Postfire Impacts on Water Quality

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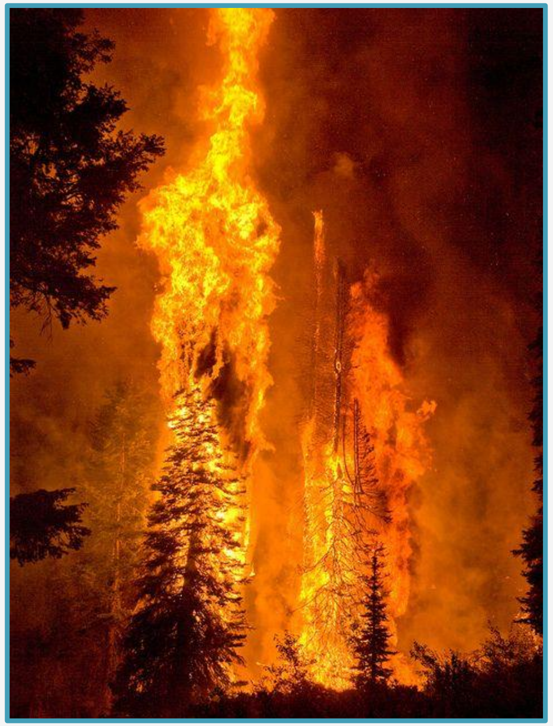
US Forest Service, Rocky Mountain Research Station

7th Annual Poudre River Forum

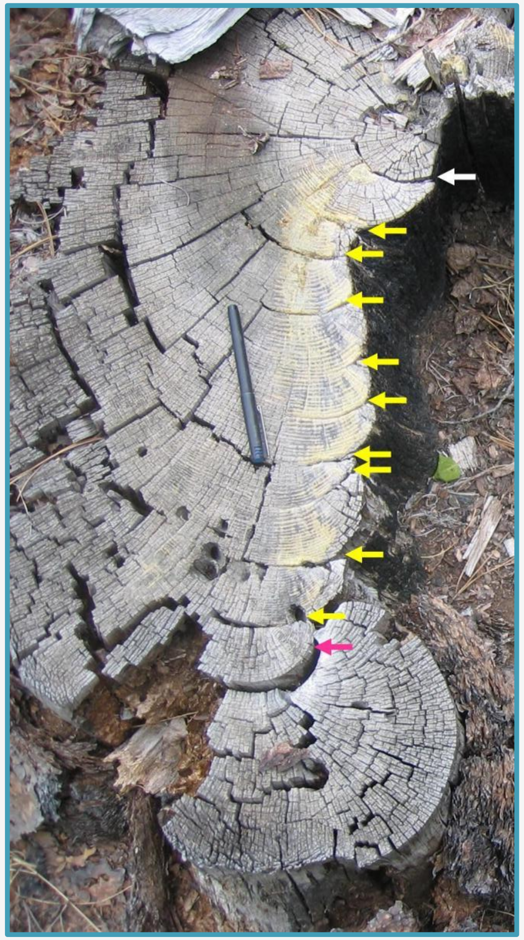
Loveland, CO; 28 February 2020

Natural Fire in Western Forests

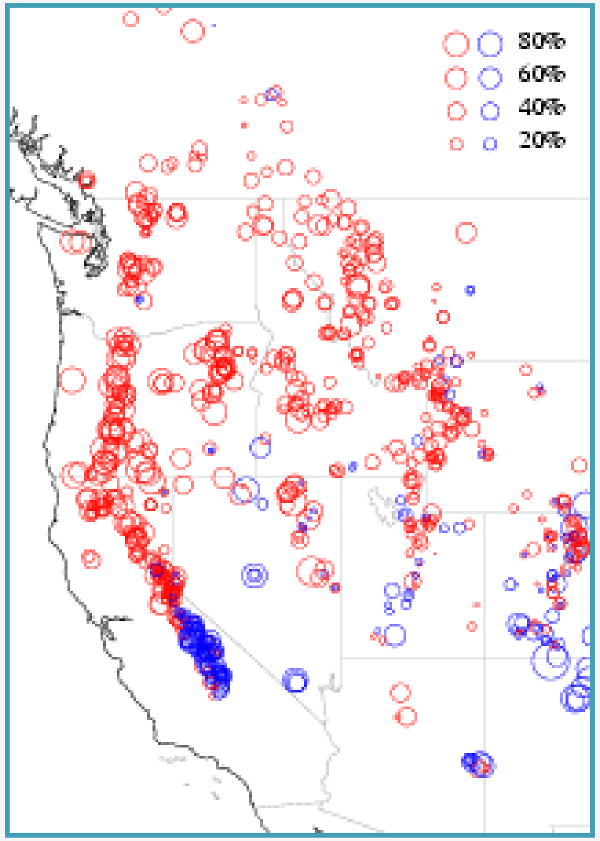


Lodgepole pine (*Pinus contorta*)

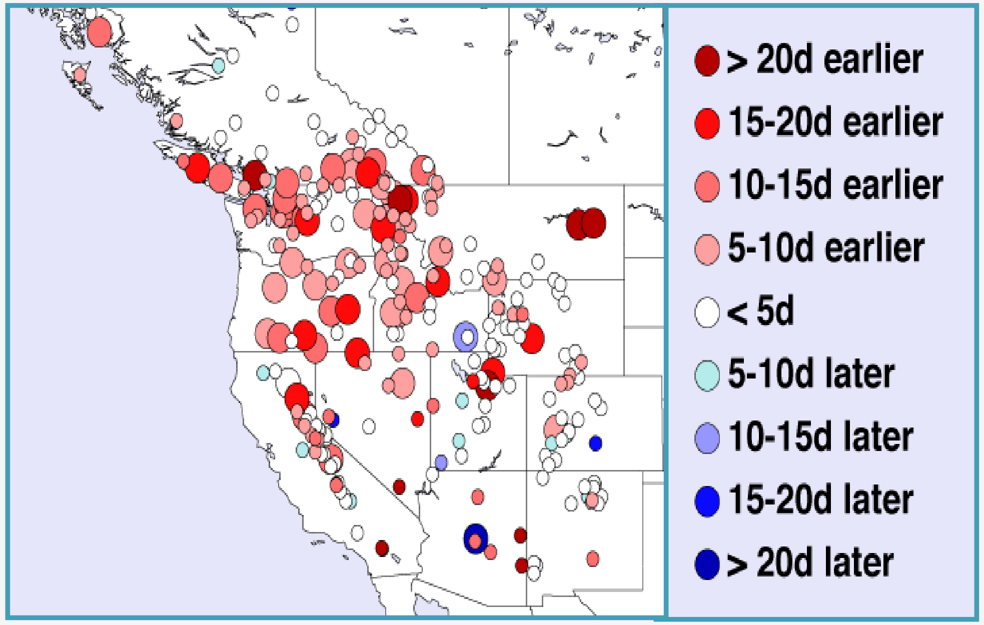
Ponderosa pine (*P. ponderosa*)



