



# Effectiveness and longevity of fuel treatments in coniferous forests across California

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WFM RD&A = Wildland Fire Management Research, Development & Application, WO  
AMSET = Adaptive Management Services Enterprise Team, WO Enterprise Program*



# Project Background

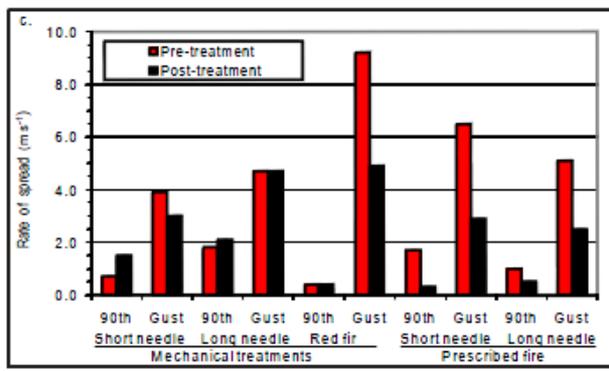
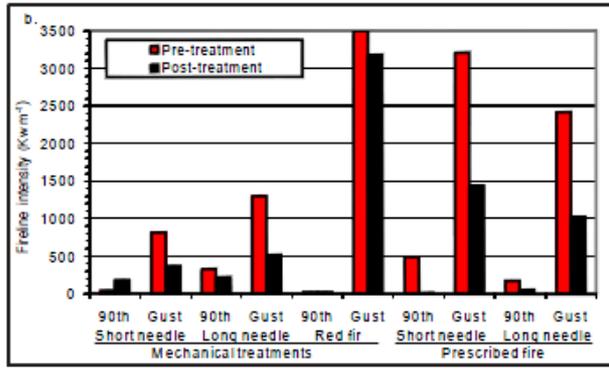
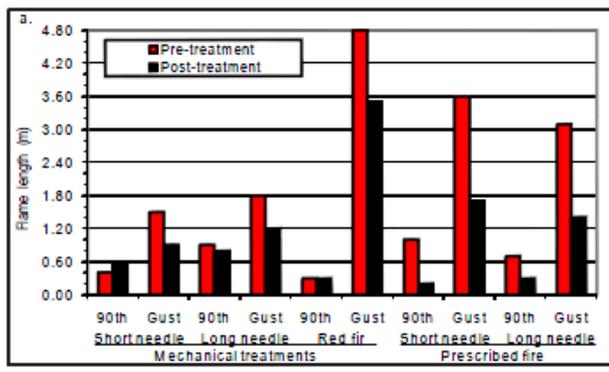
- Fuel treatment effects & effectiveness **monitoring** project in R5/PSW started in 2001
- Initially just prescribed fire treatments, then added mechanical treatments in later years
- Pre-treatment data collected on ~50 fuel projects on all National Forests in CA in many vegetation types
- Grant focused on **conifer dominated systems** treated by:
  - **Mechanical** treatments included thinning followed by a surface fuel treatment.
  - **Fire** treatments that were treated with prescribed fire only.



# Past Findings

Prior research with this data looked at pre vs. post 1 data

- Effects on fuels & forest structure
  - Prescribed fire reduced surface & ground fuels
  - Mechanical treatments increased 1-100 hr fuels and had mixed impacts on remainder
  - Mechanical treatments removed more trees and altered stand structure more so than prescribed fire
- Effects on potential fire behavior
  - Prescribed fire always reduced; mechanical mixed





# Research Objectives

Objective 1 – Determine length of time fuel treatments are effective at reducing undesirable fire behavior.

- a) Measuring effects of treatments on stand structure and fuel loads over time
- b) Modeling potential fire behavior with custom fuel models

Objective 2 - Quantify the uncertainty associated with the use of standard and custom fuel models

Objective 3 - Assess prescribed fire effects on carbon stocks and validate modeled outputs

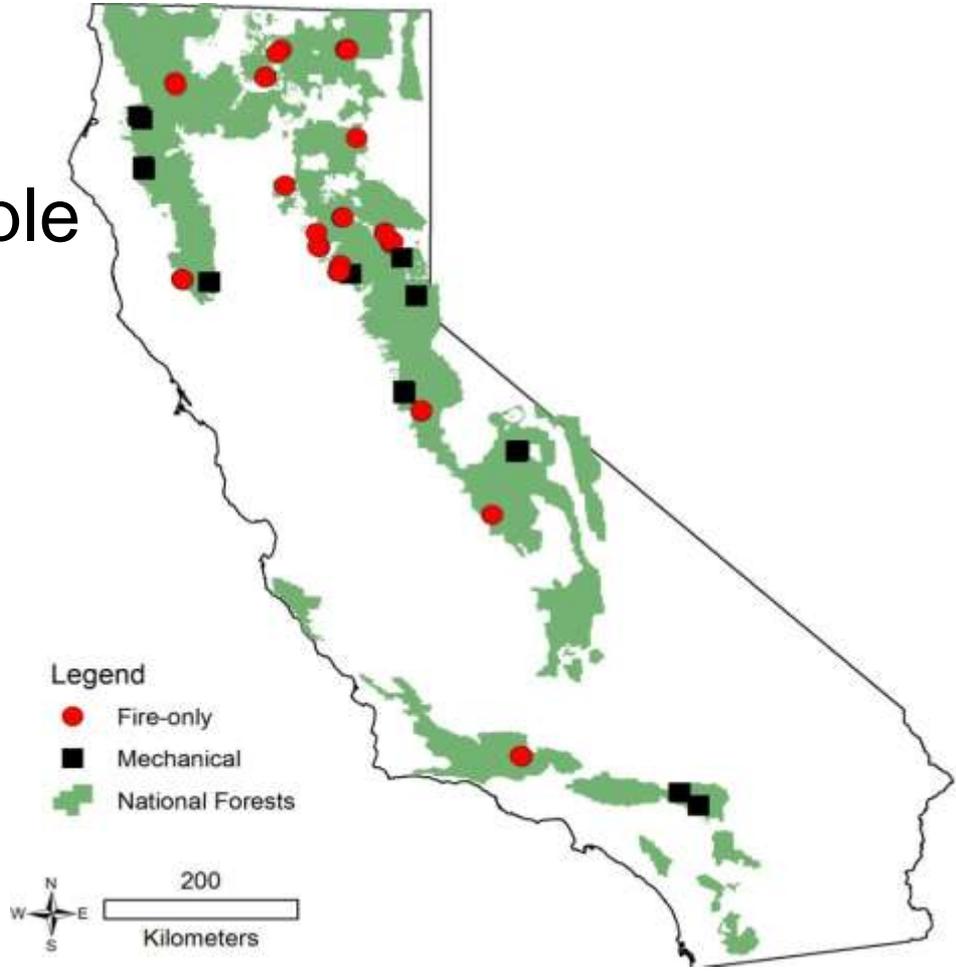


# Methods

- 14 National Forests
- 28 fuel treatment projects
- 88 plots sampled at multiple time periods
  - 47 prescribed fire plots
  - 41 mechanical plots

## Repeated measures

- P00: Pre-treatment
- P01: 1 year post-treatment
- P02: 2 years post-treatment
- P08: 8 years post-treatment





# Methods

## Field sampling overview

- Field sampling based on NPS Monitoring Handbook
- Random plot location within treatment
- Up to 6 plots installed per treatment
- 2 types of plots: “detailed” & “fuels”
  - Trees inventoried only for detailed
- Data gathered on trees, downed fuels & understory plants

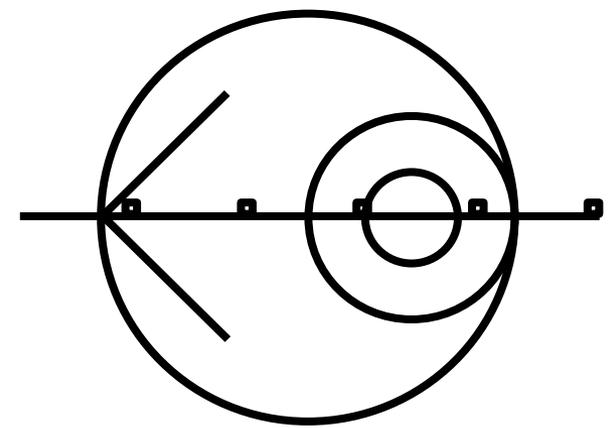
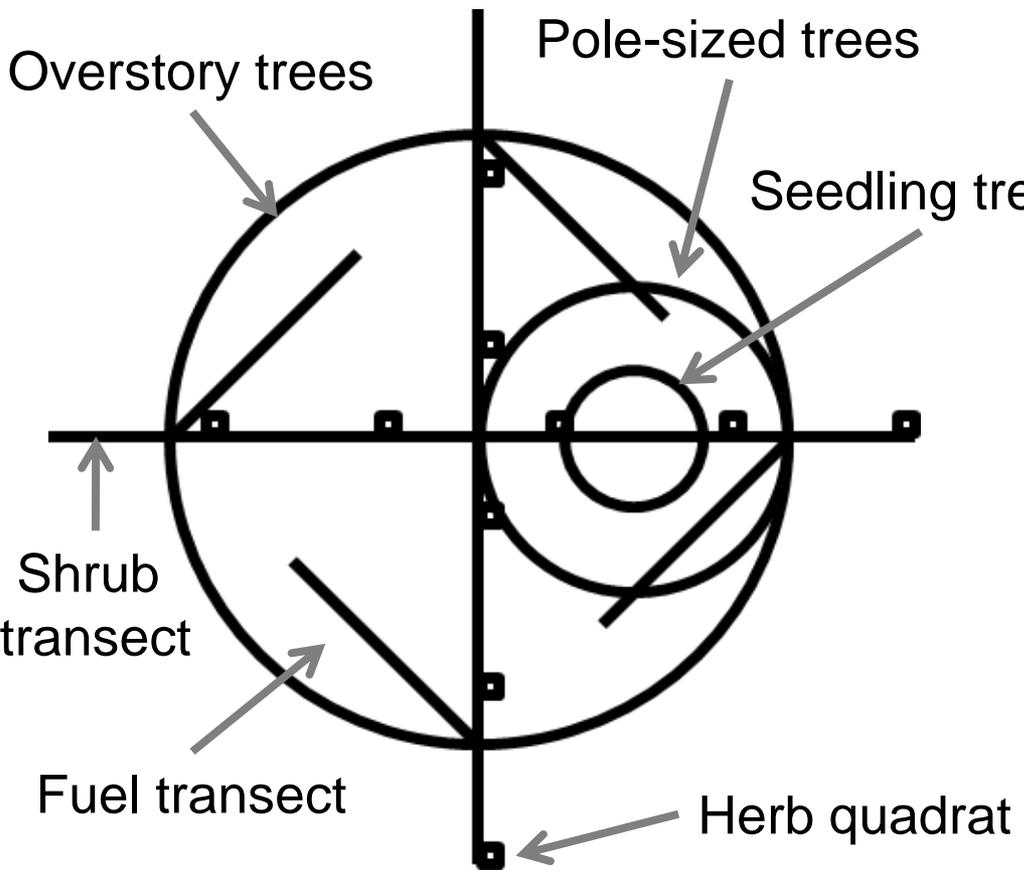




