



Long-term effects of fuel treatments on carbon pools in California

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- Fuel treatments are typically designed to reduce potential fire behavior
 - Fire, mechanical & mix
- Need for more long-term monitoring data to understand impacts on both vegetation & fire
 - To date most of empirical research only considers time immediately after treatment
 - Fuel treatment longevity is likely to depend on vegetation & treatment type



- Many studies look at carbon pre & post 1 year with field based data
 - i.e. Stephens et al. 2009, Sorensen et al. 2011, Hurteau & North 2009, Reinhardt & Holsinger 2010
- Beyond 1 year post most are simulations
 - Sorensen et al. 2011, Hurteau & North 2009, Reinhardt & Holsinger 2010
- Very few studies beyond 1 year post not based on simulations
 - i.e. Hurteau & North 2010



Project Background

In response to the 2000 National Fire Plan long-term hazardous fuel reduction plan the fuel treatment effects & effectiveness monitoring project in R5 was started by AMSET

- 2000-2006 –regional funding
- Solicit projects from all NF in CA for all vegetation types
- Monitoring for pre, 1, 2, 5, 10 & 20 yrs post treatment

Funded by JFSP 2009-2013

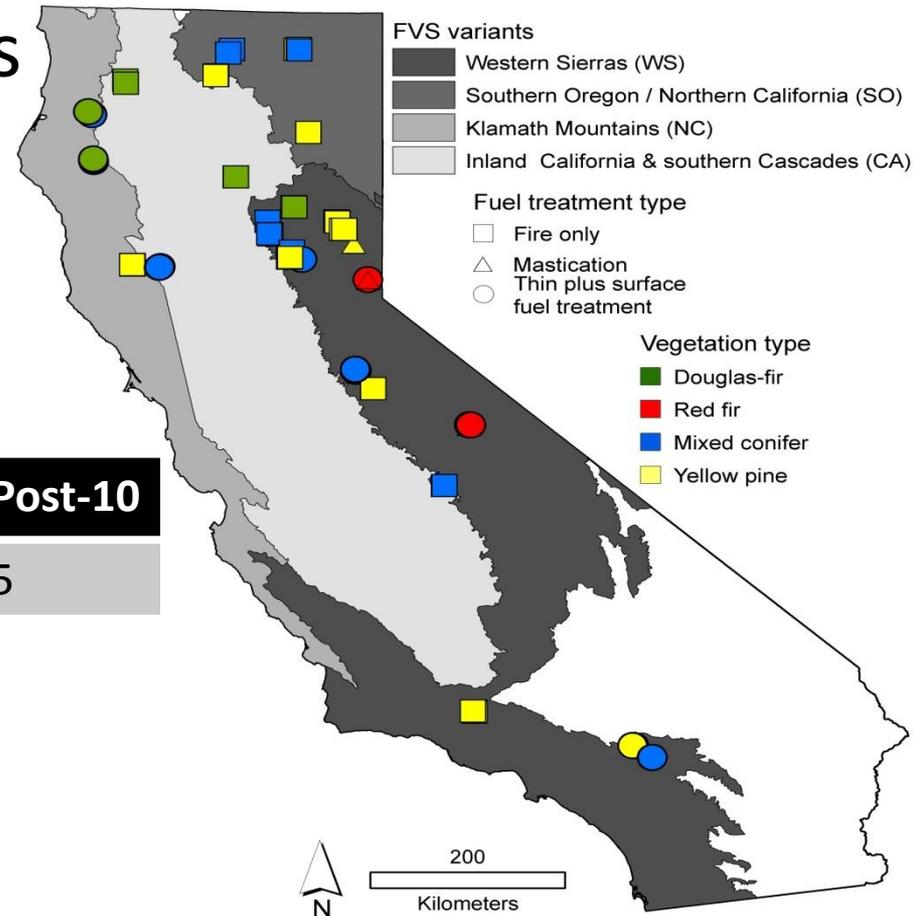
- Narrowed scope to conifer forests (published data)
 - Vaillant et al. 2009 a & b
- Changed intervals to pre, 1, 2, 5, 8 & 10 yrs post treatment



Study Site

From 2001-2011

- 28 fuel treatment projects
 - 88 plots
- Pre, Post 1, 2, 5, 8 & 10
 - 328 data points



Pre	Post-1	Post-2	Post-5	Post-8	Post-10
88	85	82	36	32	5

- No post-10 for this talk



- Random plot location within treatment
- 3-6 plots depending on year
- 2 types of plots – detailed & fuels
 - Detailed includes tree sampling
 - Fuels do not
- Actual fuel loading
 - ground, surface & live
- FVS for canopy & carbon calculations





Data Grouping

The plots have been stratified by:

Forest and treatment type

- Douglas-fir/Fire
- Douglas-fir/Thin surf. fuel treat.
- Mixed conifer/Fire
- Mixed conifer/Thin surf. fuel treat.
- Red fir/Mastication
- Red fir/Thin surf. fuel treat.
- Yellow pine/Fire
- Yellow pine/Mastication
- Yellow pine/Thin surf. fuel treat.



Pre and post-1 year fire in yellow pine



Pre and post-1 year thin & surface fuel treatment in mixed conifer



Pre and post-1 year mastication in red fir





Question 1

Do carbon loads differ between pre- and post treatment for a given forest-treatment type?





FVS Carbon Calculations

- Four FVS variants = WS, SO, NC, CA
 - Majority in WS
- Calculated carbon loads outside of FVS for ground, surface, and live herb and shrub fuels from field data
 - Used FVS assumptions carbon = 50% of measured loads for all but ground fuels which are 37%
- Used FVS to calculate tree & snag carbon loads
- Used ArcFuels to run FVS



- PROC GLIMMIX in SAS
 - Generalized Linear Mixed Models
 - Allow for non-normal data
- Tested for significance Prob $t < 0.05$ between pre and post-treatment time steps within each unique forest-treatment combination ★
 - i.e. pre vs post1, pre vs post2, etc



1-hr carbon (Mg carbon/ha)

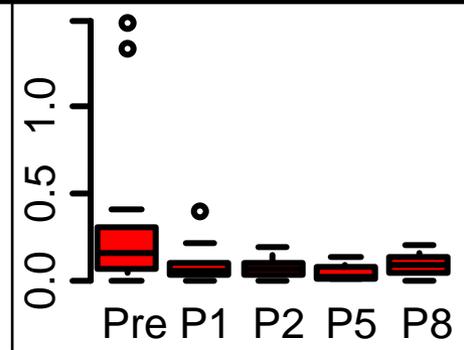
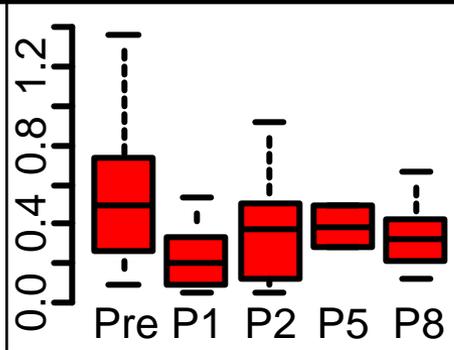
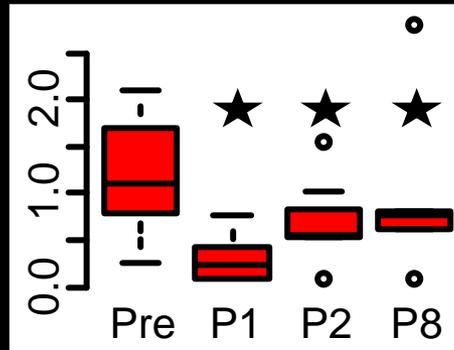
Douglas-fir