Climate Change in the Western US



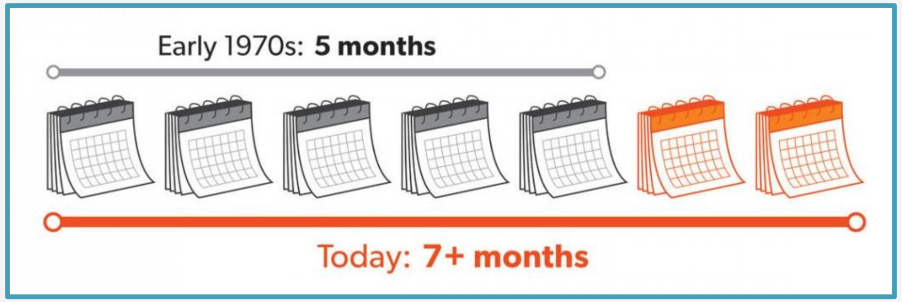
Reduced Snowpack *Mote, 2003*



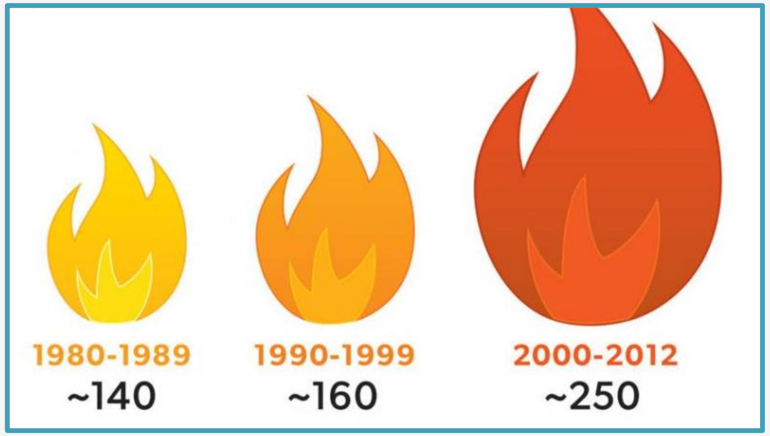
Shorter Snow Season
(16 d less in CA, NV (1951-1996))

Earlier Runoff
Stewart et al., 2004

Longer Fire Season



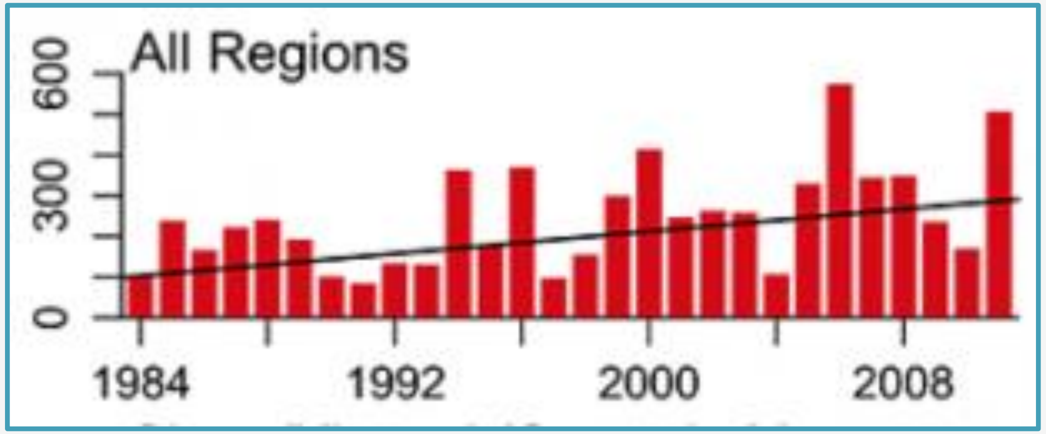
Wildfire Activity – Climate & Fire Suppression

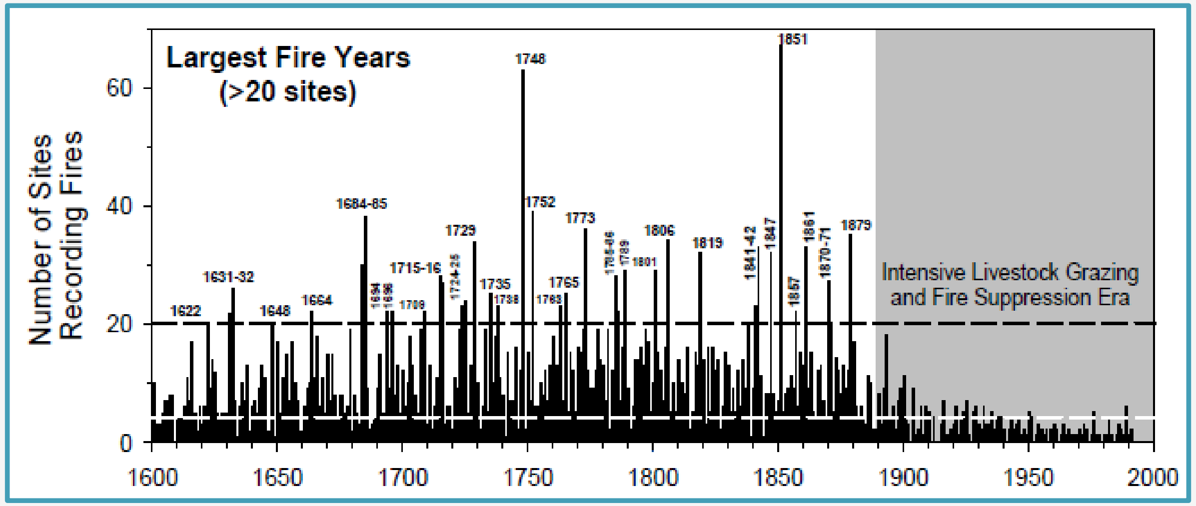


2X more Large Fires
since '80s (> 1000 Ac)

Relate to spring, summer temps

Earlier spring snowmelt





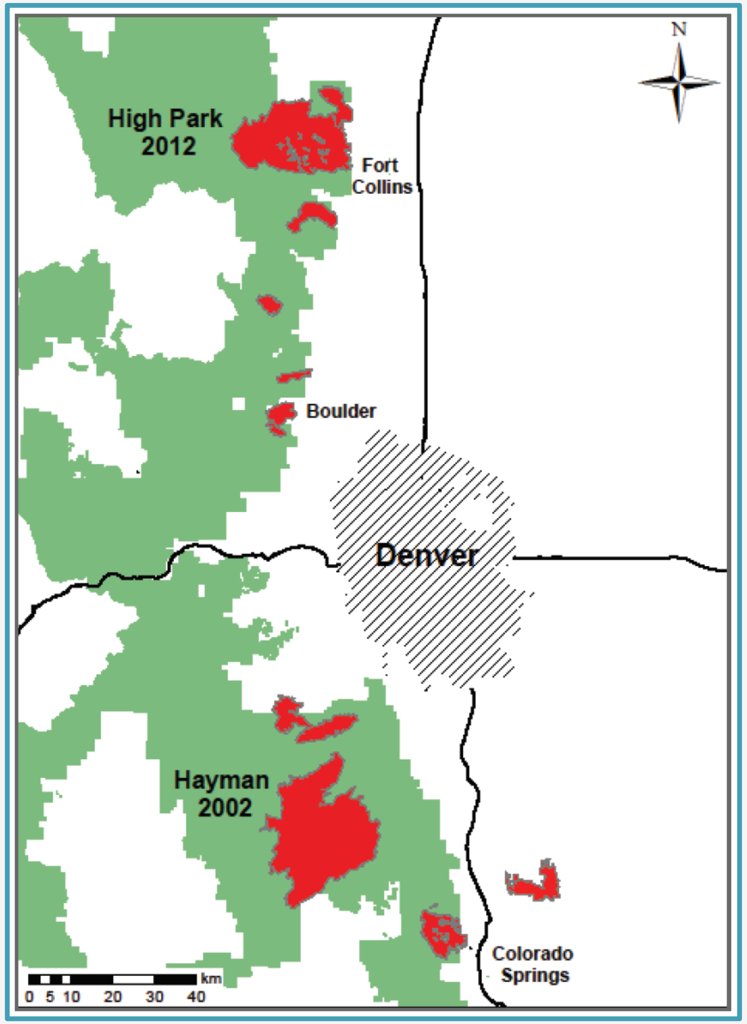
Suppression Success

98% of fires suppressed

Remaining Fires: larger, harder to control, more expensive

Dennison et al. 2014 Geophy Res Lett

Wildfires Along the Front Range



		Acres
1996	Buffalo Creek	11,999
2000	Bobcat Gulch	10,591
2000	Hi Meadow	10,789
2002	Hayman	137,273
2004	Picnic Rock	8,887
2010	Fourmile Canyon	6,197
2012	Hewlett	7,704
2012	High Park	87,253
2012	Waldo Canyon	18,196
2013	Black Forest	14,294

