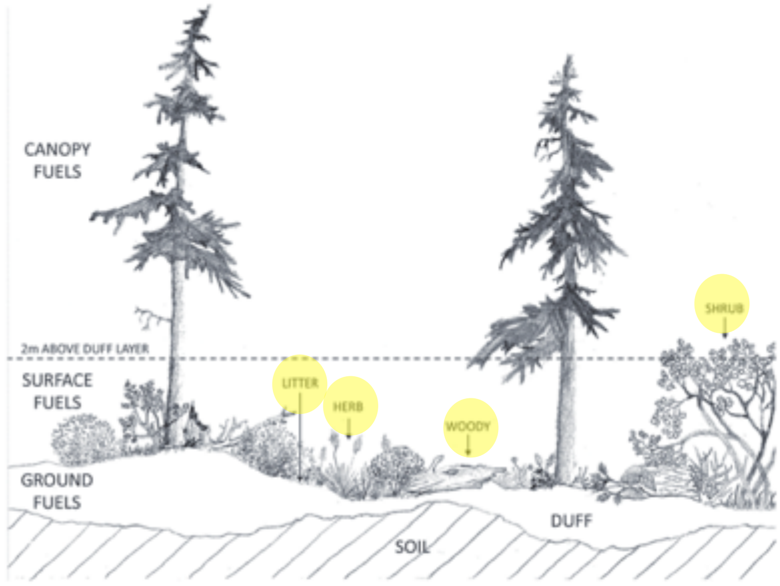


Fig. 1.1 The elements of a typical wildland fuelbed. The full representation of fuels within an area is called a fuelbed. Within a fuelbed, there are three fuel layers: ground, surface, and canopy. Each layer is composed of fuel types, such as litter, shrubs, grasses, and woody biomass in the surface fuel layer

- A wildland fuel bed: fuel layers
  - Ground fuels are all organic matter below the litter layer.
  - Surface fuels are all biomass within 2m above the ground surface
  - Canopy fuels are all biomass above the surface fuel layer

Describing wildland fuels



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- A wildland fuel bed: fuel types
  - fuel types are a general description of the kinds of fuels within a fuel layer
  - In surface fuel layer we might identify litter, herb, woody and shrub fuel types

fuels management and reduced fire behavior: guiding principles

Principle	Effect
Reduce surface fuels Fuel loading (kg m^{-2})	Reduce fireline intensity, reduce risk of crown torching and crown fire initiation
Increase height to live canopy Canopy base height (m)	Reduce risk of crown torching and crown fire initiation
Decrease canopy density Canopy bulk density (kg m^{-3}), basal area (m^2 ha^{-1}), trees per hectare	Reduce potential for crown fire spread
Keep large trees of fire resistant species	Decrease large tree mortality

Implementing these principles

- Modifying surface fuels
  - Pile and burn, broadcast burn, mastication
- Reduce canopy fuels and increase height to live canopy
  - Thin from below to 20-60 ft^2/ac BA
- Maintain large trees
  - Thin from below
- Other objectives can be included into treatment design by adjusting the density and arrangement of the fuel bed

Fuel hazard reduction treatment

Forest restoration treatment with a fire hazard reduction goal

Do fuel treatments reduce potential fire behavior:

- Review article from Fule et al. (2012)
  - Over 139 publications were included

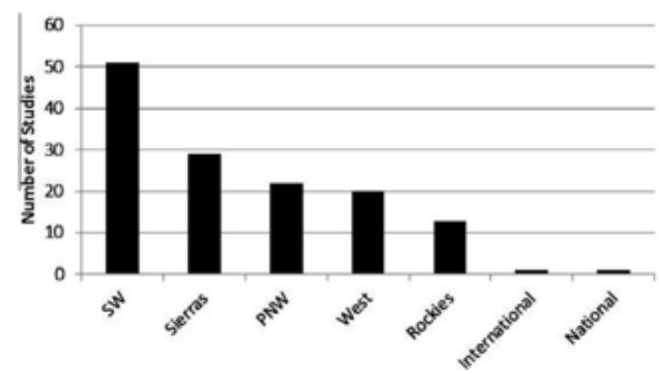


Fig. 6. Number of studies reviewed by region. "PNW" is Pacific Northwest, "SW" is Southwest. The international study was a U.S./Mexico comparison.