Mixed conifer

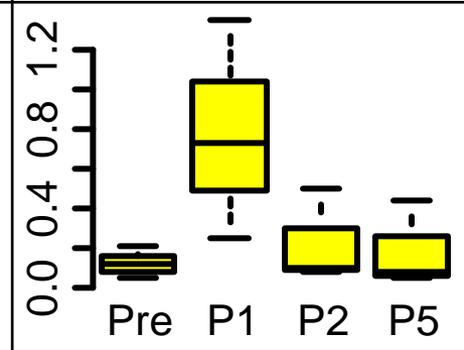
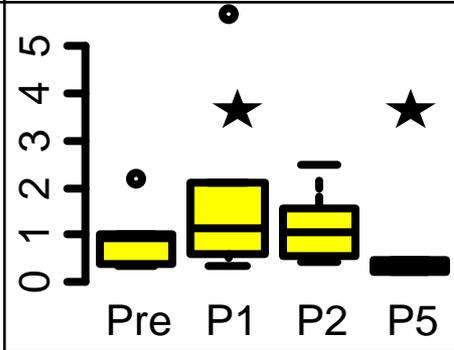
Red fir

Yellow pine

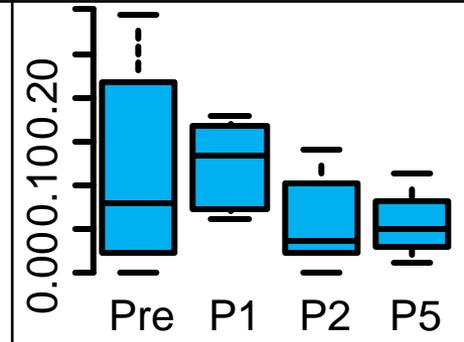
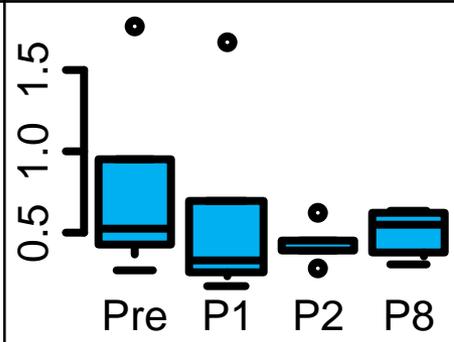
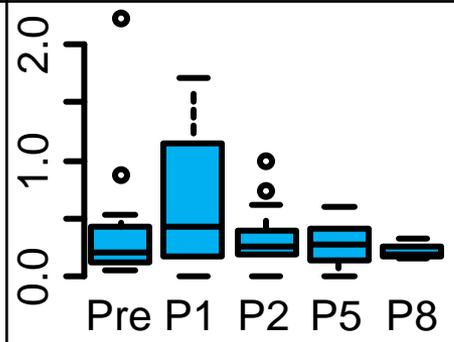
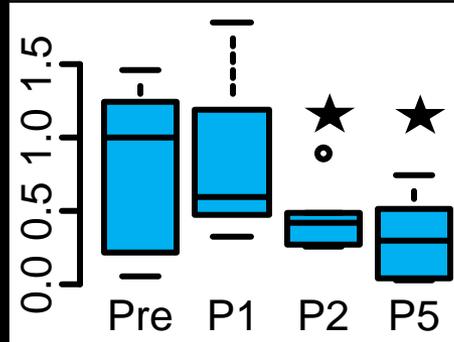
Fire



Mastication

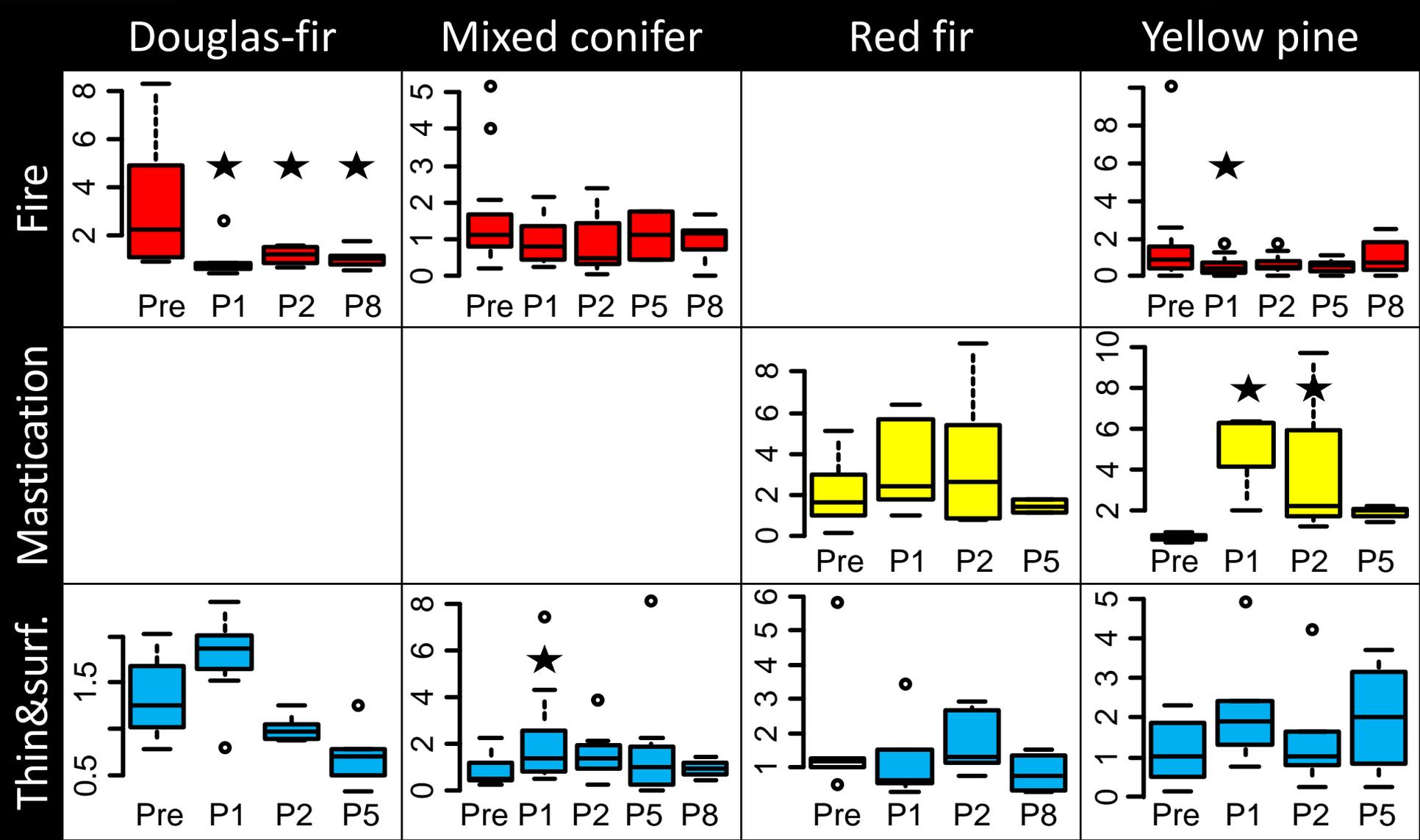


Thin&surf.