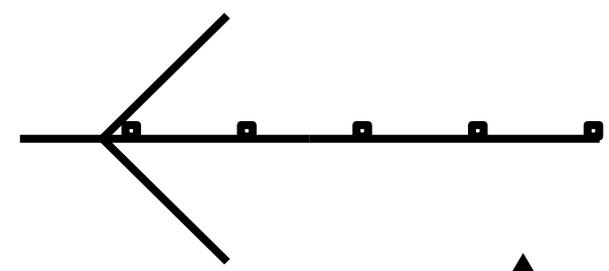
# Methods

“Detailed” 2001-2002

“Detailed” 2003-2006



“Fuels” 2003-2006



↑ Upslope



# Methods

## Calculations

- Dead fuel biomass calculated using CA constants
  - *van Wagtendonk et al. 1996, 1998*
- Live fuel biomass calculated using FIREMON constants
  - *Lutes et al. 2006*
- Canopy metrics were calculated with the FFE-FVS
  - Canopy base height (CBH), canopy bulk density (CBD), tree density
- NEXUS used for the fire behavior modeling
  - Created custom fuel models from field calculated values
  - 90<sup>th</sup> percentile conditions specific to each fuel treatment project



# Statistical Methods

The plots have been stratified by treatment and dominant forest type:

- Mechanical-Mixed conifer
- Mechanical-Yellow pine
- Mechanical-Red fir
- Fire-Mixed conifer
- Fire-Yellow pine



Used generalized linear mixed models (SAS Proc GLIMMIX) to test significance ( $P < 0.05$ ) for fuels and stand structure. No stats on fire outputs.



# Statistical Methods

Treatment-forest type	P00	P01	P02	P08
FIRE-MC	25	24	25	18
FIRE-YP	22	20	18	<u>11</u>
MECH-MC	24	24	19	17
MECH-YP	6	6	6	6
MECH-RF	11	11	10	<u>5</u>
<b>Total</b>	<b>88</b>	<b>85</b>	<b>78</b>	<b>57</b>

## Unbalanced sample size

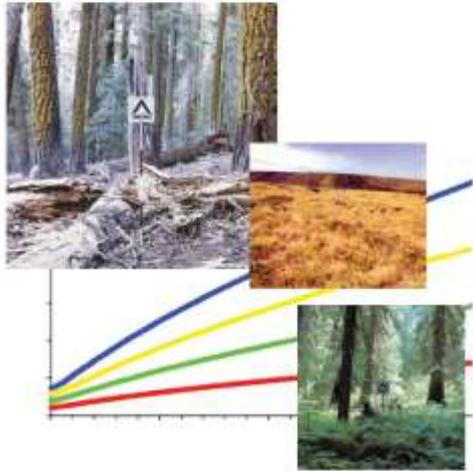
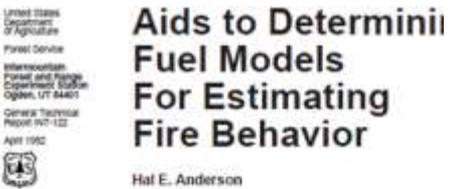
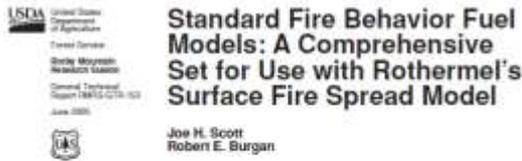
- Not enough time
- Re-treatment occurred
- Wildfire burned some
- Missed 2 yrs in field

## Monitoring data

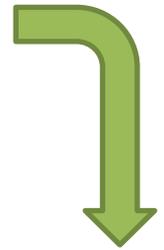


# Custom Fuel Modeling

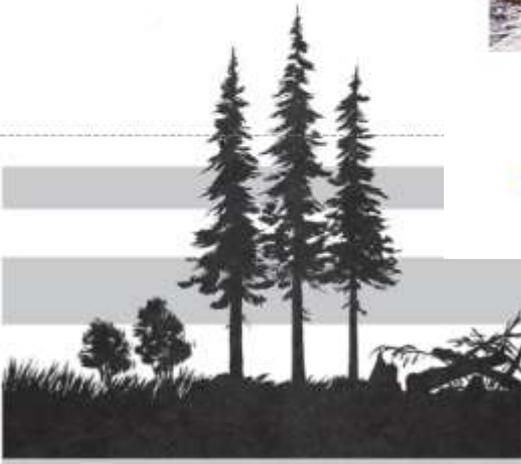
Quantify the uncertainty associated with the use of standard and custom fuel models



**VS.**



Fuel load (t/ac)					Fuel bed
1-hr	10-hr	100-hr	Live herb	Live woody	depth (ft)
5.1	0.77	1.84	0	0.01	2.1

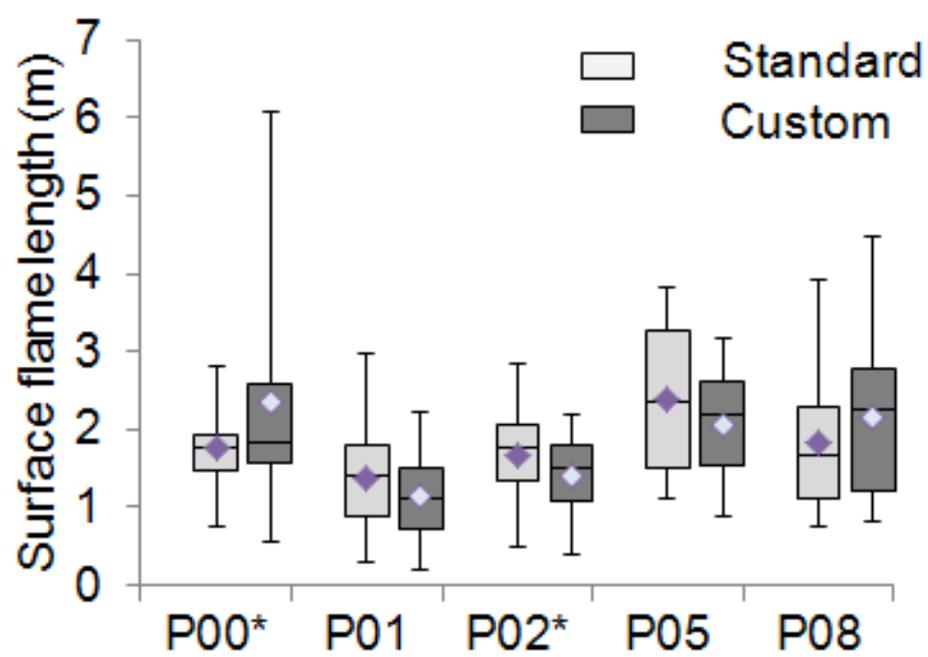


Noonan-Wright, EK, NM Vaillant, AL Reiner. 2013. The effectiveness and limitations of fuel modeling using the Fire and Fuels Extension to the Forest Vegetation Simulator. Forest Science. In press.



# Custom Fuel Modeling

## Why custom fuel models?



Plots treated with prescribed fire;  
 \*significantly different (  $P < 0.05$  )

RX FIRE PLOTS ONLY – Compare surface fire flame length and fire type using standard and custom fuel models

- Good agreement & similar trends
- Custom fuel models –
  - represent live and dead fine fuel loading associated with treatments
  - accumulation of fine fuels after the treatment



# Treatment Effects & Longevity

Determine length of time fuel treatments are effective at reducing undesirable fire behavior by

- a) Measuring effects of treatments on stand structure and fuel loads over time
- b) Modeling potential fire behavior with custom fuel models





# Mechanical - Yellow Pine

Mechanical treatment in Jeffrey pine, Tahoe NF (Hot Springs)