Data Credit: P.J. Fornwalt

Watershed Ecosystem Perspective

Clean Water/Human Health

Expected output of Forest Watersheds

Eutrophication

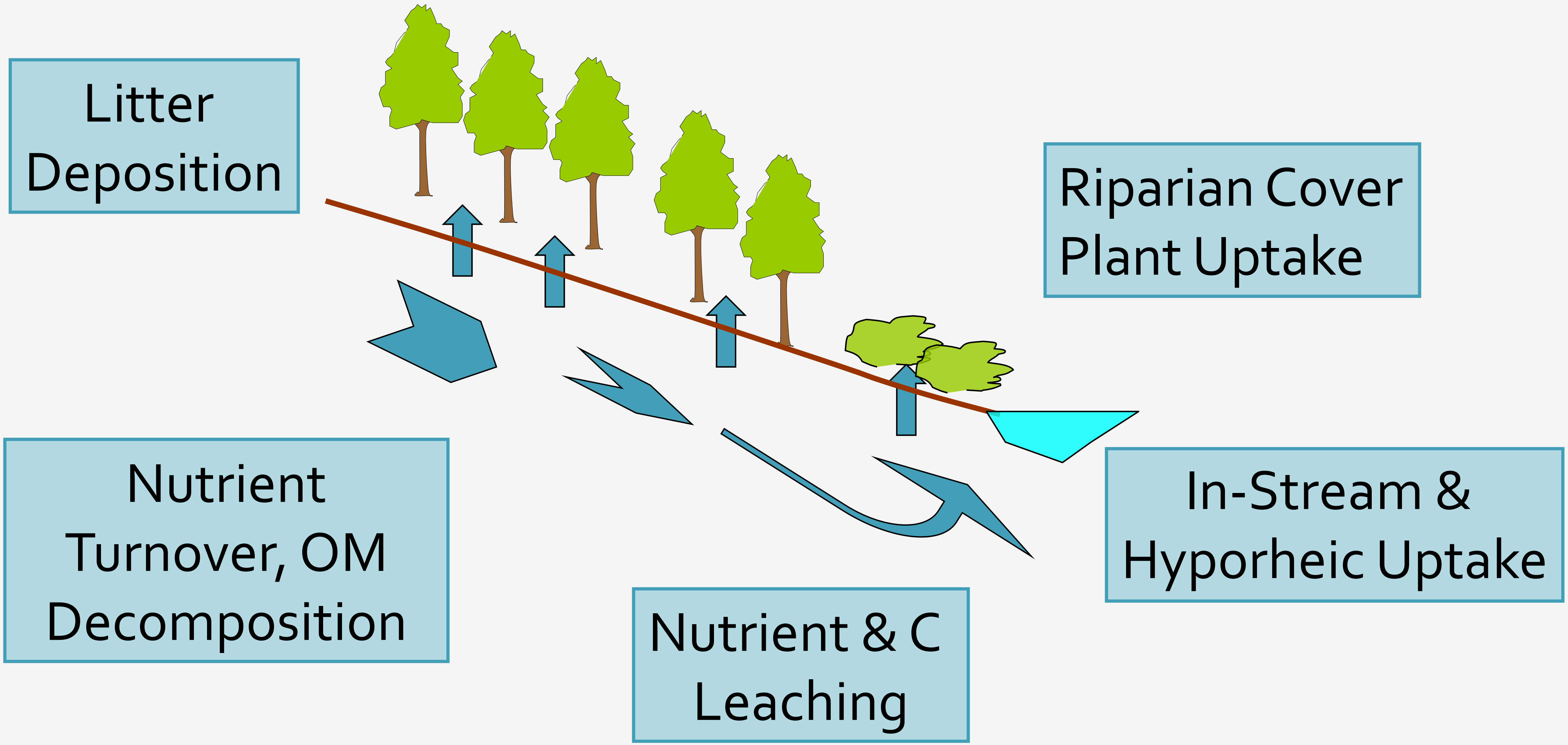
Nutrient Enrichment degrades Aquatic Habitat, Water Treatment