10-hr (Mg carbon /ha)





100-hr (Mg carbon /ha)

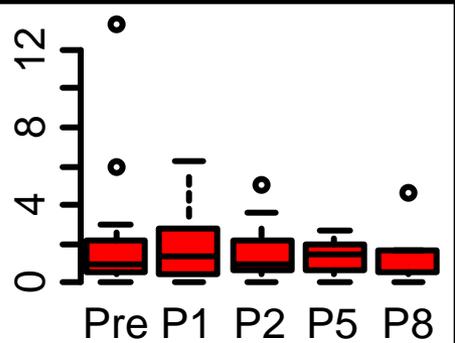
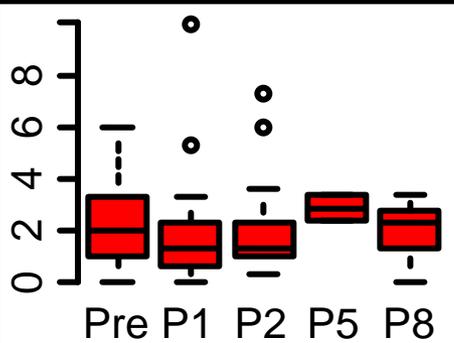
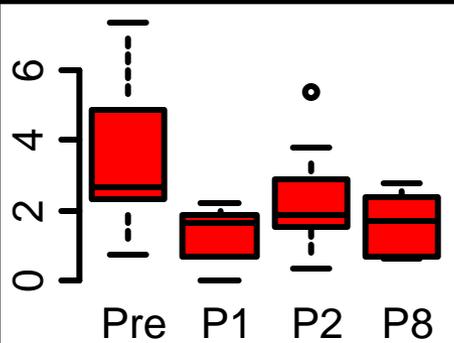
Douglas-fir

Mixed conifer

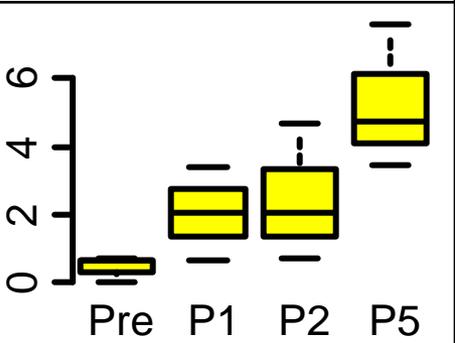
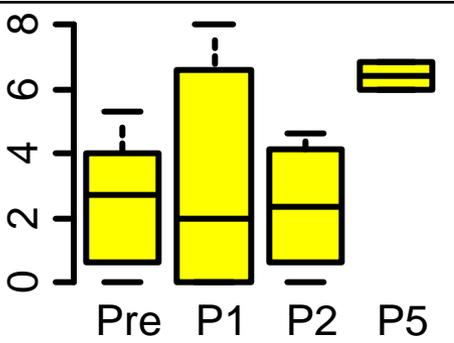
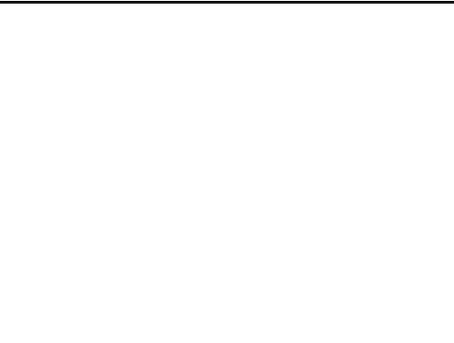
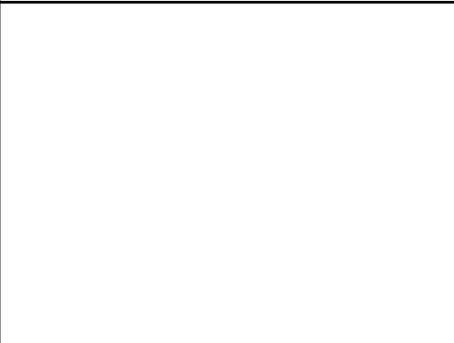
Red fir

Yellow pine

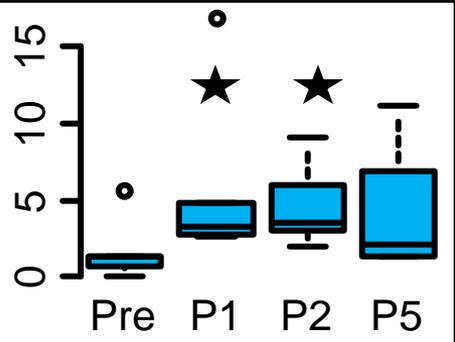
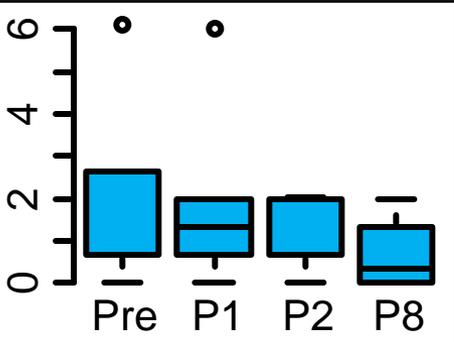
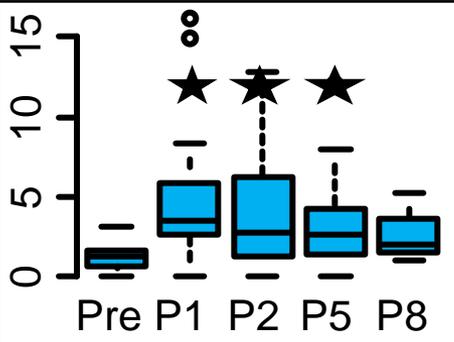
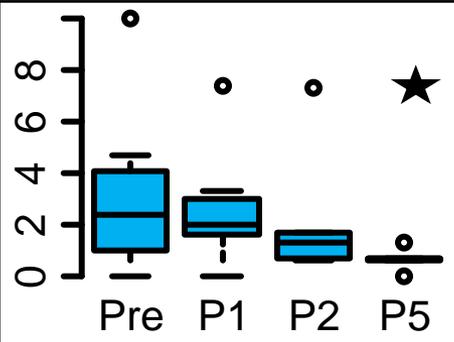
Fire



Mastication



Thin&surf.