Pre-treatment



1-year post



2-year post



5-year post



8-year post



Pre-treatment



1-year post



2-year post



5-year post



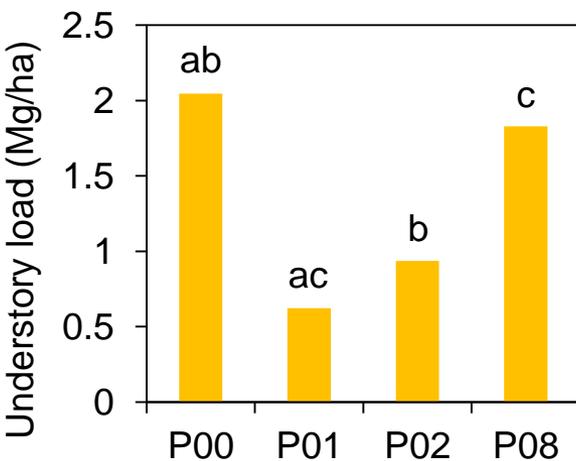
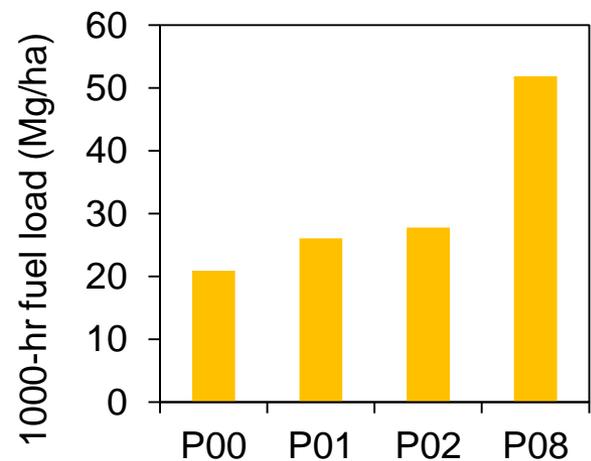
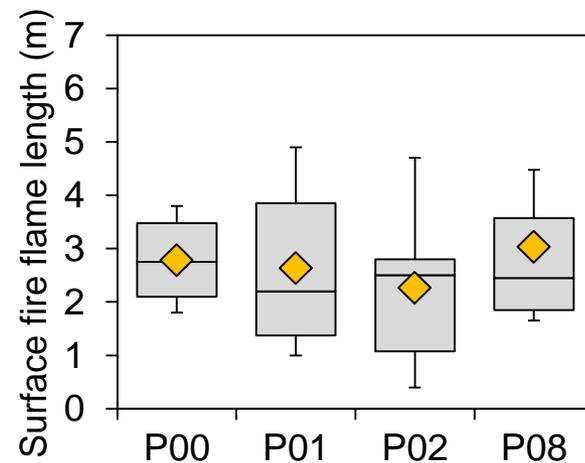
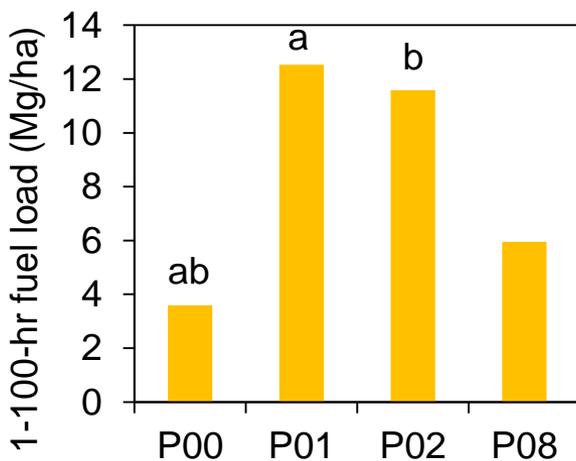
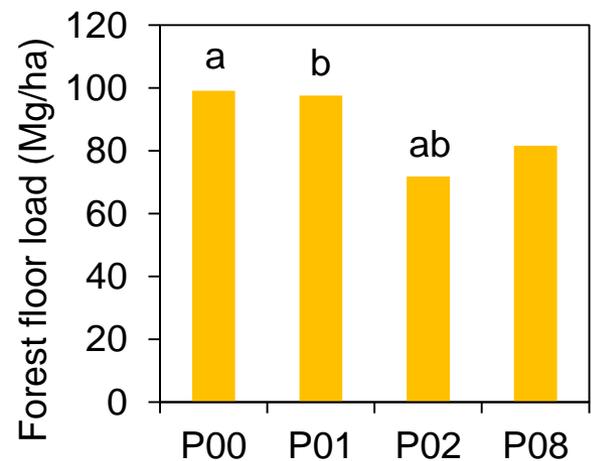
8-year post



# Mechanical - Yellow Pine

## Fuel loads and surface fire flame length

P00=6    P01=6    P02=6    P08=6



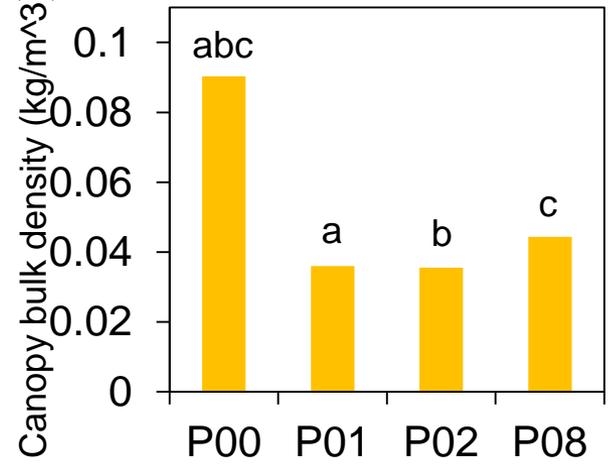
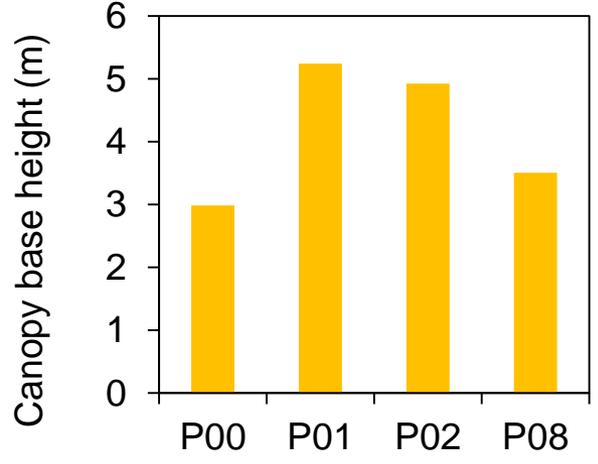
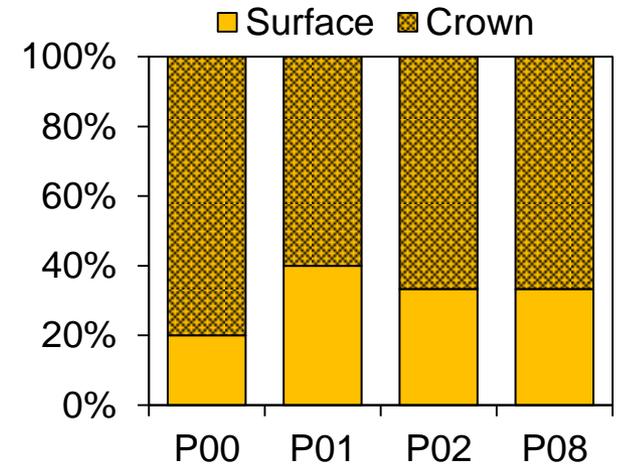
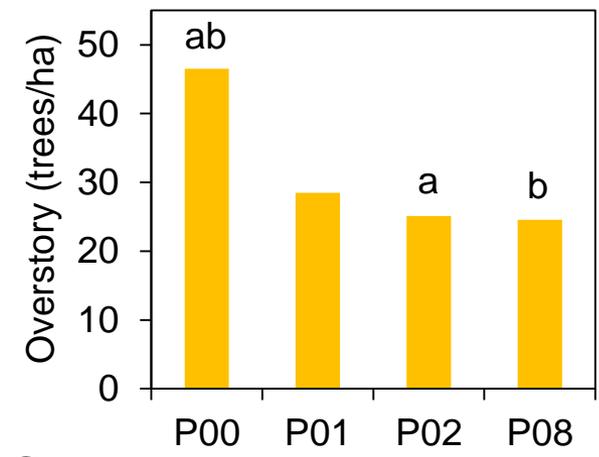
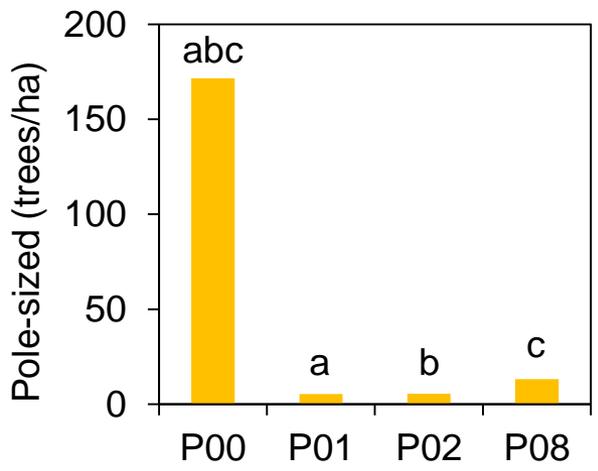
- Initial ↑ in 10- & 100-hr fuels, then steady ↓ overtime
- Over time, increase in fine fuels like litter, 1-hr, live herbs & shrubs leads to increase in surface FL



# Mechanical - Yellow Pine

## Stand structure and type of fire

P00=5    P01=5    P02=6    P08=6



Treatment ↓ in poles,  
 ↑ CBH, and ↓ CBD =  
 1/2 crown fire potential



# Mechanical - Mixed Conifer

Mechanical treatment in mixed conifer, Stanislaus NF (Big Love)