Ecosystem Productivity

Disturbance Indicator

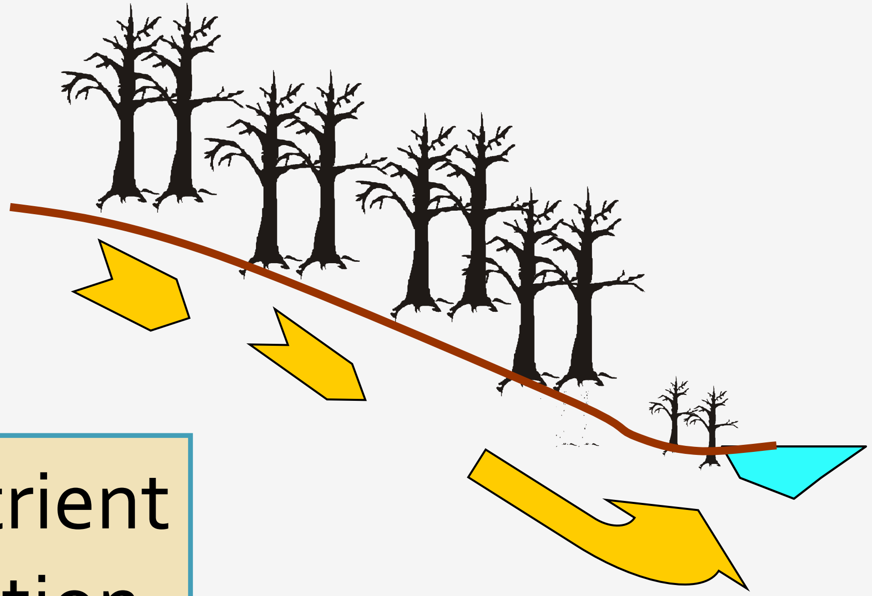
Restoration Target

Biogeochemical Processes Influence
Stream Nutrients & Carbon



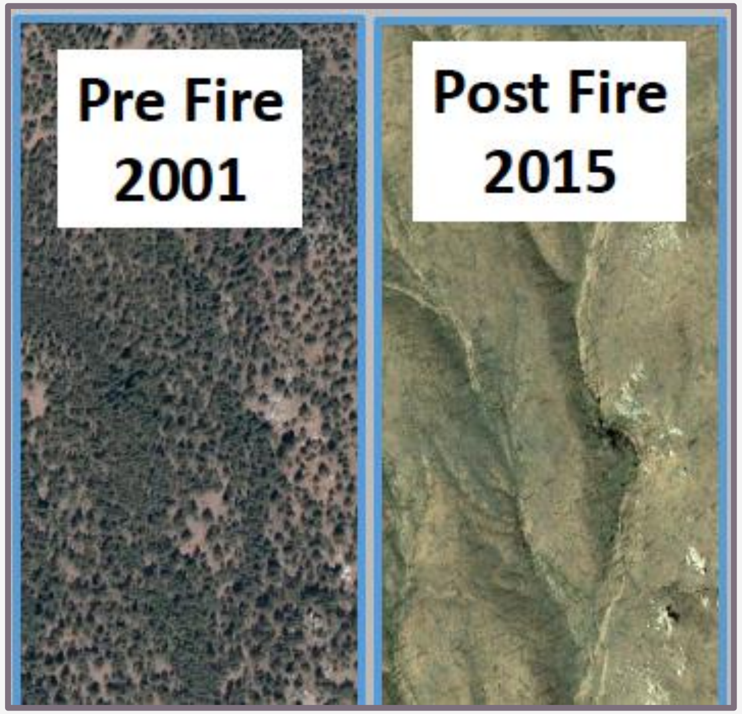
Post-Fire Stream
Nutrients & Carbon

Lower
Litter
Inputs



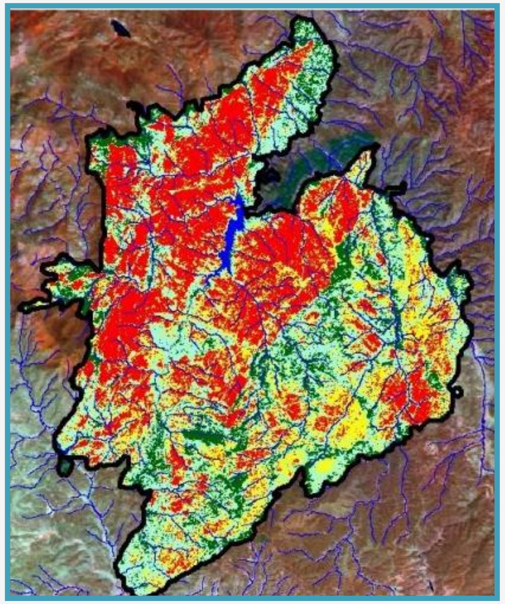
Soil Nutrient
Production
+/-

Runoff/Leaching
+ N / - C



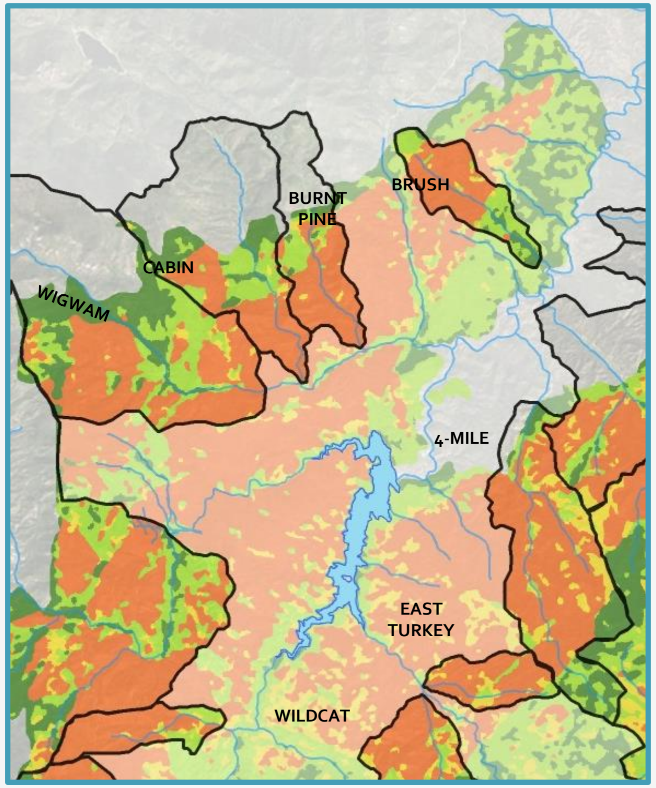
Lower N
Uptake
Lower Riparian
Cover

Fire Severity Determines
Watershed Effects



Hayman Fire

Largest in CO History
~40% High Severity



Wildfire Severity Gradient

0-100% burned; 1-80% Hi Severity

Low Severity

Vegetation remains 'green.' OM layers not fully consumed. Soil structure, roots unchanged

Moderate Severity

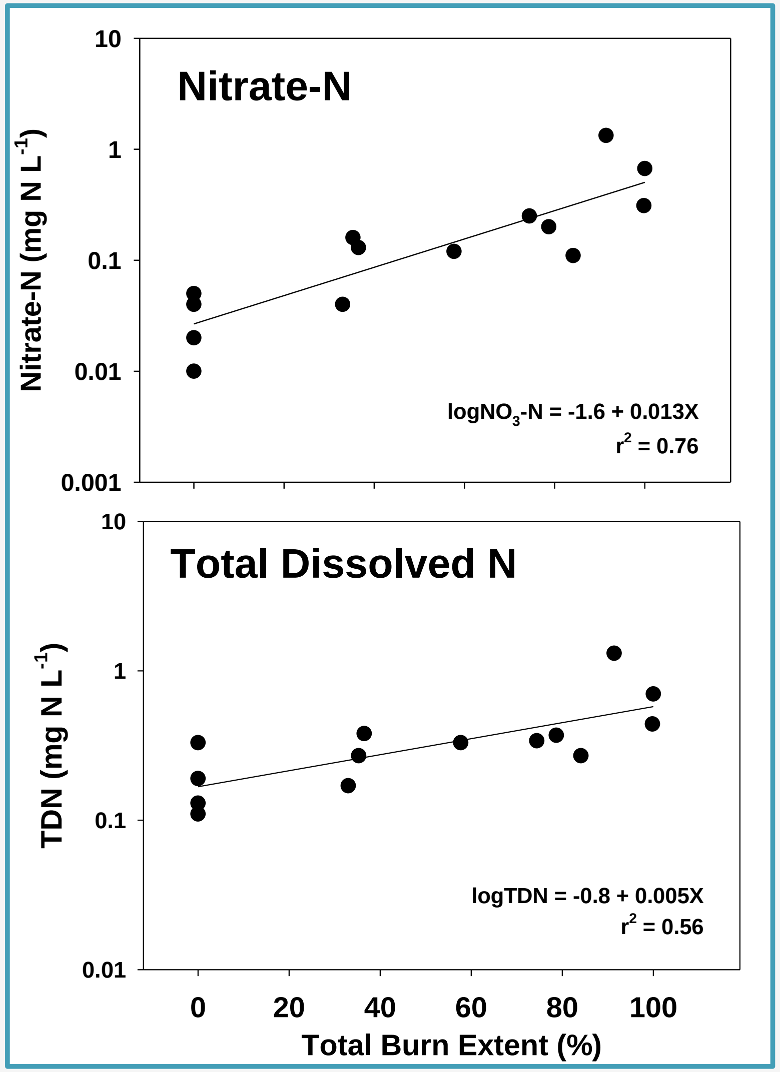
Most (50-80%) ground cover, OM consumed. Foliage may remain in tree canopies.

High Severity

Consumption of nearly all pre-fire ground cover & surface organic matter.