1000-hr (Mg carbon /ha)

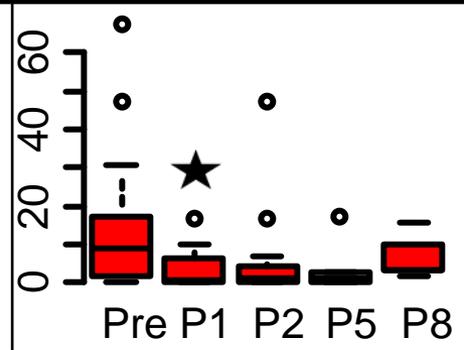
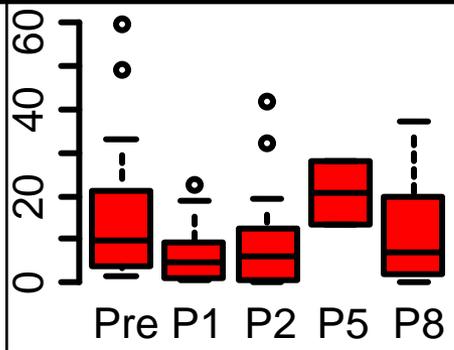
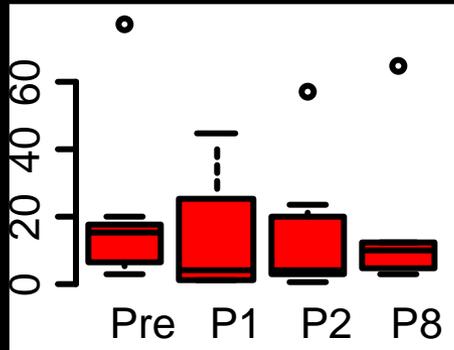
Douglas-fir

Mixed conifer

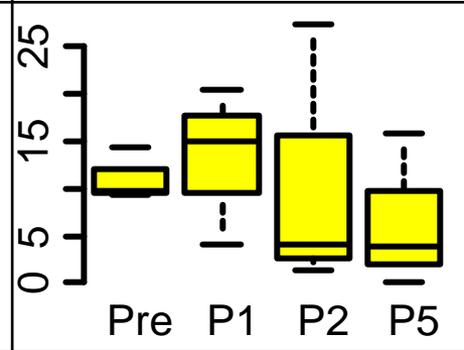
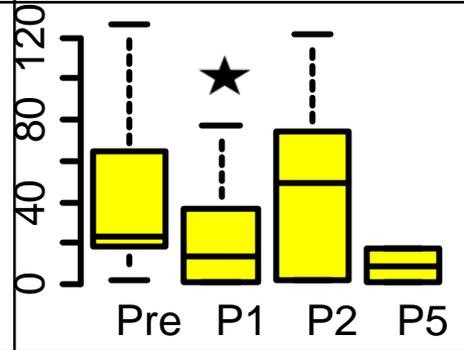
Red fir

Yellow pine

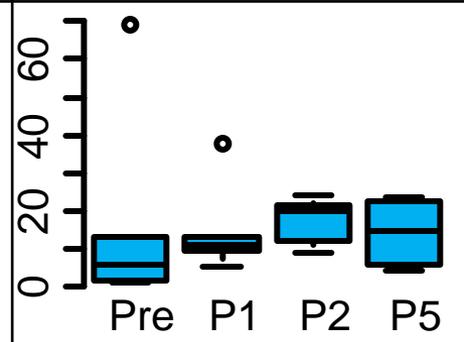
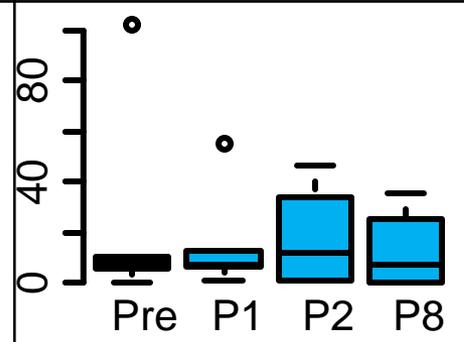
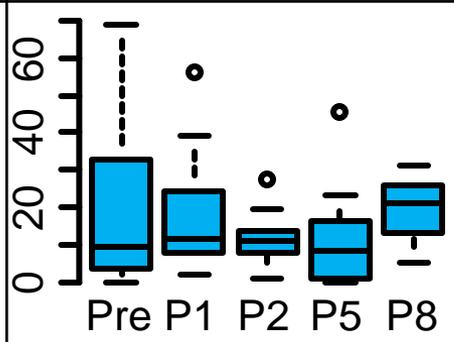
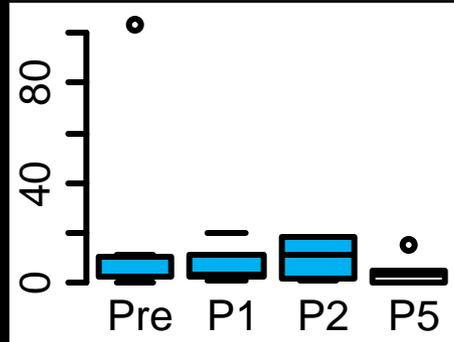
Fire