Pre-treatment



1-year post



2-year post



5-year post



8-year post



STF47 21 01  
F2  
7/15/05

STANISLAUS  
F2  
7-15-05

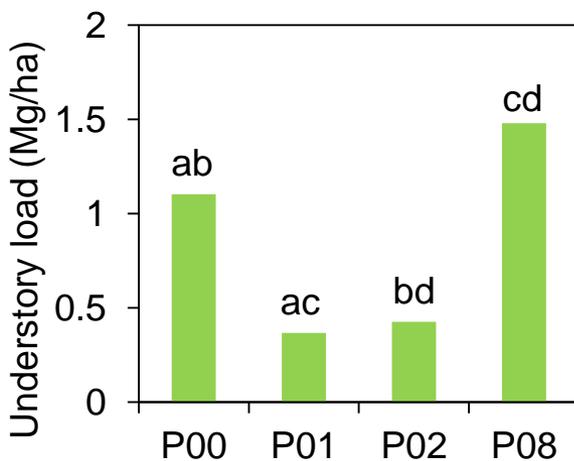
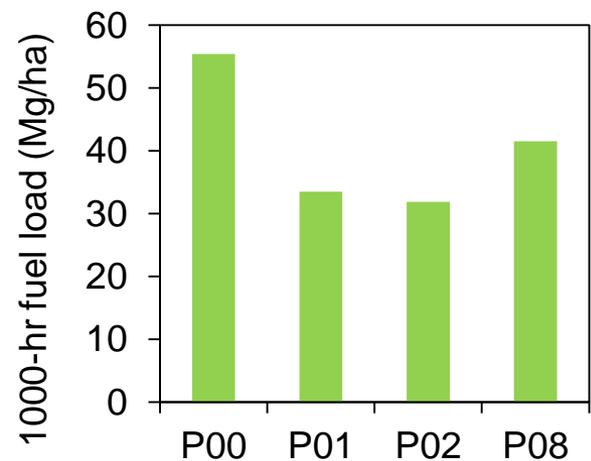
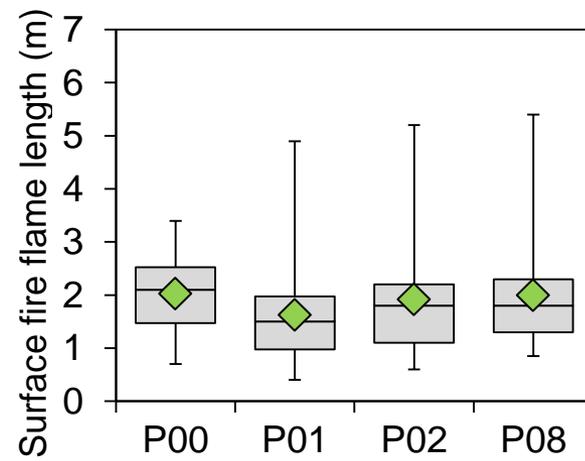
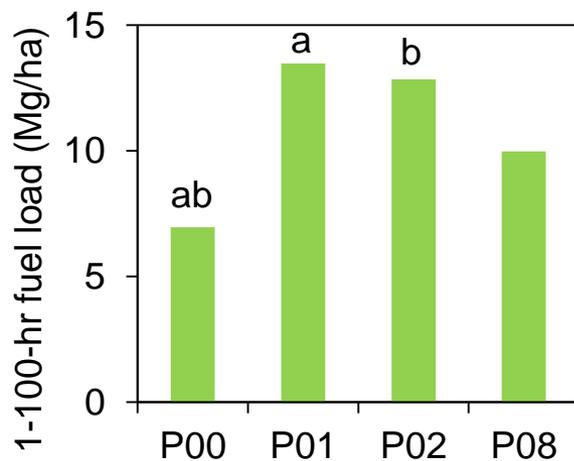
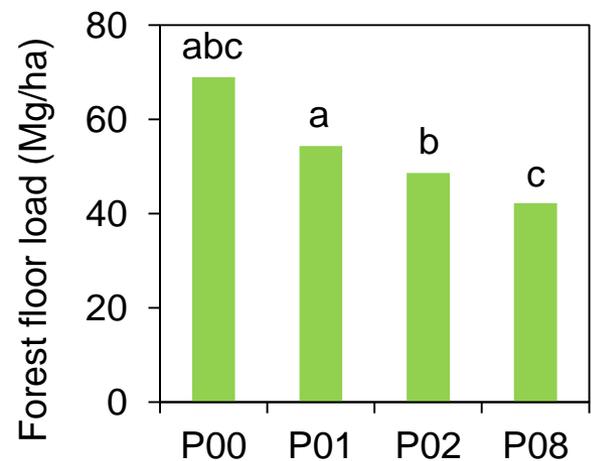
STANISLAUS  
F2  
7-15-05



# Mechanical - Mixed Conifer

## Fuel loads and surface fire flame length

P00=24    P01=24    P02=19    P08=17



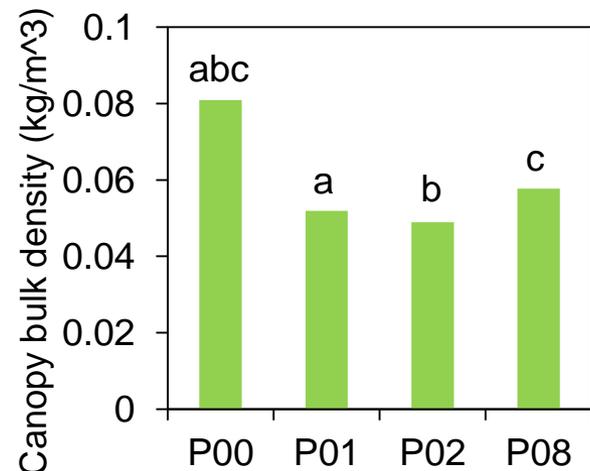
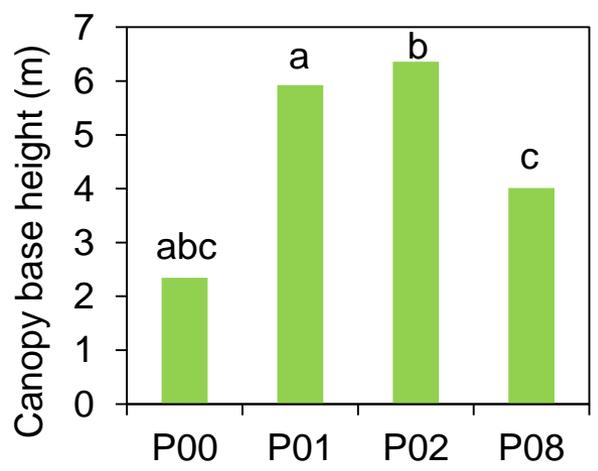
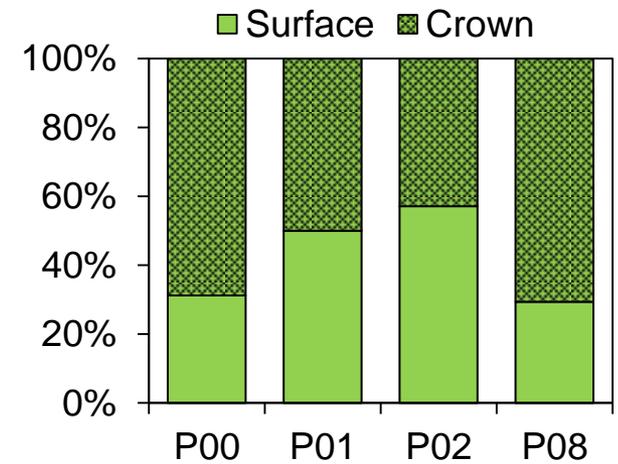
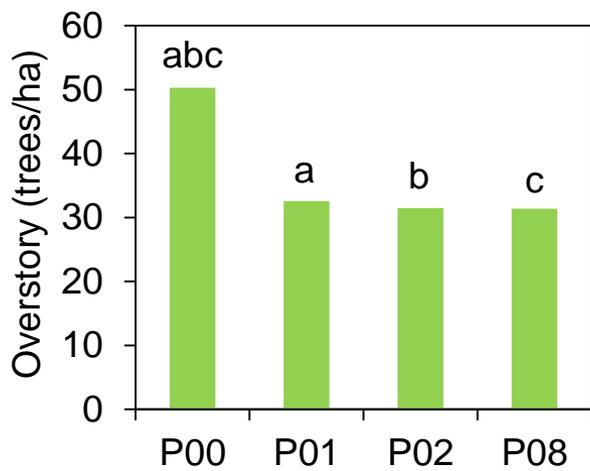
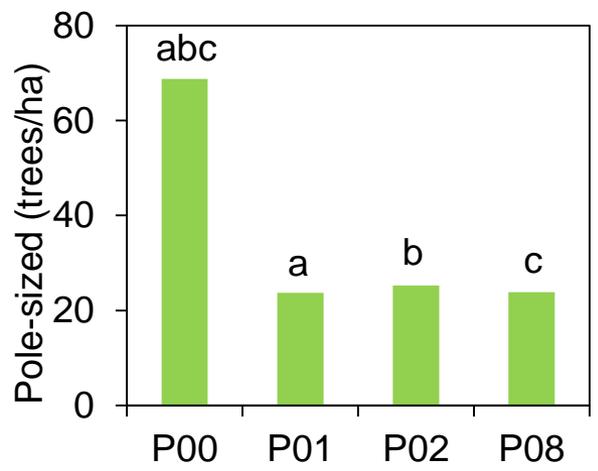
Surface FL varies little thru time: ↓ in surface FL is due to slight ↓ litter load



# Mechanical - Mixed Conifer

## Stand structure and type of fire

P00=16   P01=16   P02=14   P08=17

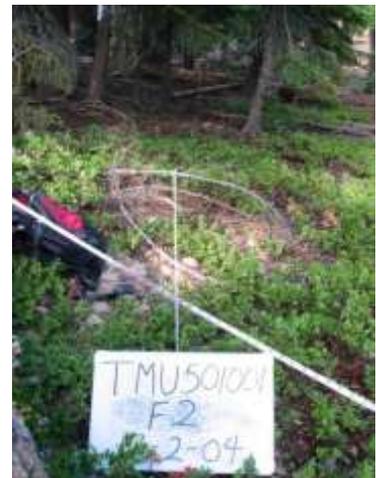


Treatment ↓ trees, ↑ CBH, and ↓ CBD = 50% crown fire potential initially then CBH ↓ & CBD ↑ around P08



# Mechanical - Red Fir

Mechanical treatment in red fir, Lake Tahoe Basin (Dollar)