WATERSHED RESPONSES

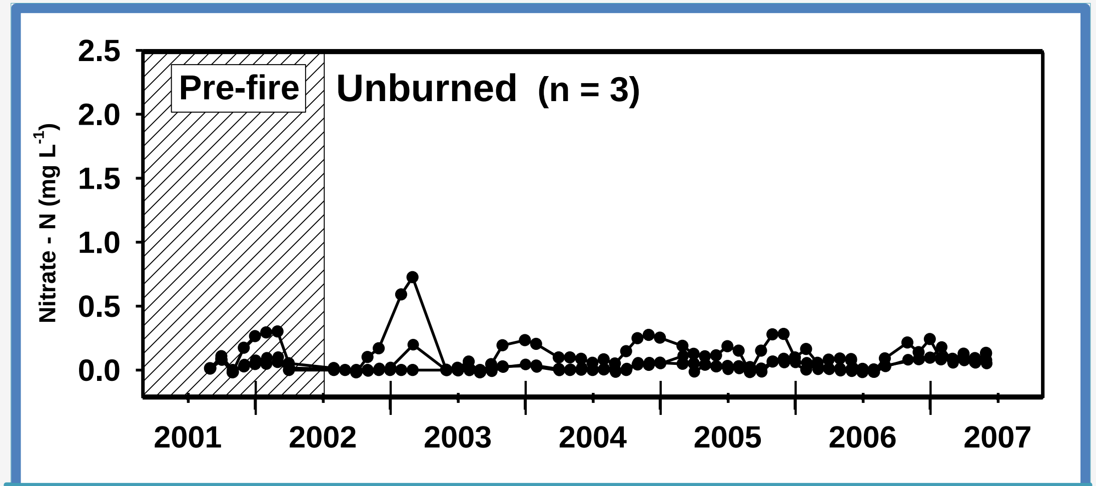
STREAM N INCREASES WITH WILDFIRE EXTENT & SEVERITY



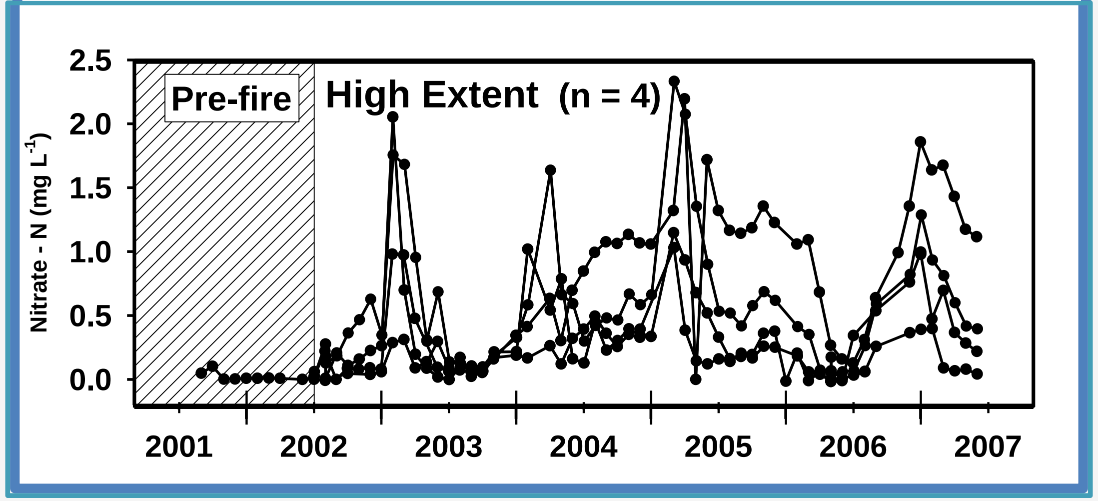
5 Yrs post-fire

Nitrate spans 2 orders of magnitude

Threshold ~ 50%



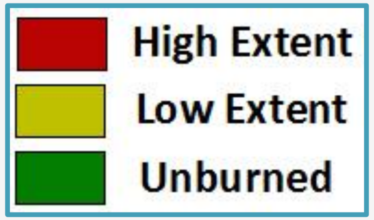
Rhoades et al. 2011 IJWF



Extensive High Severity Wildfire (>60%)

Higher peaks, sustained, elevated concentrations

Long-term Response
Water Quality



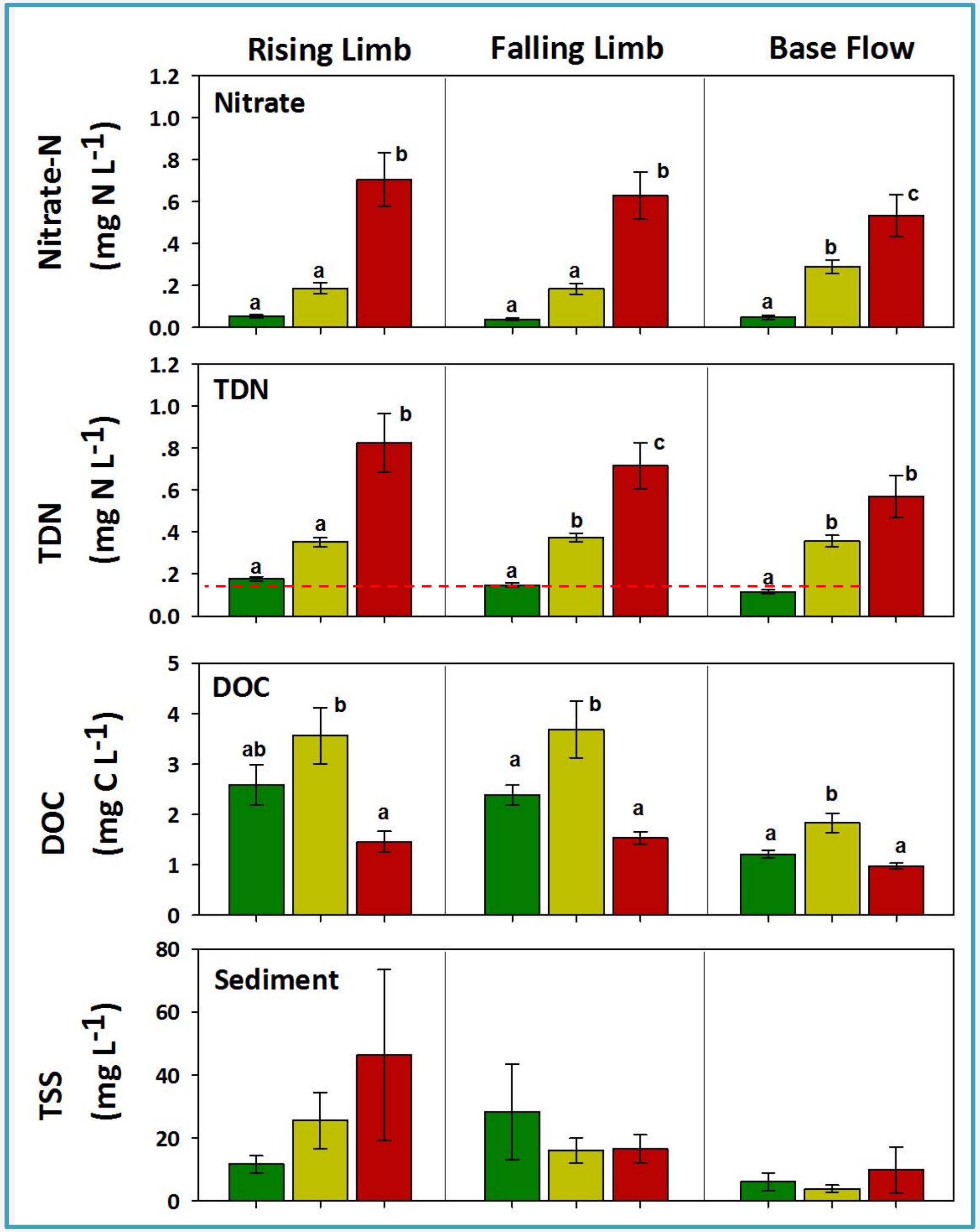
Hayman Fire
(14-15 yr post-fire)