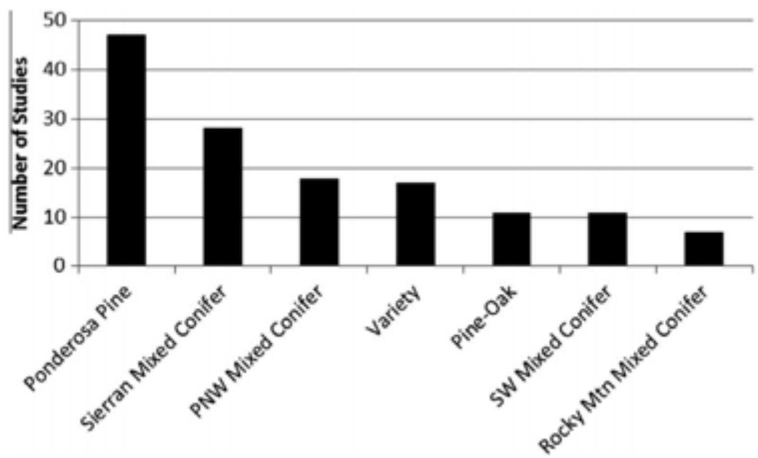


Fig. 5. Number of studies reviewed by forest type. "PNW" is Pacific Northwest, "SW" is Southwest.

Do fuel treatments reduce potential fire behavior:

- Findings of Fule et al (2009)
  - Principle 1: Reduce surface fuel loads
    - Thinning and burning decreased surface fuel loading
    - Thin only increased surface fuel loading
  - Principle 2: increased canopy base height
    - Both thin and burn increased canopy base height
  - Principle 3: Decrease canopy density
    - Both treatment types decreased canopy density

Do fuel treatments reduce potential fire behavior:

- Conclusions of Fule et al (2009)
    - Changes in fuel bed result in a decreased potential for crown fire activity
    - "Findings strongly indicate that treatments (thinning and/or burning) have effects consistent with fuel hazard reduction and restoration of natural fire behavior"
  - But serval limitations are identified in the current research Including:
    - Lack of spatial heterogeneity information
    - Long term understanding of treatment effectivness
    - Potential biases in modeling simulations

Advancing our understanding: where we are going

- Current treatments around Colorado are often implemented with specific spatially explicit objectives at the stand scale
    - Little scientific guidance
  - On going CSU Work to address this knowledge gap.
    - 7 Ponderosa pine dominated sites were stem mapped (4ha) pre- and post- restoration treatment
    - Fire behavior was simulated using the Wildland Urban Interface Dynamics Simulator (WFDS)
      - 3 dimensional, physics based fire behavior model