Pre-treatment



1-year post



2-year post



5-year post



8-year post



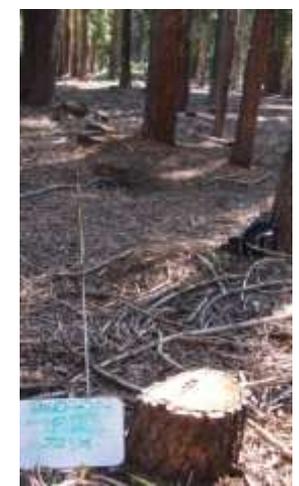
Pre-treatment



1-year post



2-year post



5-year post



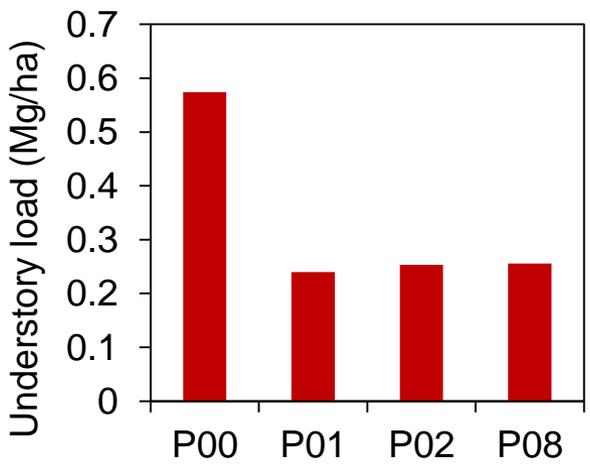
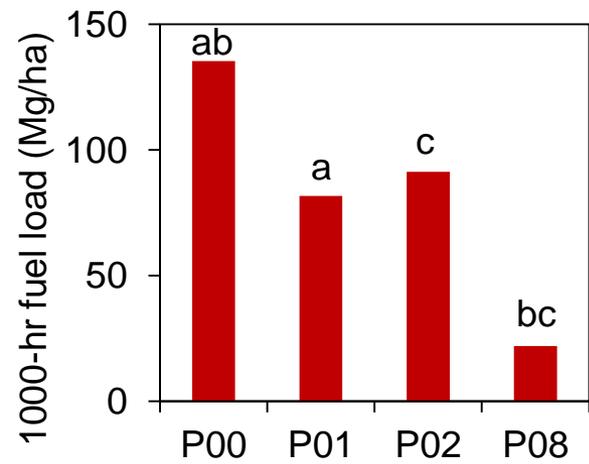
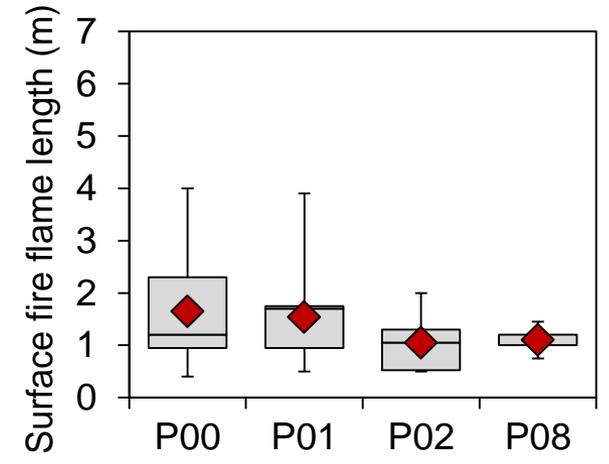
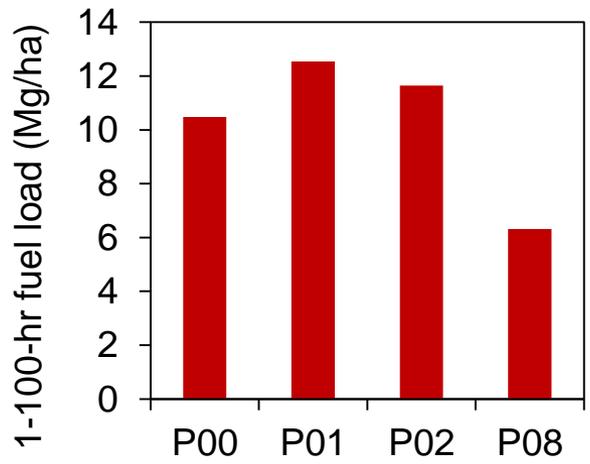
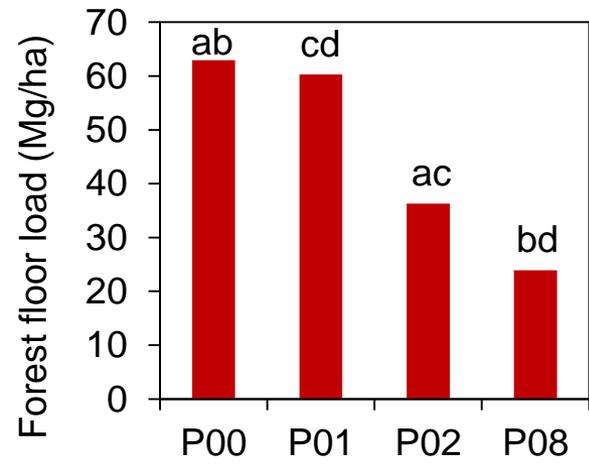
8-year post



# Mechanical - Red Fir

## Fuel loads and surface fire flame length

P00=11    P01=11    P02=10    P08=5



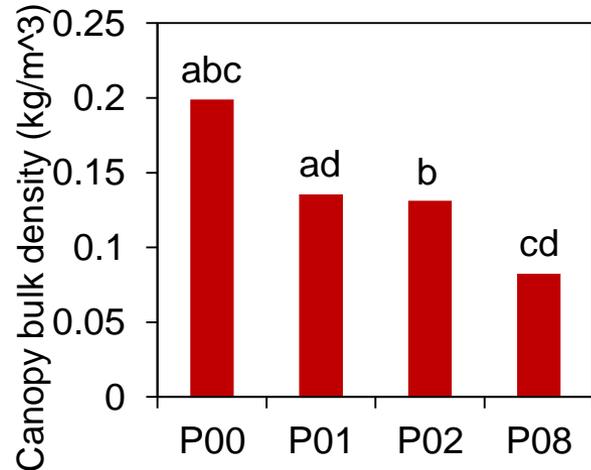
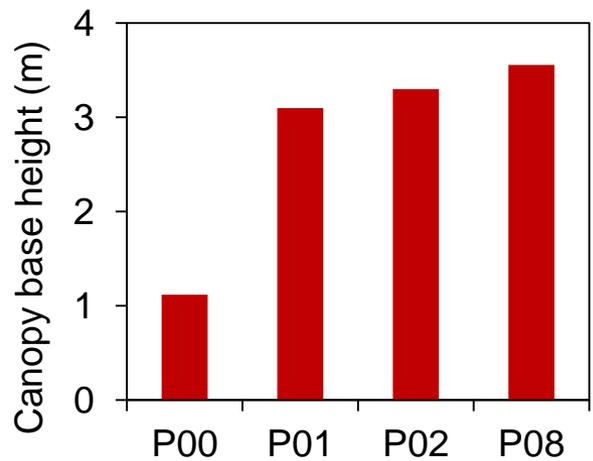
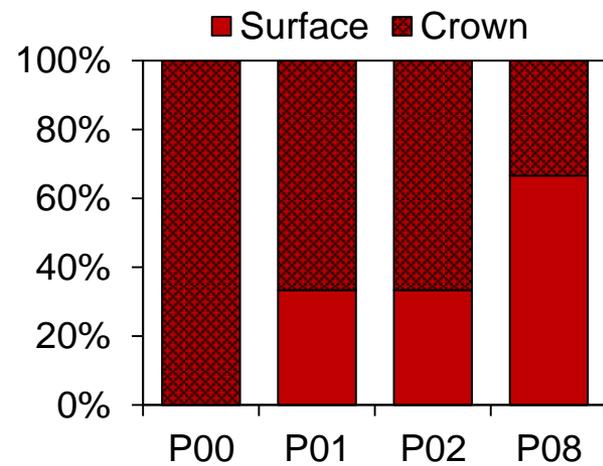
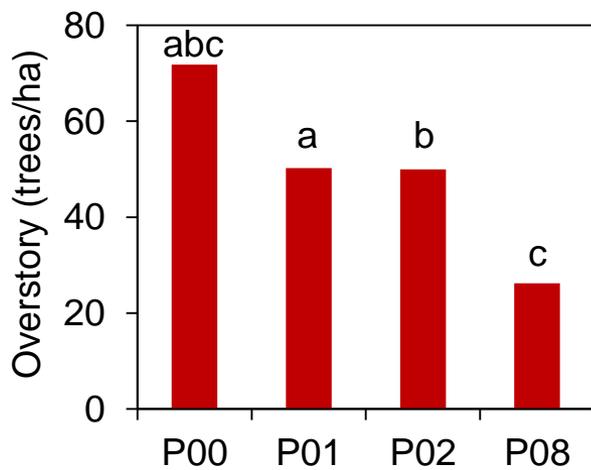
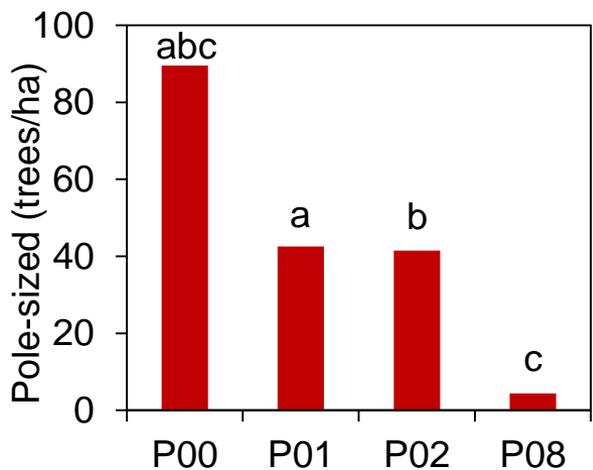
Surface FL varies little thru time: ↓ in live fuel loading (also resulting in ↓ fuel bed depths) are resulting in ↓ surface FL



# Mechanical - Red Fir

## Stand structure and type of fire

P00=6    P01=6    P02=6    P08=3



- 33% more surface fire after treatment
- Surface fire continues to increase up to P08



# Mechanical Treatment Summary

## Surface fuels & surface fire flame length:

- ✓ Mechanical treatments initially  $\uparrow$  10- & 100-hr fuel loads but is similar to pre-treatment levels by P08
- ✓ Negligible change in litter right after treatment but by P08,  $\uparrow$ litter
- ✓ Surface fire flame lengths: treatment effect was negligible.