Nitrate & TDN 5-10X above background in Extensive, elevated in Moderate

Long-term changes in nutrient retention
(>95% pre-fire ; 48% post-fire)

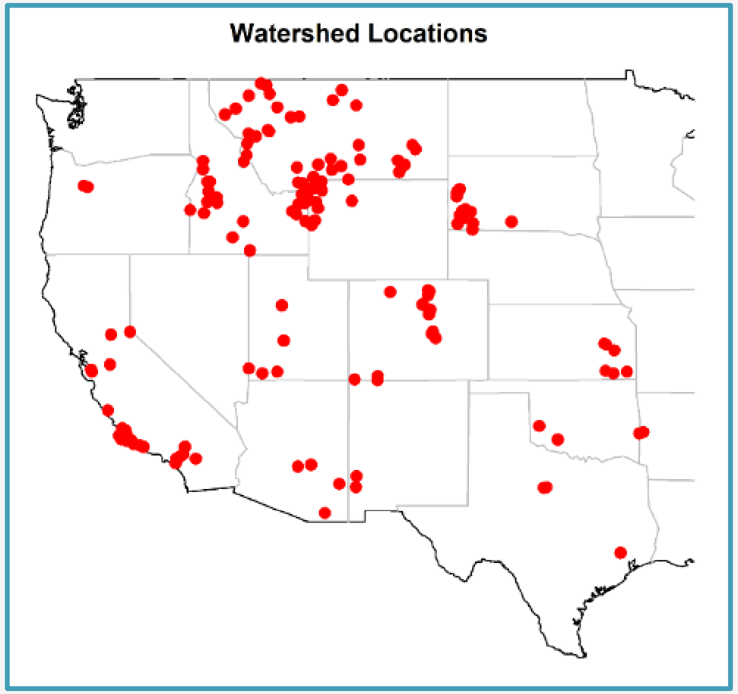
DOC highest for moderate burns

Sediment mostly recovered



Rhoades et al. 2019, Ecosystems

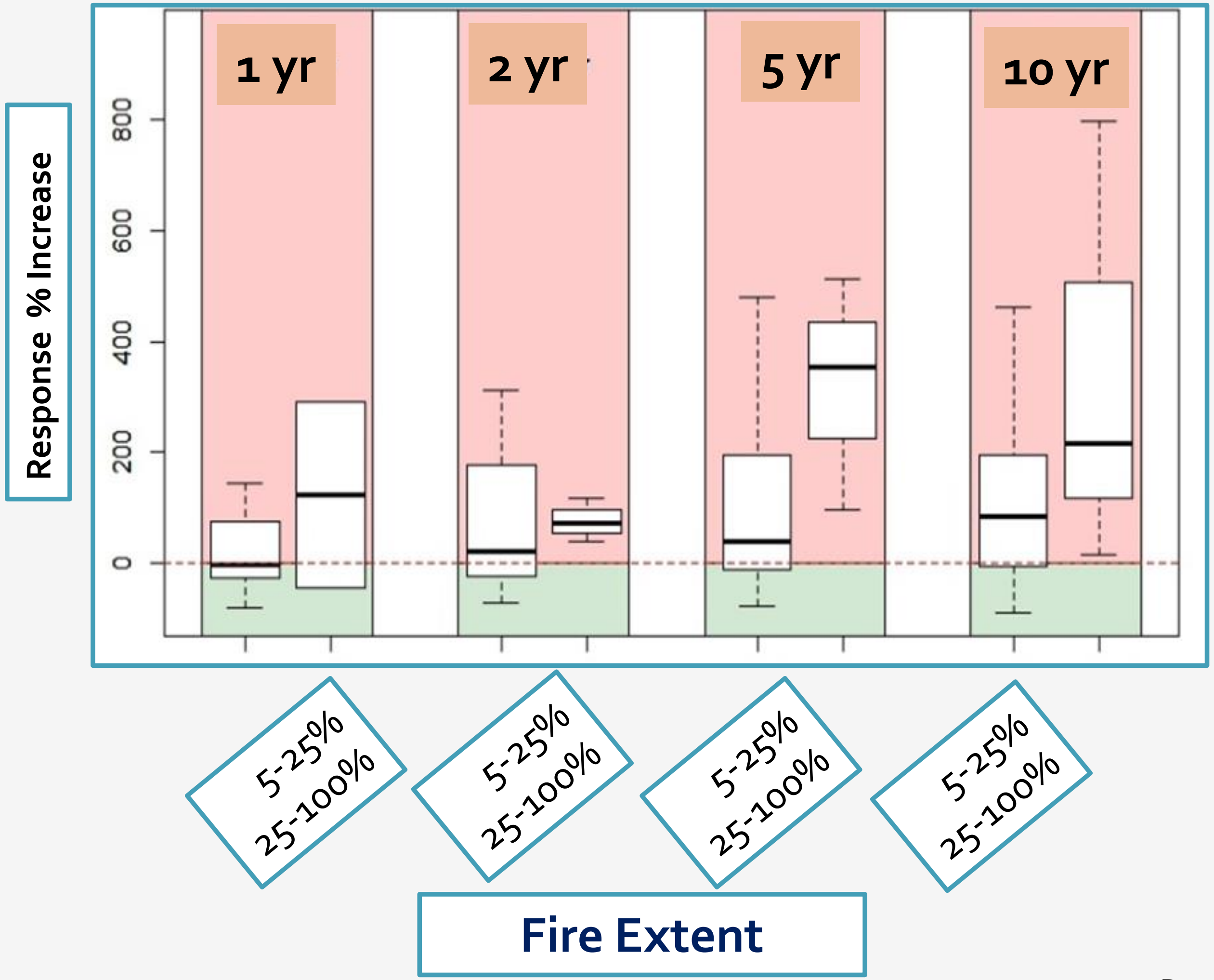
WIDESPREAD, LASTING EFFECTS
STREAM N & P



159 fires in Western US
Publically available Q, concentration
5 Post-fire vs 5 pre-fire years

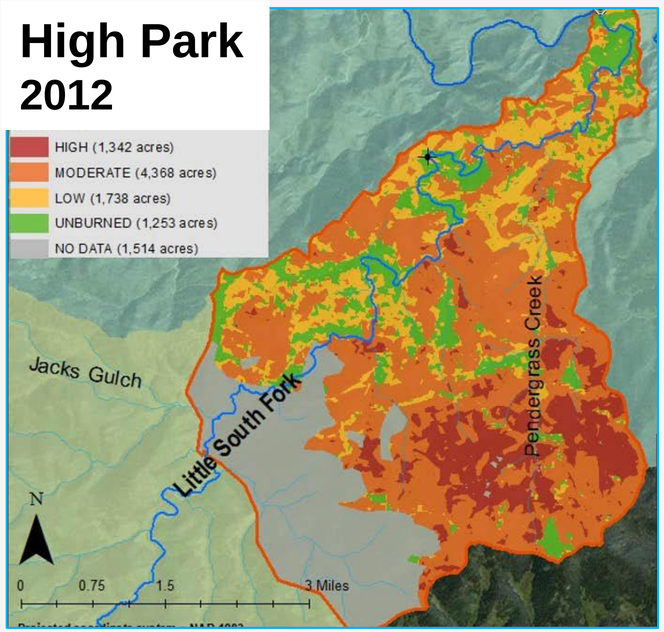
Nitrate increased in 25% of fires
Ortho-P increased in 19% of fires