treatments effects on fire behavior

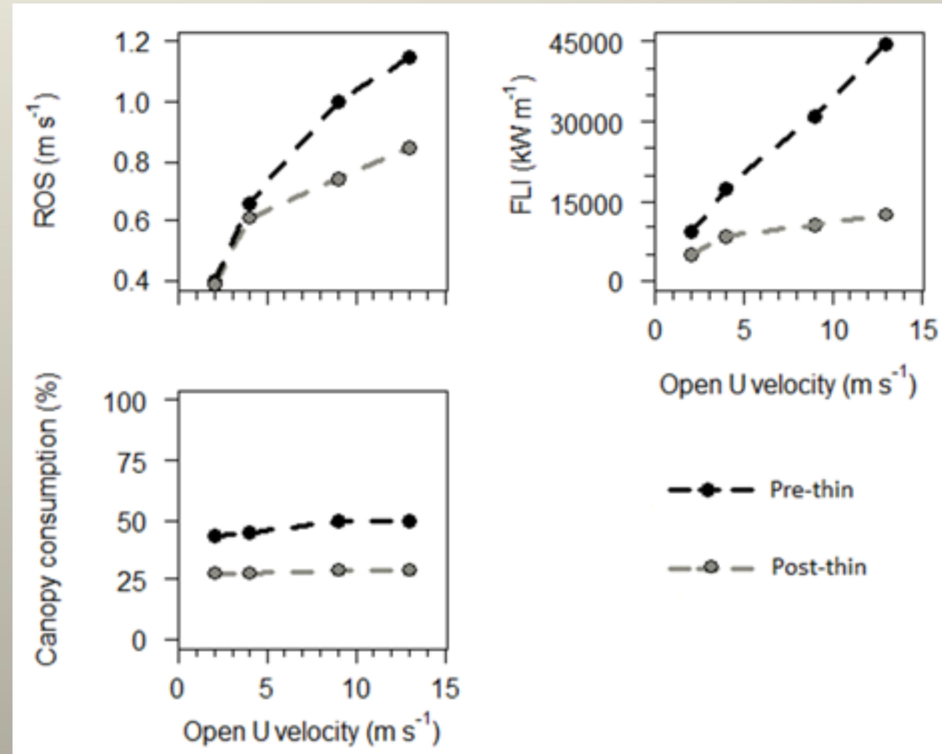
Canopy fuels were reduced

Surface fuels increased

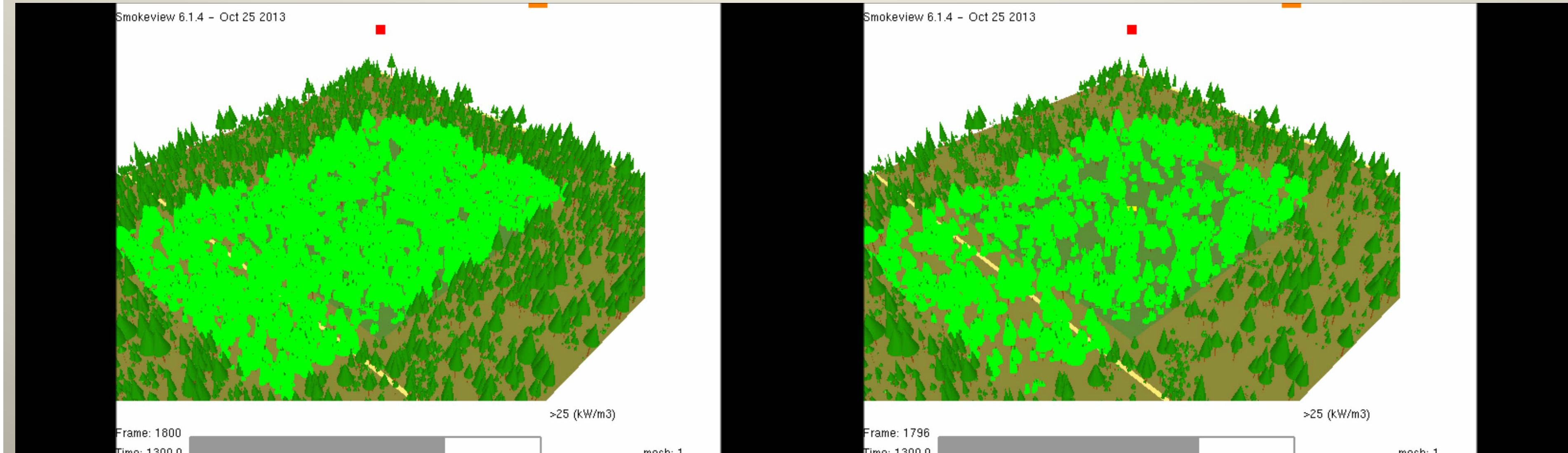
Reduced fire behavior

- Consistent with findings of Fule et al. (2009)

Treatments were more effective at high wind speeds



Example simulations



- Treatments did not “Fire Proof” the stand
- Fire rate of spread and intensities can remain high under extreme weather scenarios (although reduced compared to the untreated forest)

Conclusions and other thoughts from the literature

- Scientific evidence provides support for the idea for reduced fire behavior following thinning and/or burning treatments
- Treatments do not “fire proof” wildlands
- The primary benefits of treatments occur on the site that is treated (Reinhardt et al. 2008)
- Fuel treatment benefits are transient
  - Need to think about fuel treatment regimes
- Fuel treatments may not reduce fire suppression expenditures or the area burned by wildfires

Questions

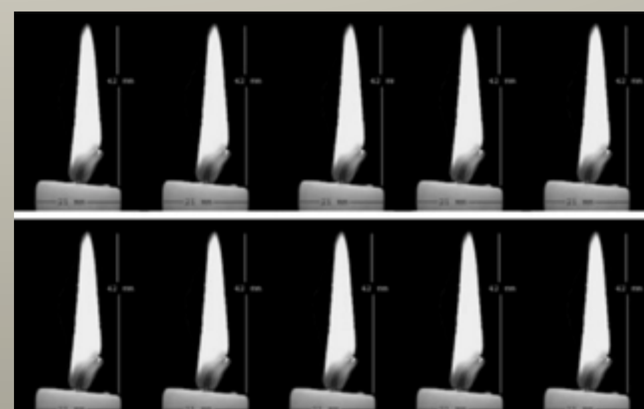
Measures of fire behavior

- Fuel consumption (kg): how much fuel consumed by a fire
- Heat energy: The amount of energy produced by a fire can be measured in several ways:
  - Heat release rate (kW): the rate at which a fire releases energy (sometimes reported per unit area)
  - Fireline intensity (kW m-1): the rate of energy release per 1 meter of length of fireline
- Fire spread ($m\ s^{-1}$): how fast a fire moves

Measures of fire behavior: Heat release rate vs temperature

- A common value reported in popular media is the temperature of a fire…
  - However not particularly useful measure of fire behavior of effects (Van Wagner and Methven 1978, Bova and Dickenson 2008).

HRR: 80 W
Temperature:
500 C - 1400 C



HRR: 800 W
Temperature:
500 C - 1400 C

Managing for fire hazed and risk

- Fire hazard expresses the potential fire behavior for a wildland fuel bed regardless of the influences of weather.
  - Implies that fire hazard is based exclusively on the amount, type, and arrangement of fuels…
- Fire risk is defined as the chance that a fire might start, as affected by the nature and incidence of causative agents
  - Connecting risk, wildfire behavior and wildfire effects
    - Example: Risk of large, uncontrollable, catastrophic fire
      - Can introduce several layers of ambiguity to the language used in wildland fuel management