## Stand structure & type of fire:

- ✓ Mechanical treatments resulted in less CBD post-treatment which remained consistent thru P08.
- ✓ Increase in CBH reflects large  $\downarrow$  of poles/ha post-treatment.
- ✓ Crown Fire:  $\downarrow$  crown fire



# Fire – Yellow Pine

Fire-only treatment in Jeffrey pine, Modoc NF (Hackamore)



Pre-treatment



1-year post



2-year post



8-year post



10-year post

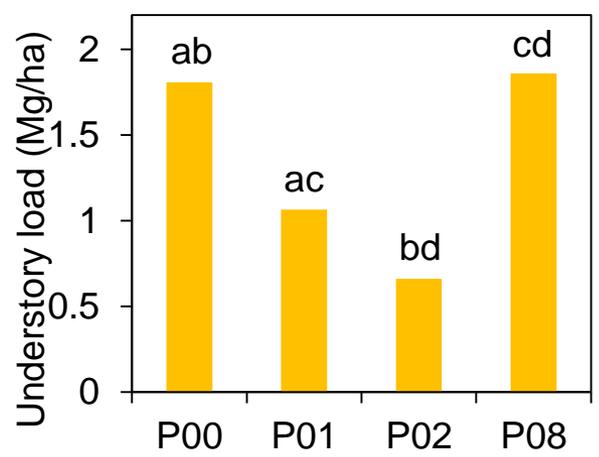
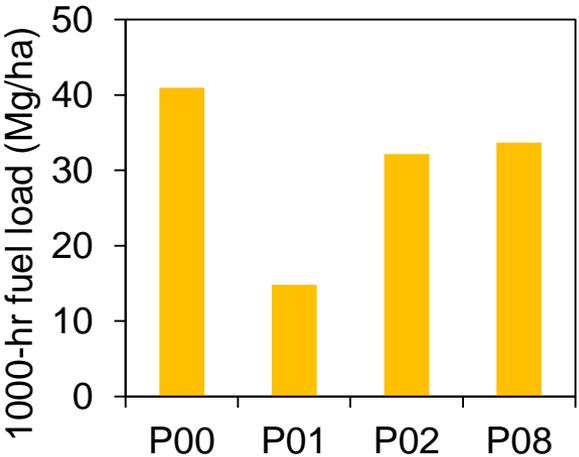
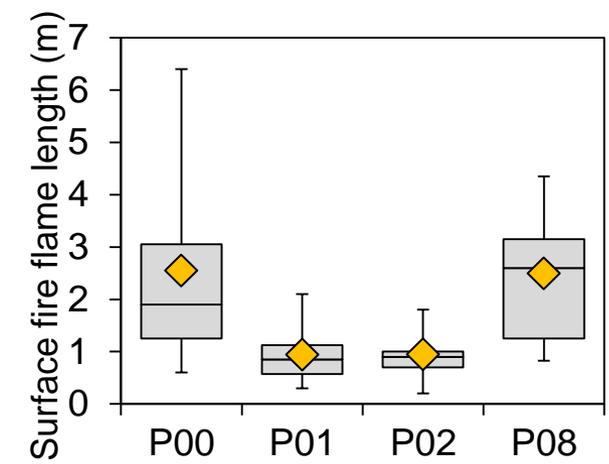
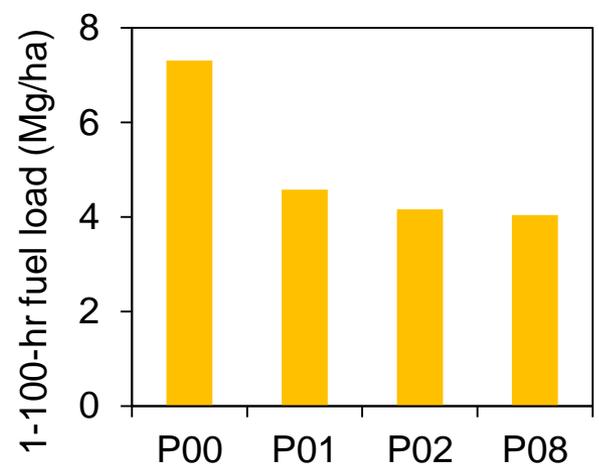
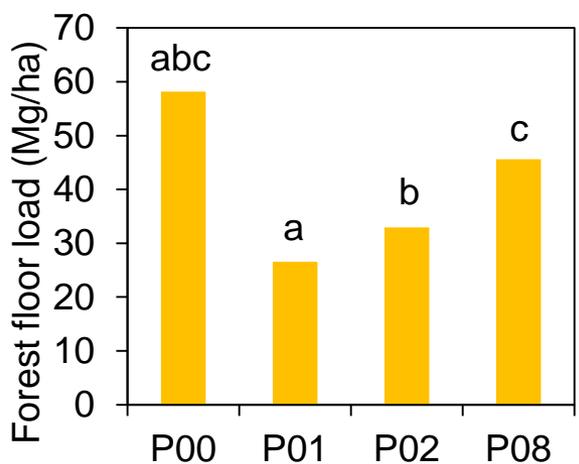




# Fire – Yellow Pine

## Fuel loads and surface fire flame length

P00=22    P01=20    P02=18    P08=11



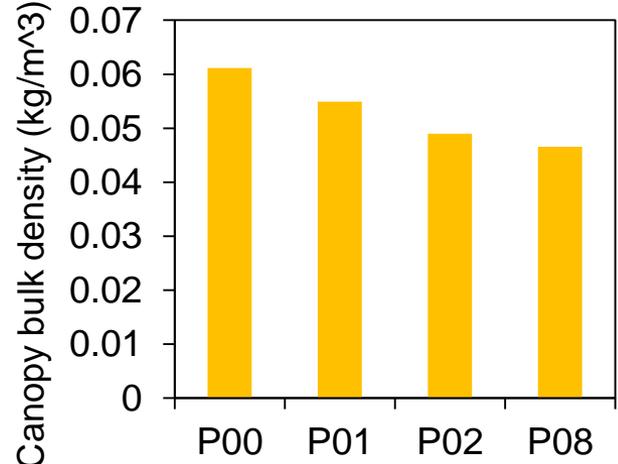
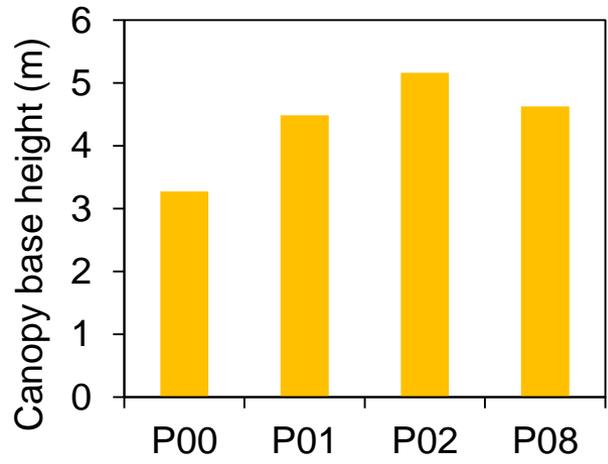
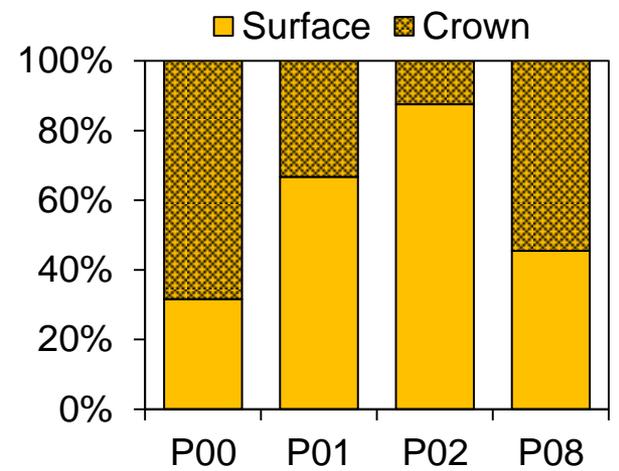
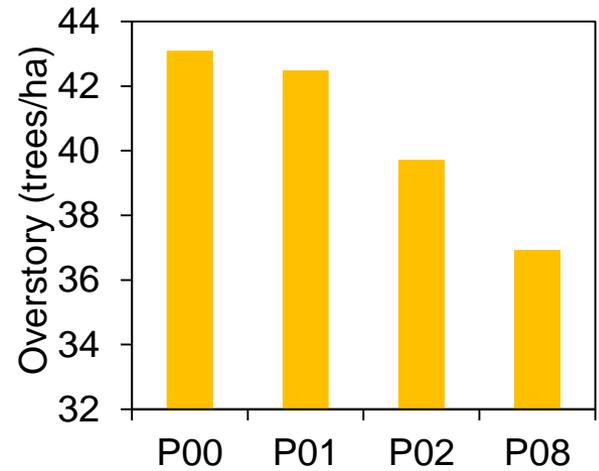
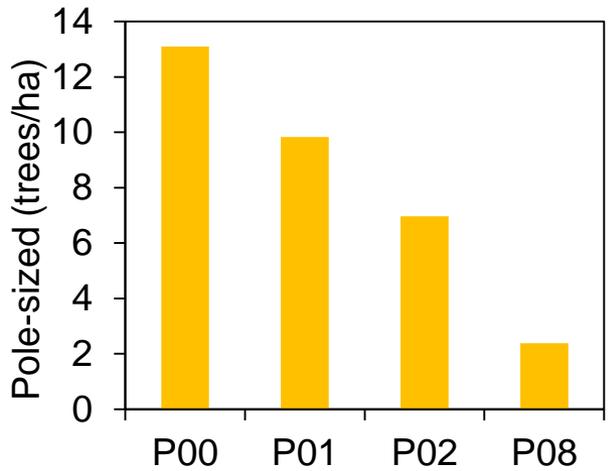
- Initial ↓ in fuel load = ↓ surface FL
- By P08 surface FL=P00 from ↑ in live and smaller fuels



# Fire – Yellow Pine

## Stand structure and type of fire

P00=19    P01=18    P02=16    P08=11



✓ ↑ CBH & ↓ CBD  
lead to ↑ surface  
fire P01 & P02

✓ Delayed mortality  
of trees seen P02  
& P08



# Fire – Mixed Conifer

Fire-only treatment in mixed conifer, Klamath NF (Surrogate)