Mastication

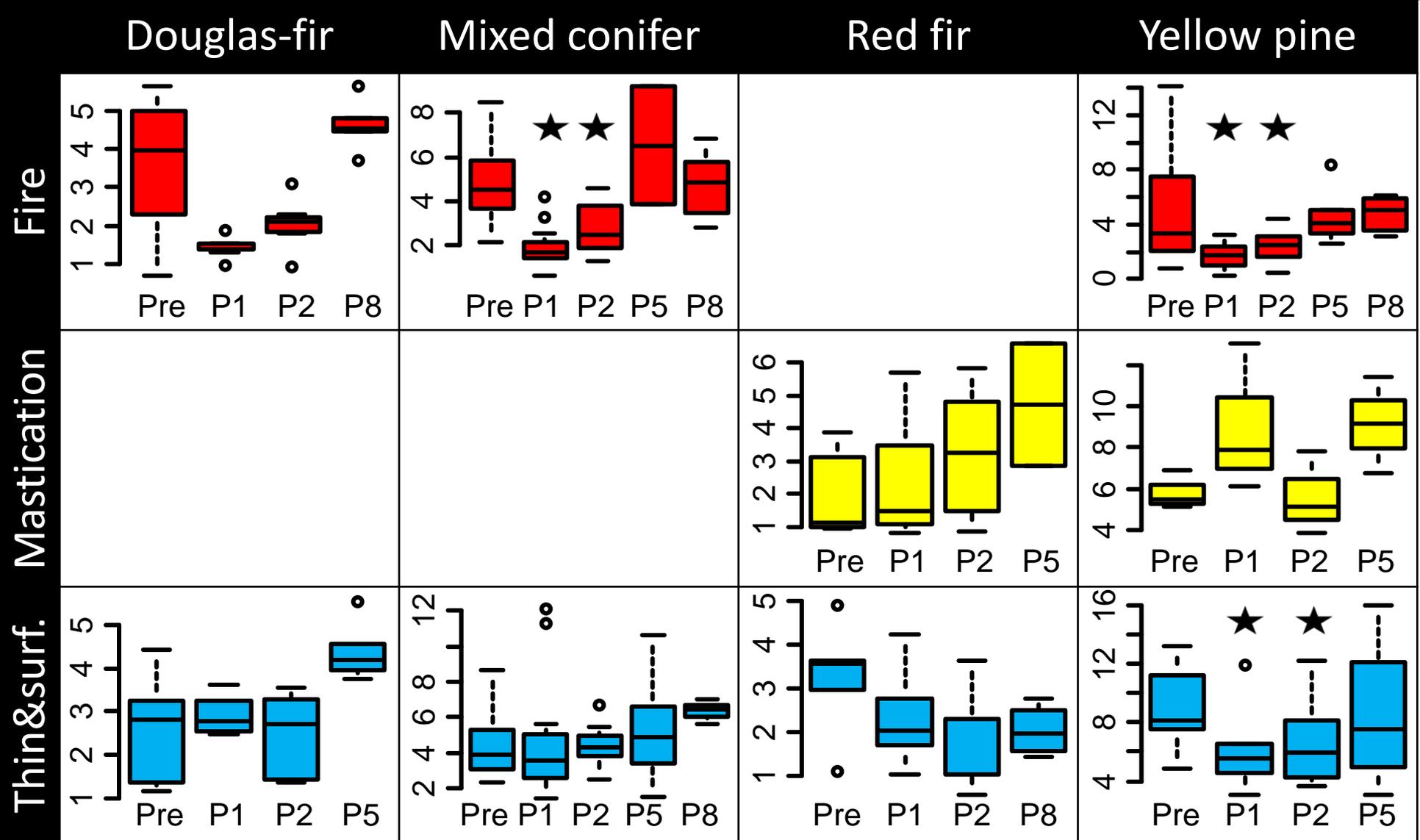


Thin&surf.



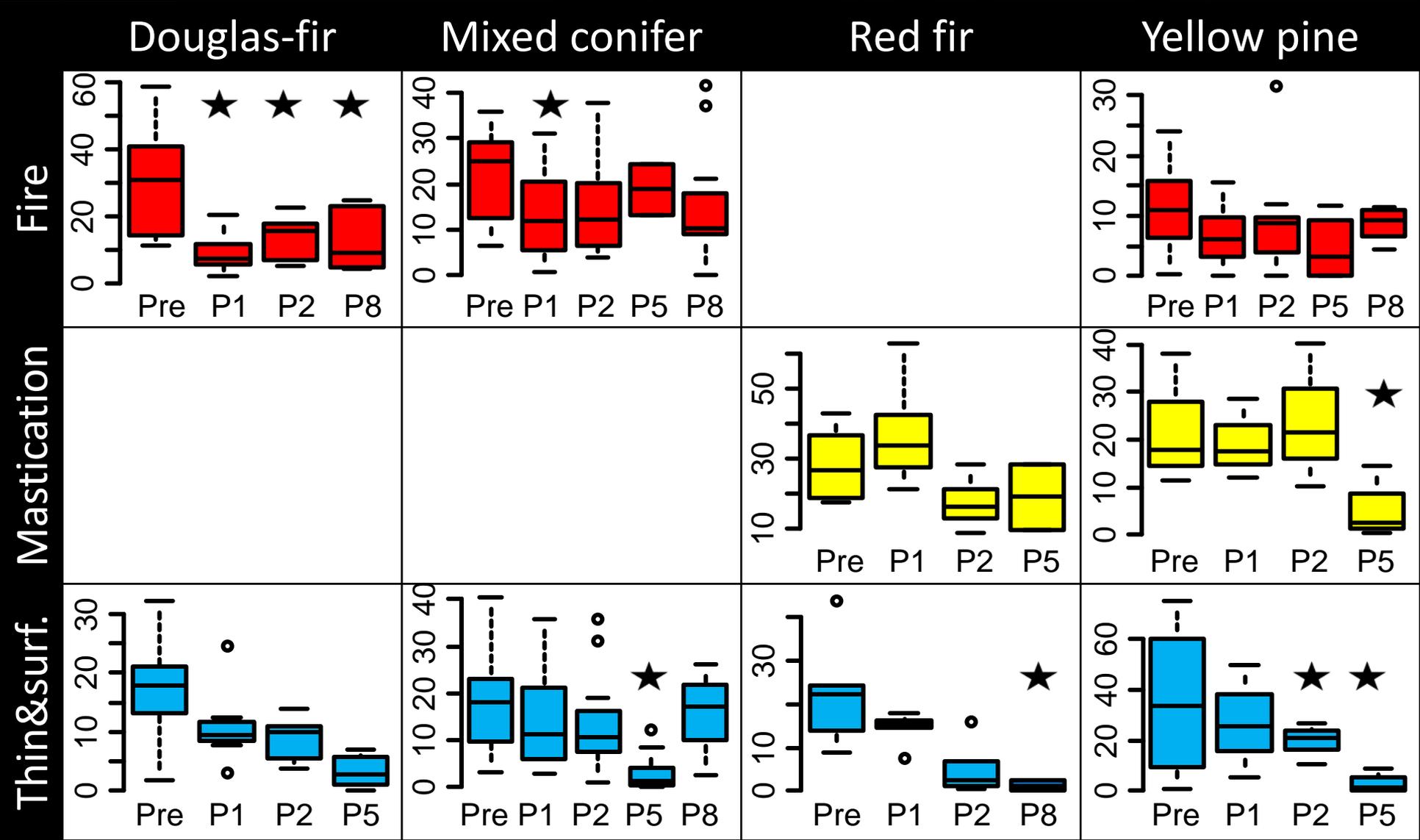


Litter (Mg carbon/ha)





Duff (Mg carbon/ha)





Herbs & shrubs (Mg carbon/ha)

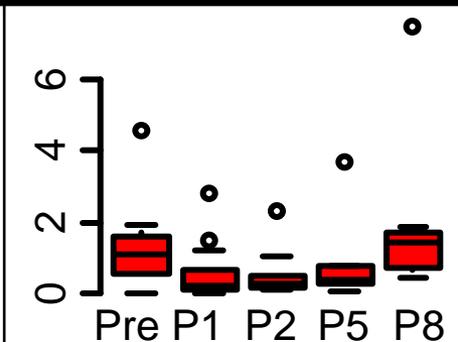
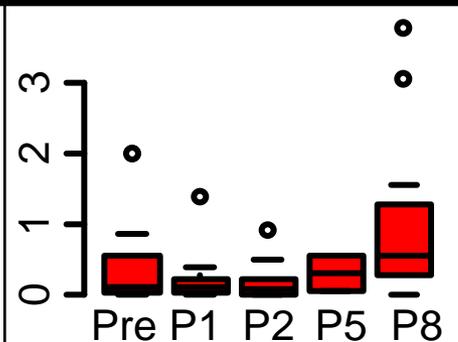
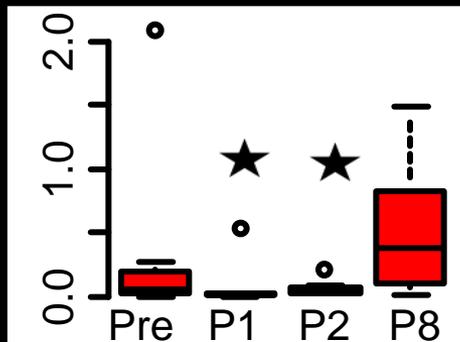
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Mixed conifer