Alberta, Canada
8 yrs post-fire sediment P in streambed
(shift in stream biota)

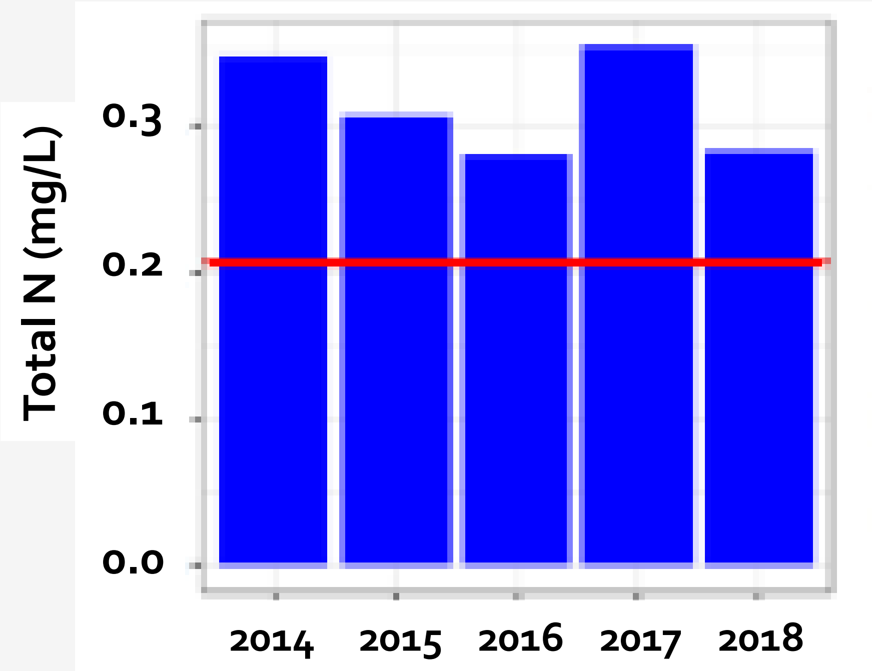


Rust et al. 2018 IJWF
Silins et al. 2014 Ecohydro; Martens et al. 2019 IJWF

Widespread but not Universal



South Fork CLP
17% burned; 8.5% at Hi/Mod



Post-fire Changes in TN

Increase:

47% (‘14 – ’17 vs baseline)

Decline :

51% since ‘14-’17

2018 :

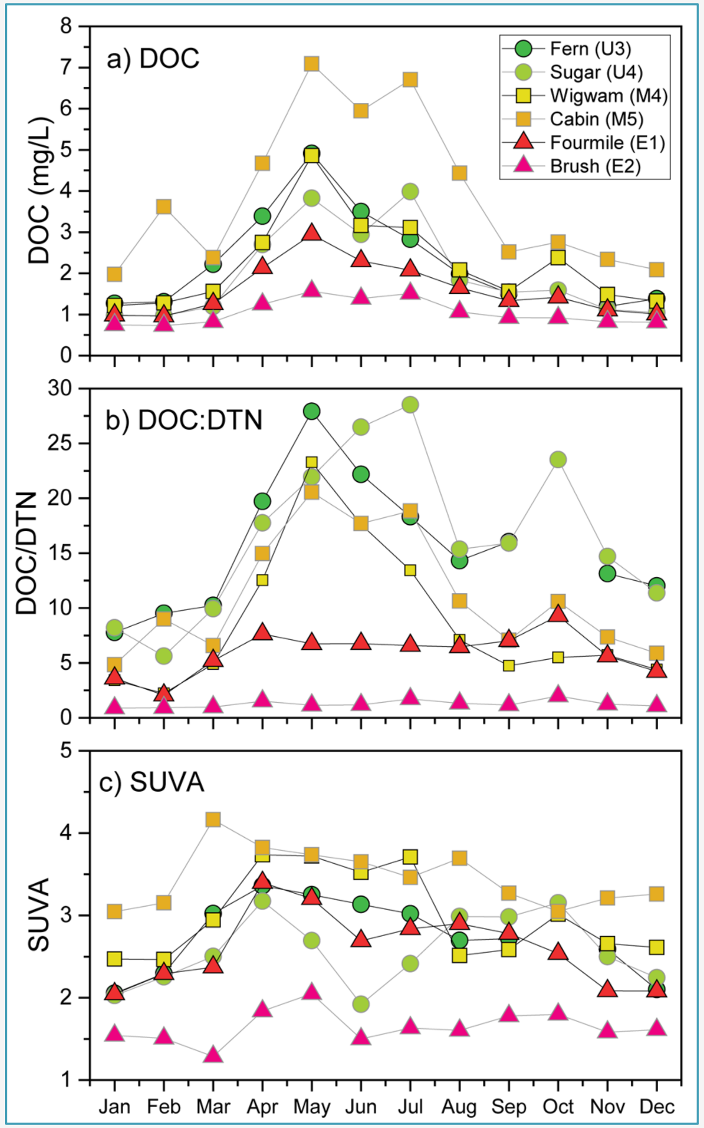
25% above baseline.

Eurich & Heath 2019

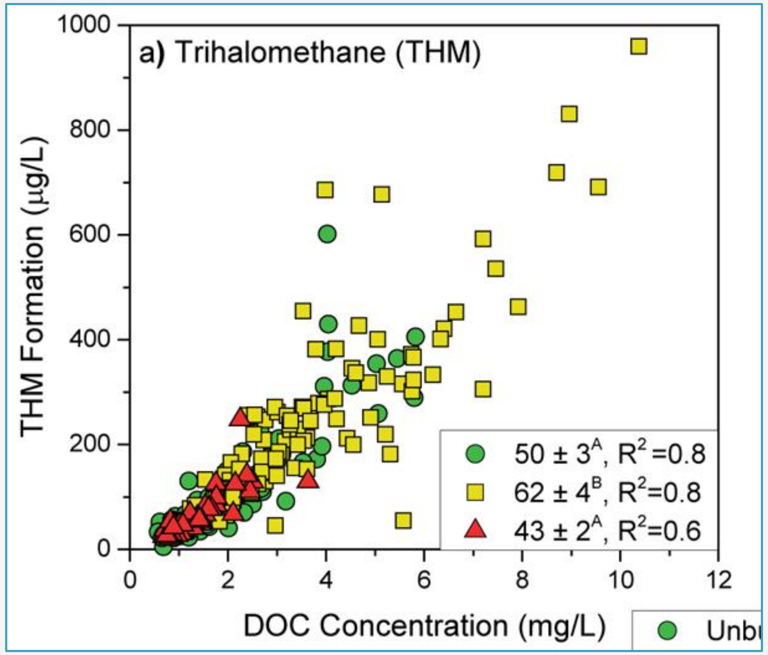
‘…**overall decreasing trends since 2014** indicating that water quality … is returning to pre-fire condition…’