Pre-treatment



1-year post



2-year post



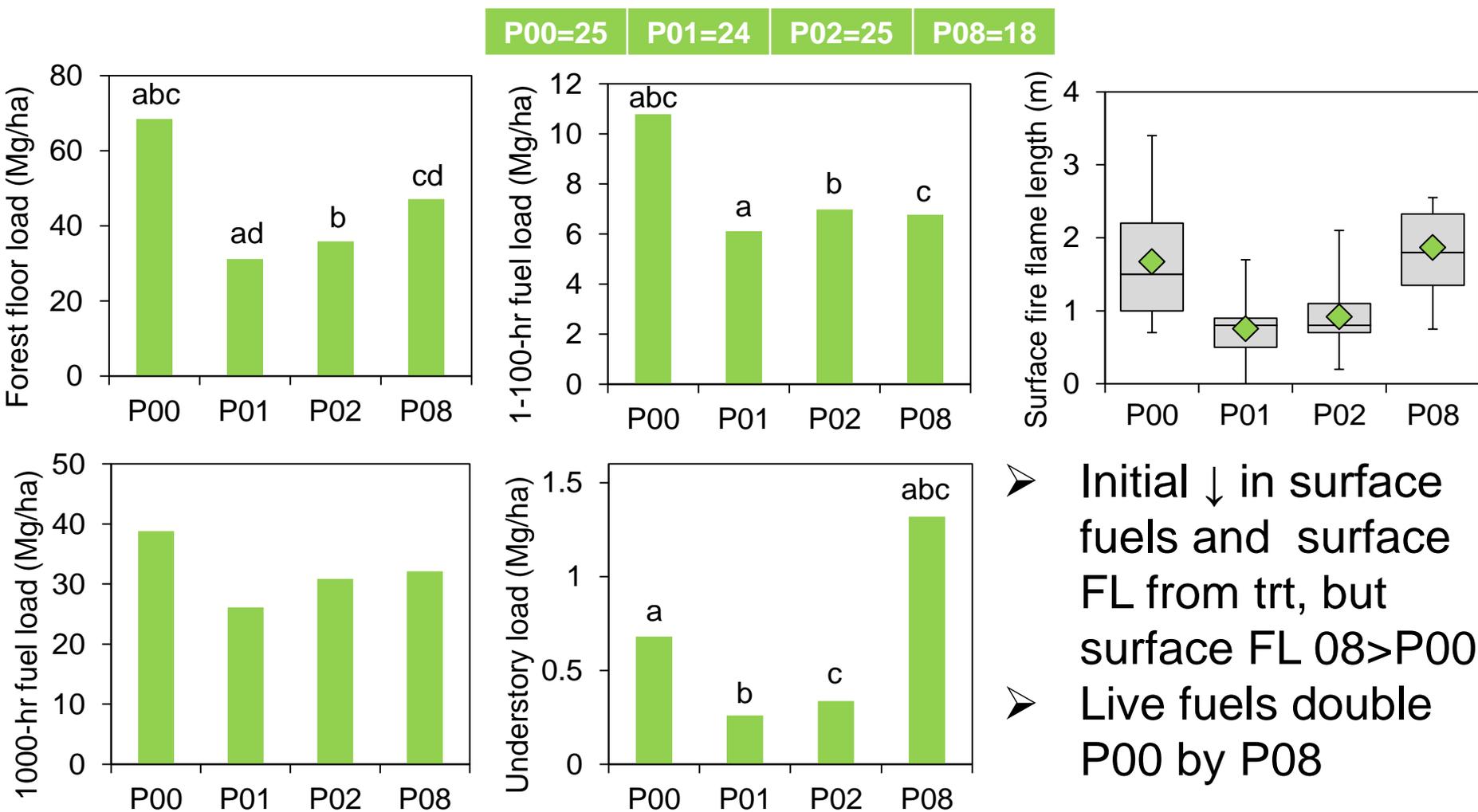
8-year post





# Fire – Mixed Conifer

## Fuel loads and surface fire flame length



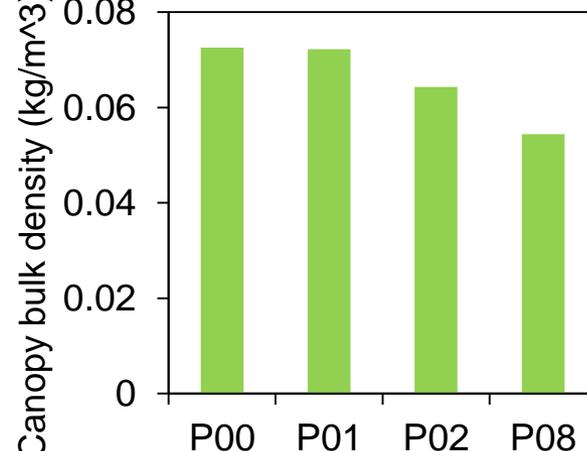
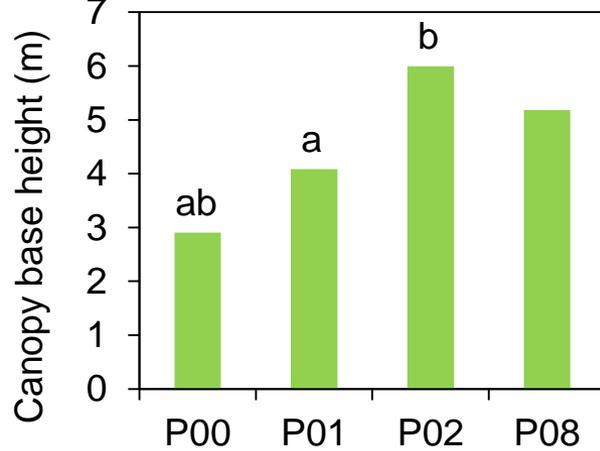
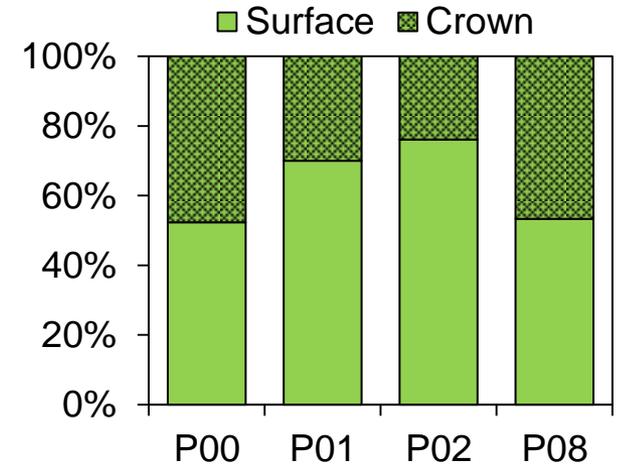
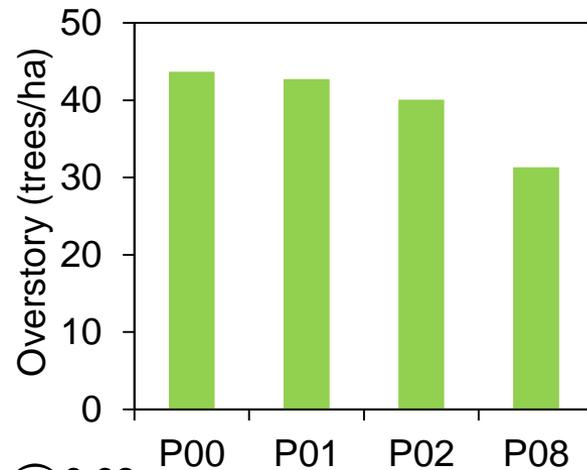
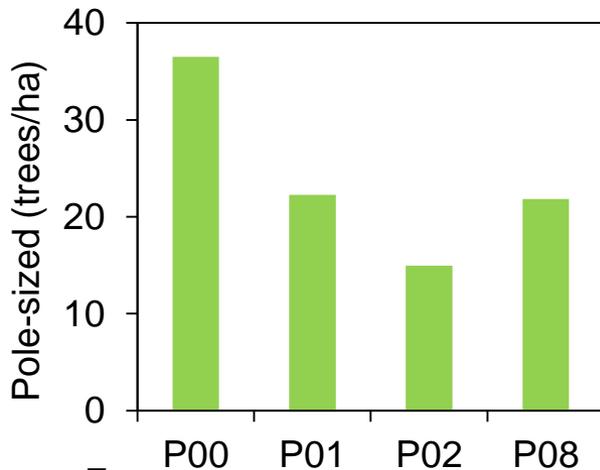
- Initial ↓ in surface fuels and surface FL from trt, but surface FL 08>P00
- Live fuels double P00 by P08



# Fire – Mixed Conifer

## Stand structure and type of fire

P00=21   P01=20   P02=21   P08=15



- ↑ in CBH & ↓ in CBD did ↓ crown fire P01 & P02
- Ingrowth of pole-sized trees P08 ↓ CBH



# Prescribed Fire Summary

## **Surface fuels & surface fire flame length:**

- ✓ Fire only-treatments initially ↓ loads followed by ↑
- ✓ Understory live fuels exceeded P00 by P08
- ✓ Surface FL exceeded P00 levels by P08
  - The ↑ in litter and live fuels are the driving factor

## **Stand structure & type of fire:**

- ✓ Not a large impact on stand structure, very little sig diff.
- ✓ Delayed mortality is evident from continued ↓ in density
- ✓ ↑ in CBH & ↓ in CBD did ↓ crown fire likelihood P01 & P02, but by P08 crown fire likelihood ↑ with ↑ surface fuels



# Management Implications

- Despite extensive variability between plots, overall trends for treatment-forest combinations exist.
- Stand structure and fuel load trends help inform both fuel and silviculture integrated objectives and prioritizations.
  - ✓ Increases in live understory loads indicate potentially need for retreatment



- ✓ Total fuel load (forest floor, woody & live) in fire plots ~75% of pre- also indicate potential need for re-treatment
- ✓ Mechanical treatments would benefit from prescribed fire treatments to reduce still elevated fuel loads