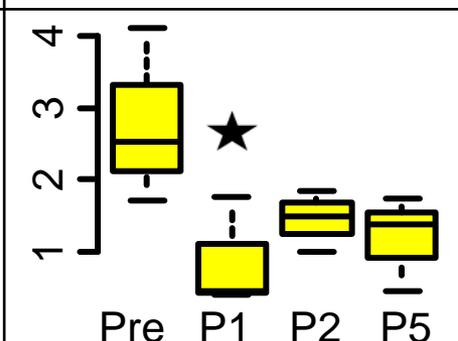
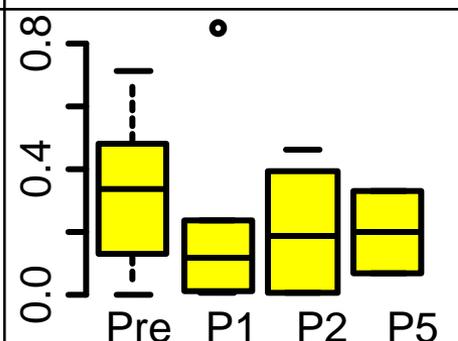
Red fir

Yellow pine

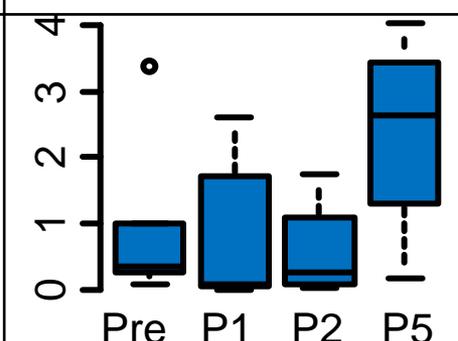
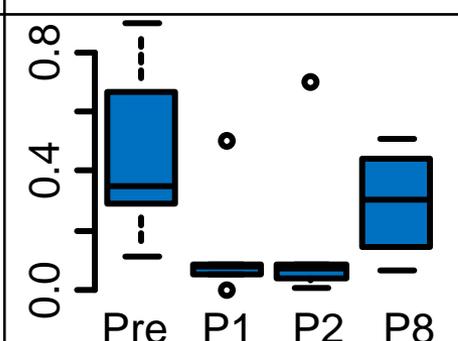
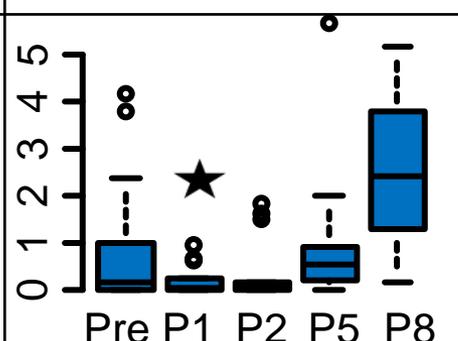
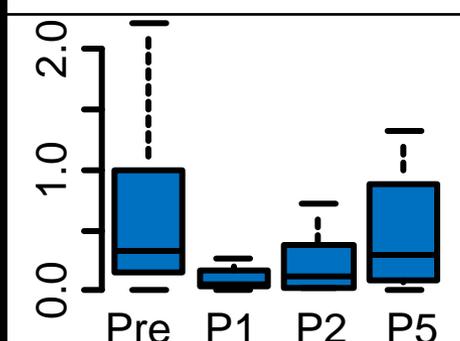
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Mastication

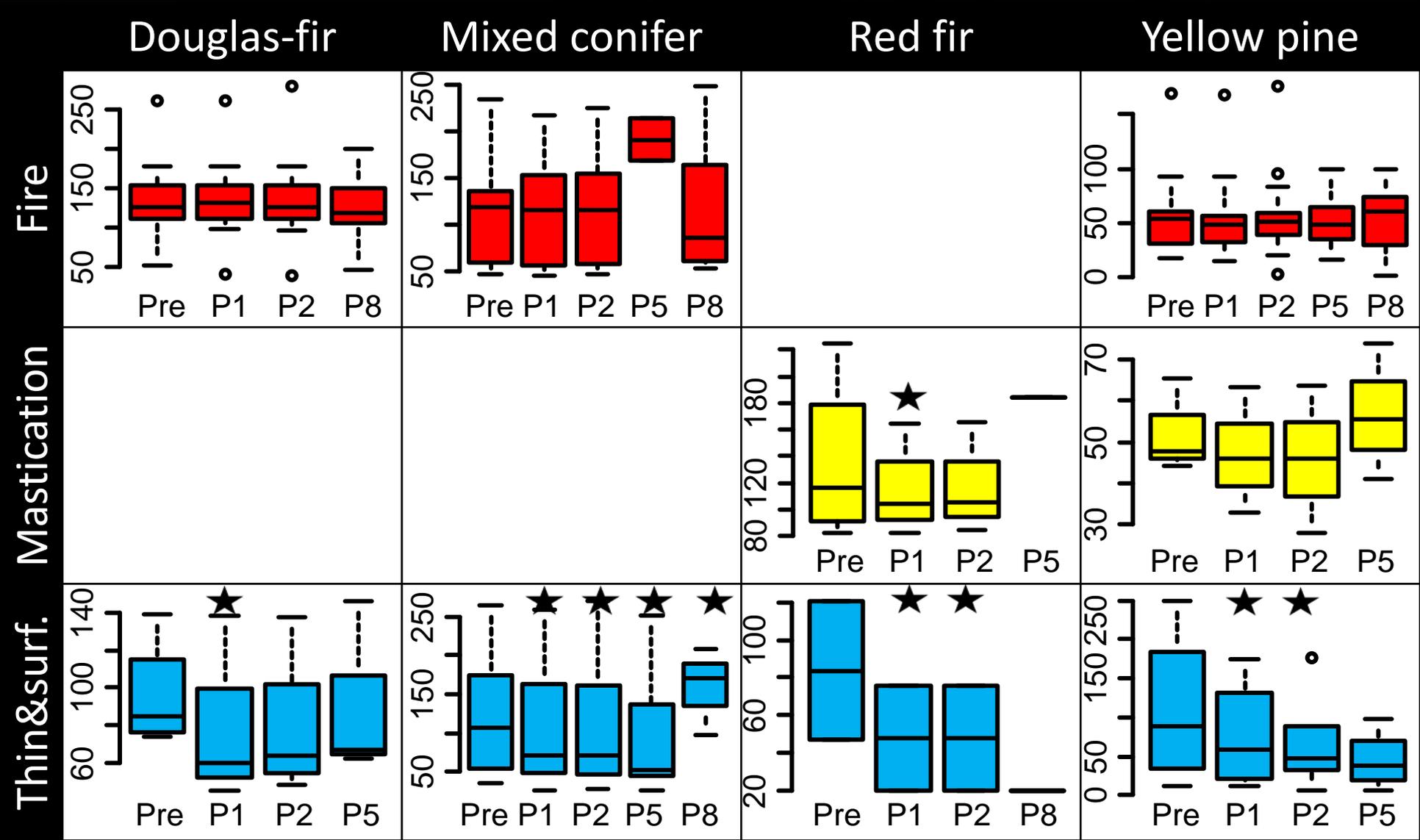


Thin&surf.



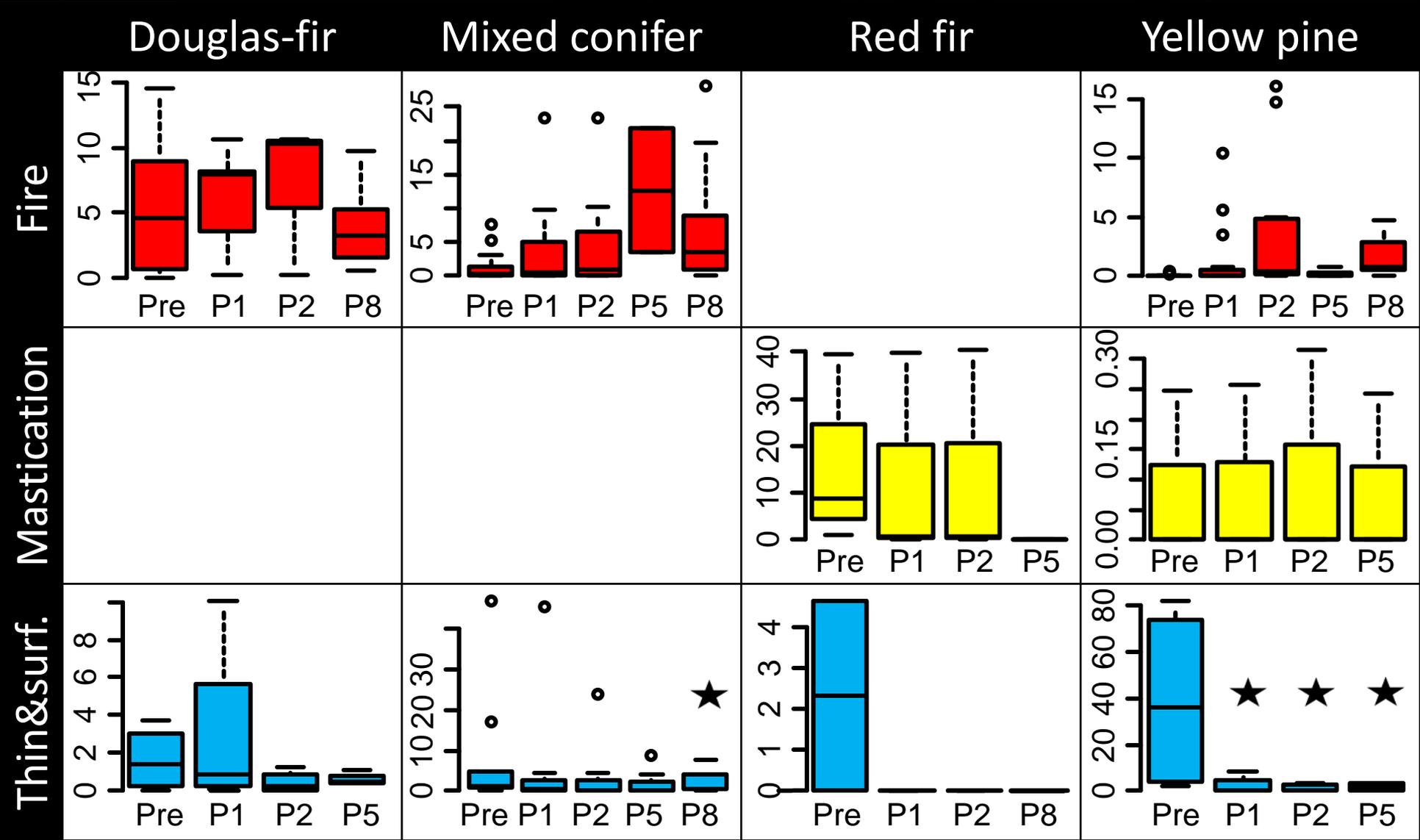


Trees (Mg carbon/ha)





Snags (Mg carbon/ha)





Above ground total (Mg carbon/ha)

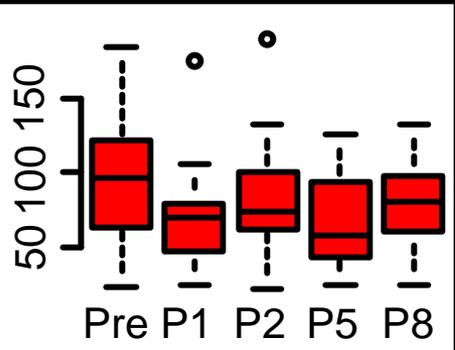
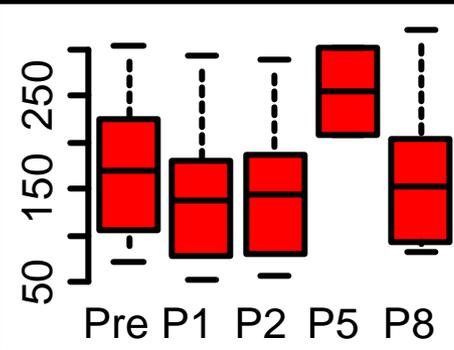
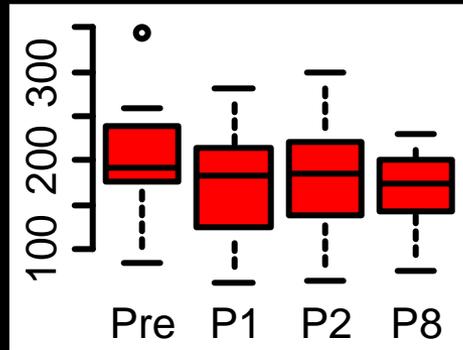
Douglas-fir