# Management Implications

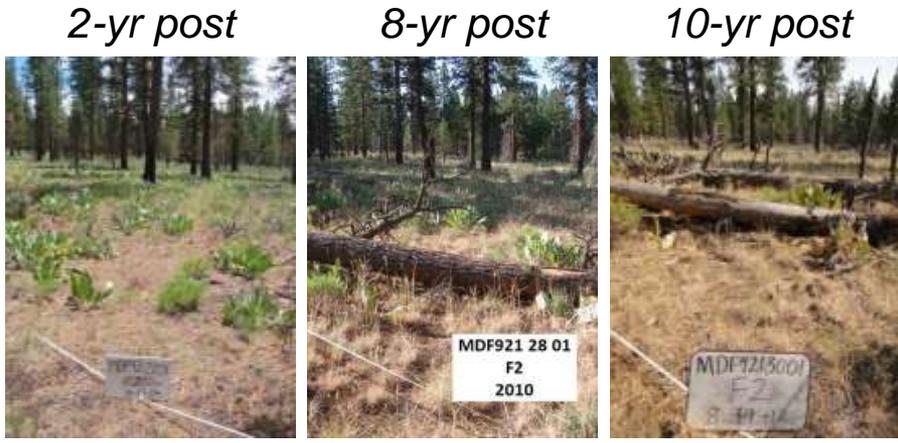
- Although not represented in our plots we agree with past research that mechanical treatments followed by prescribed fire is likely the best option
- Challenges exist with completing prescribed fire, but using only non-fire techniques does not mitigate the complete risk nor does it alone meet restoration goals
- Need for more intense prescribed fires that potentially kill more trees to further alter stand structure and consume more fuels to sustain the treatment effect
- Subsequent burns are also needed and often are easier and cheaper than initial entry to maintain treatment effectiveness



# Plea For More Monitoring

## Need for more long term monitoring

- To understand how fuels change from treatment over time
  - For **all** treatment types and **more** forest types
- Monitoring needs to extend beyond the first year or two in fire treated areas to not miss delayed mortality
- FFI is a great tool to archive & analyze data





# Future Monitoring Plans

- We want to continue to monitor the plots
  - We will be back in the field this summer to continue gathering data on 24 of the plots.
- We want to expand the scope of the project within CA and throughout the west
  - Do you have any existing monitoring data that could be added to this?
  - Please let us know and we will work with you to incorporate it!



# Future Work

Continue to use the data to answer other questions beyond the grant objectives

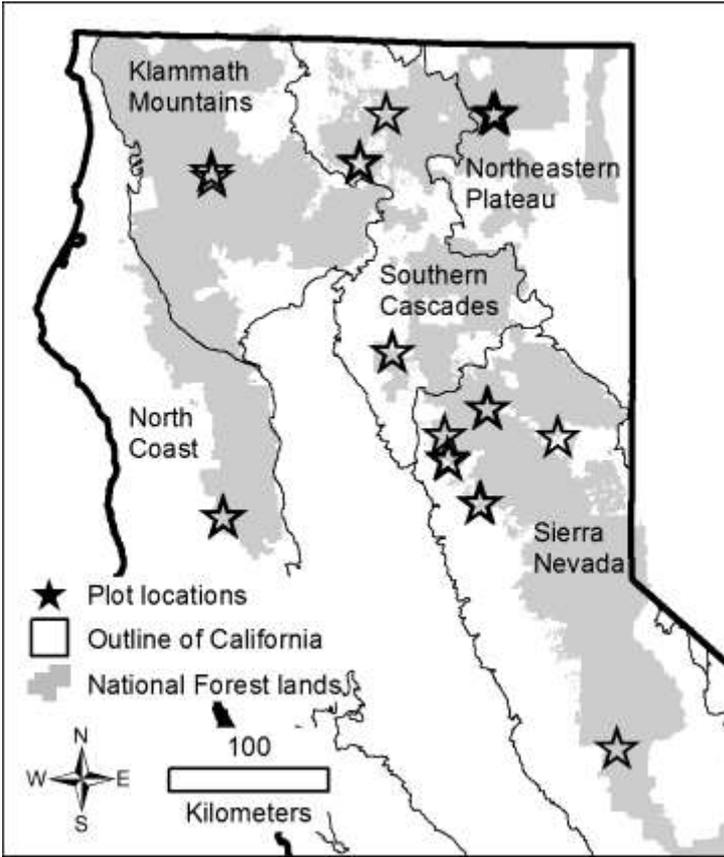
- Fire effects – use the post prescribed fire data collected on char, scorch, torch, and severity to see impacts on tree survivorship and plant response
- Vegetation response – use the species level herbaceous and shrub data to explore vegetation response to treatment
- And.....?





# Prescribed Fire & Carbon

Assess prescribed fire effects on carbon stocks and validate modeled outputs



**VS.**



*NM Vaillant, NM, AL Reiner, EK Noonan-Wright. Prescribed fire effects on field-derived and simulated forest carbon stocks over time. In review.*

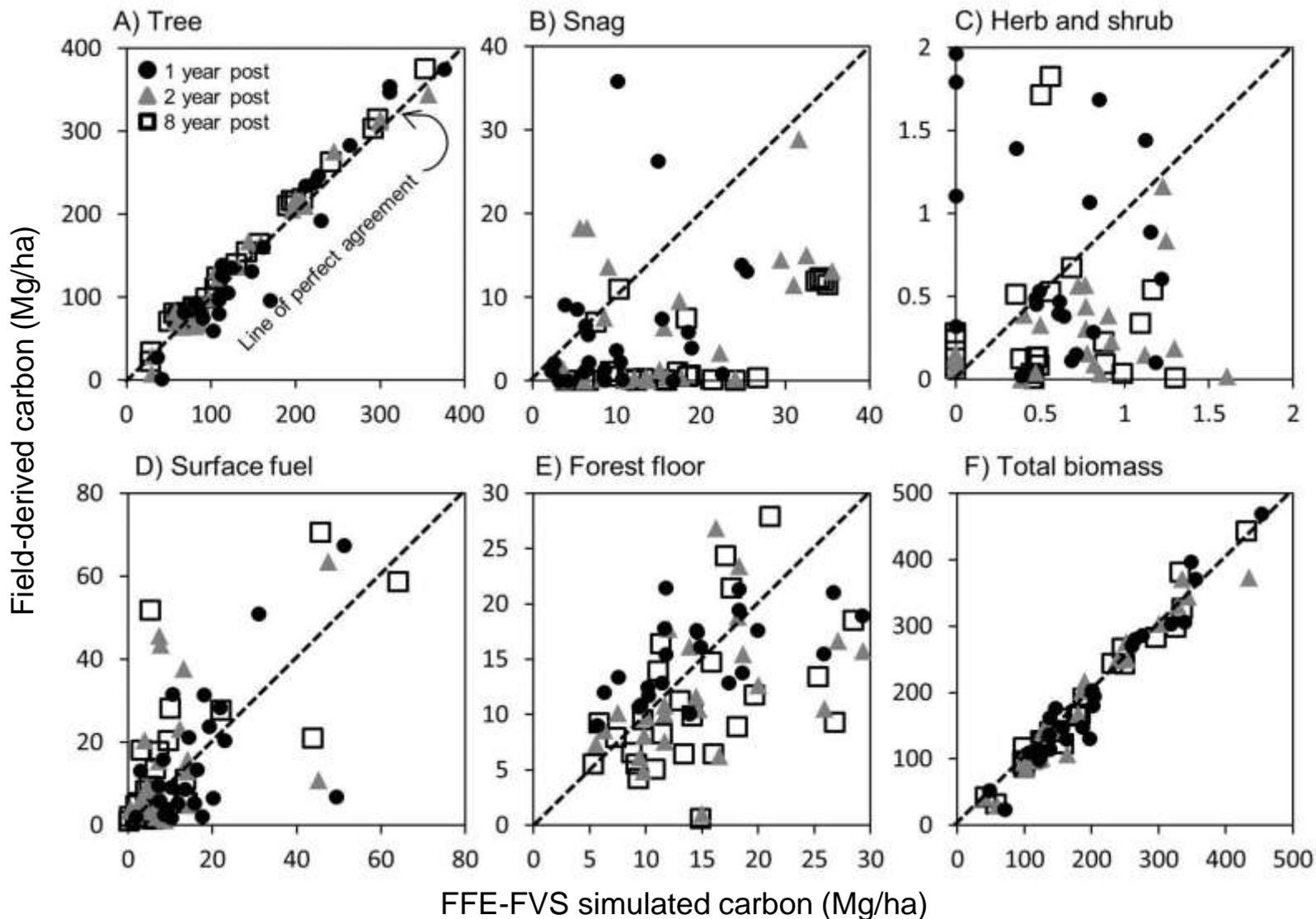


# Prescribed Fire & Carbon

Carbon pool	Pre	1 year post	2 year post	8 year post
-----Mg/ha-----				
<b>Tree</b>	150.2(18.8) <sup>a</sup>	147.1(18.7) <sup>a</sup>	145.7(18.8)	154.7(20.5)
<b>Snag</b>	3.3(1.3) <sup>ab</sup>	3.7(1.0) <sup>c</sup>	6.6(1.6) <sup>ac</sup>	6.1(1.7) <sup>b</sup>
<b>Herb and shrub</b>	0.7(0.1) <sup>ab</sup>	0.4(0.1) <sup>ac</sup>	0.3(0.1) <sup>bd</sup>	0.8(0.1) <sup>cd</sup>
<b>Surface fuel</b>	26.0(5.2) <sup>a</sup>	15.7(3.8) <sup>a</sup>	18.5(4.5)	19.0(4.3)
<b>Forest floor</b>	24.8(2.2) <sup>abc</sup>	11.1(1.3) <sup>ad</sup>	12.0(1.2) <sup>be</sup>	16.4(1.1) <sup>cde</sup>
<b>Total biomass</b>	204.0(21.1) <sup>a</sup>	177.9(21.2) <sup>a</sup>	181.8(20.7)	197.1(22.2)
<b>Simulated wildfire emissions</b>	34.7(3.6) <sup>abc</sup>	19.0(2.4) <sup>a</sup>	20.5(2.4) <sup>b</sup>	23.0(2.0) <sup>c</sup>



# Prescribed Fire & Carbon





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- John Caratti & Nate Benson for FFI data import

[http://www.fs.fed.us/adaptivemanagement/pub\\_reports/JFS\\_vaillant2.shtml](http://www.fs.fed.us/adaptivemanagement/pub_reports/JFS_vaillant2.shtml)

[http://www.firescience.gov/projects/09-1-01-1/project/09-1-01-1\\_final\\_report.pdf](http://www.firescience.gov/projects/09-1-01-1/project/09-1-01-1_final_report.pdf)