Mixed conifer

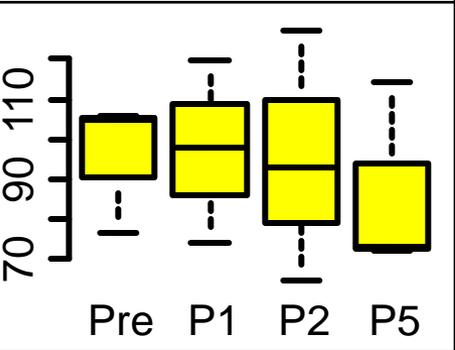
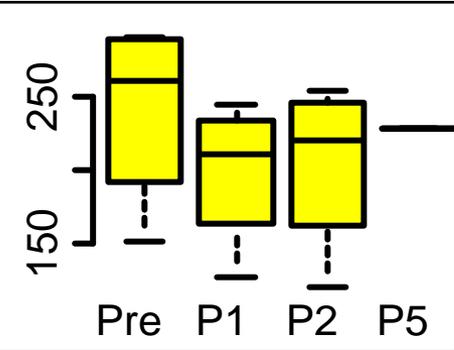
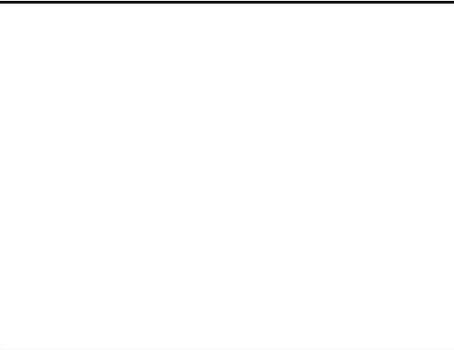
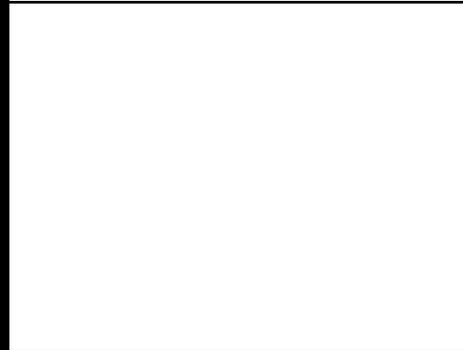
Red fir

Yellow pine

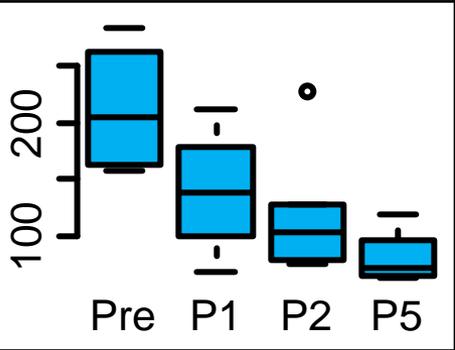
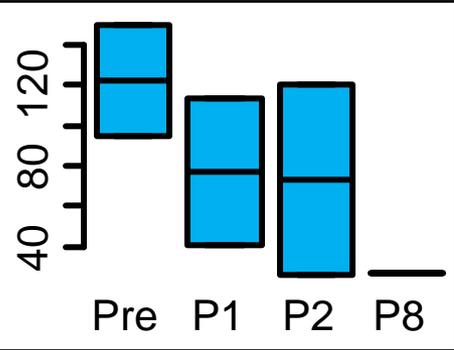
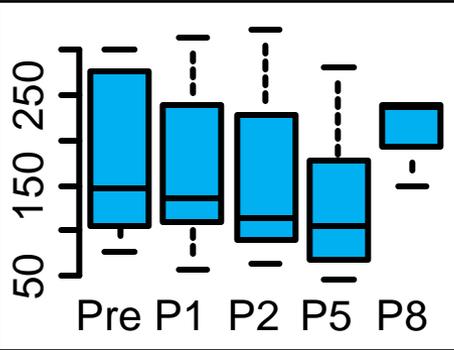
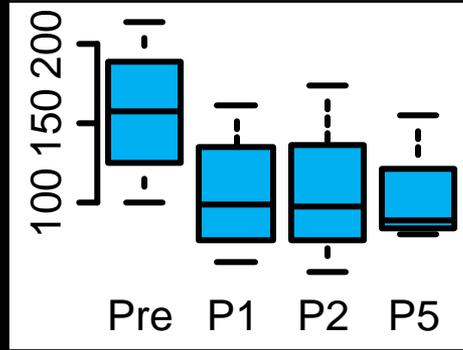
Fire



Mastication



Thin&surf.





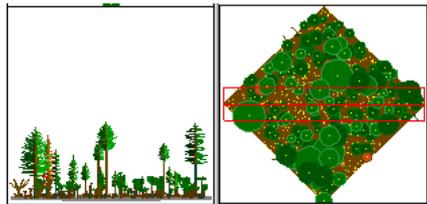
Trends in carbon recovery after treatment are similar to Hurteau & North 2010

- Low treatment intensity treatments can re-sequester carbon lost from treatment in a relatively short time (<10 years)
 - This was seen with our fire only treatments
- Higher intensity thinning treatments will take longer to recover
 - This was seen for both our mastication and thin plus understory treatment treatments
 - Post 5 & 8 year show little to no signs of reaching pre-treatment levels
 - Exception when re-sprouting is prolific carbon recovery might be faster



Question 2

Do out year modeled estimates of carbon pools differ from those measured in the field?





- Subset of the data – only plots with trees
- Comparison of carbon loads (Mg/ha) between actual and modeled values
 - Compared post-2, post-5 and post-8 treatments modeled forward from post-1
- Conformed to FFE-FVS pools
 - Dead down wood, forest floor, herb & shrub, standing live (trees), standing dead (snags)
- Paired t-test to test significance at $\alpha_{0.05}$ (<< and>>) and $\alpha_{0.10}$ (< and>)



Modeled vs. Actual

Trt	Forest	Post	n	Herbs & Shrubs	DDW	Forest Floor	Trees	Snags
Fire	Douglas-fir	2	7	A << M	A < M	A > M	A > M	A < M
		8	6	A > M	A < M	A > M	A < M	A < M
	Mixed conifer	2	14	A < M	A > M	A > M	A > M	A < M
		5	2	A < M	A > M	A > M	A > M	A < M
		8	9	A > M	A > M	A > M	A < M	A < M
	Yellow pine	2	14	A < M	A > M	A > M	A < M	A < M
		5	5	A > M	A > M	A > M	A < M	A < M
		8	7	A > M	A < M	A >> M	A < M	A < M

Green = actual greater than modeled
 Blue = actual less than modeled



Modeled vs. Actual

Treatment	Forest	Post	n	Herbs & Shrubs	DDW	Forest Floor	Trees	Snags
Mast	Red fir	2	4	A < M	A > M	A < M	A < M	A < M
	Yellow pine	2	3	A >> M	A < M	A > M	A < M	A < M
		5	3	A > M	A < M	A << M	A << M	A < M
Thin&surf	Douglas-fir	5	3	A < M	A > M	A << M	A > M	A < M
		2	4	A < M	A > M	A < M	A > M	A < M
	Mixed conifer	2	10	A < M	A << M	A > M	A > M	A < M
		5	8	A > M	A < M	A << M	A > M	A < M
		8	3	A > M	A < M	A > M	A > M	A < M
	Red fir	2	2	A < M	A > M	A < M	A < M	A < M
	Yellow pine	2	5	A << M	A > M	A < M	A > M	A < M
		5	4	A > M	A < M	A < M	A > M	A < M

Green = actual greater than modeled

Blue = actual less than modeled



- About a 50/50 split of over/under estimation with the exception of snags where modeled always over predicts
- Ability to input initial herb & shrub data would help
- More information about fuel accumulation and decomposition after treatment might strengthen model prediction
- Limitations to our work
 - Relatively small sample size
 - Maintained all defaults in FFE-FVS (decay, accumulation, etc.)
 - Did not simulate the treatment itself



Acknowledgements

- Join Fire Science JFSP-09-1-01-1
- Region 5 FAM
- JoAnn Fites-Kaufman, retired AMSET
- Forest fuels, fire, GIS & silviculture staff
- Field crews