Stream Dissolved Carbon

Influences On Character & Treatability



Chow et al. 2019. JEQ



Unburned Streams

High Aromaticity HI , Decr Freshness
Older, more complex C

Disinfection Byproducts

Formation potential of THM, other DBPs increases with stream DOC

Highest in moderate burns

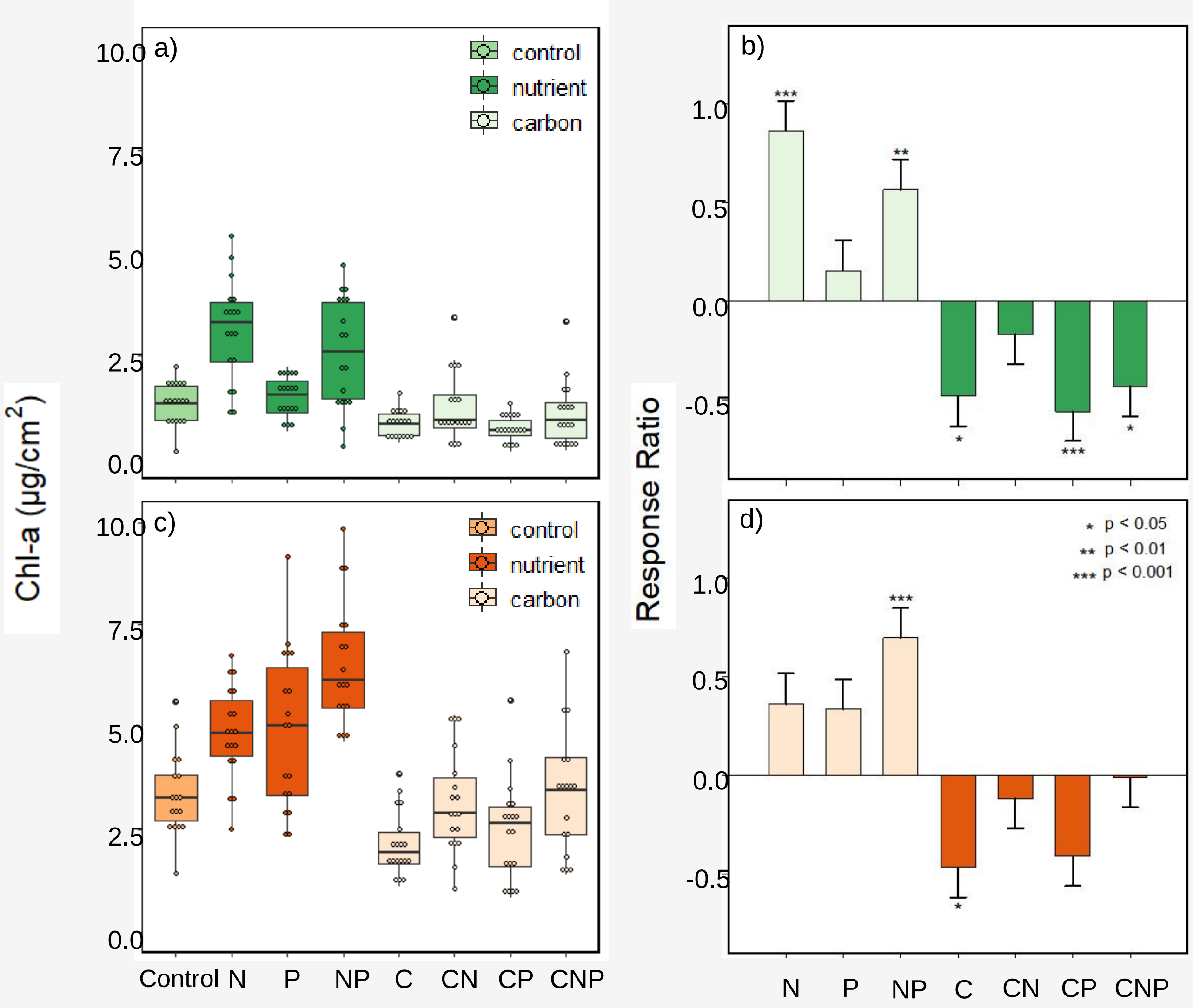
Burned Streams

Higher Fluorescence (FI)
Lower Humification (HI)
Higher Freshness

Sparse vegetation = newer, less complex C, greater microbial signal

What Explains Lasting Fire Effects?

Lower In-Stream Production



Burned Streams are Productive

Higher Chl-a, autotroph, algae

Unburned streams are N limited

(respond to N fertilizer)

Lower N response in burned streams

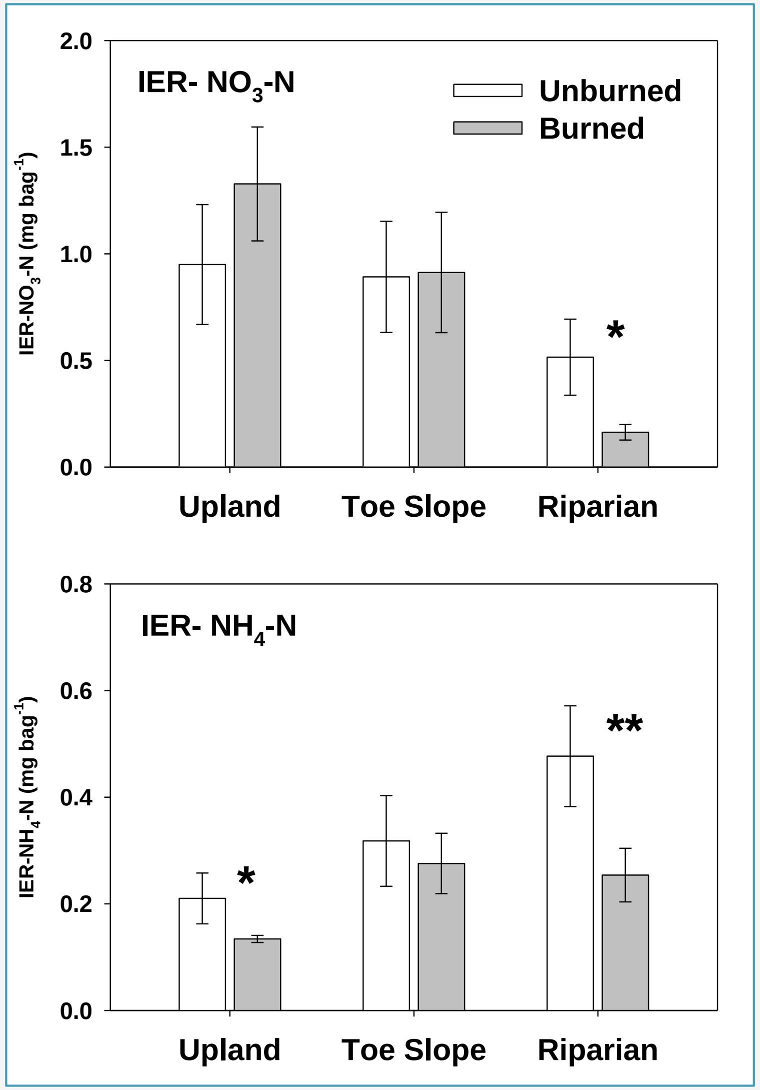
Higher stream N lower N limitation

… so lower in-stream production <u>does not</u> explain elevated N export

*Stream Metabolism, biofilm production from Hayman and High Park Fires; A. Rhea et al. in prep manuscript

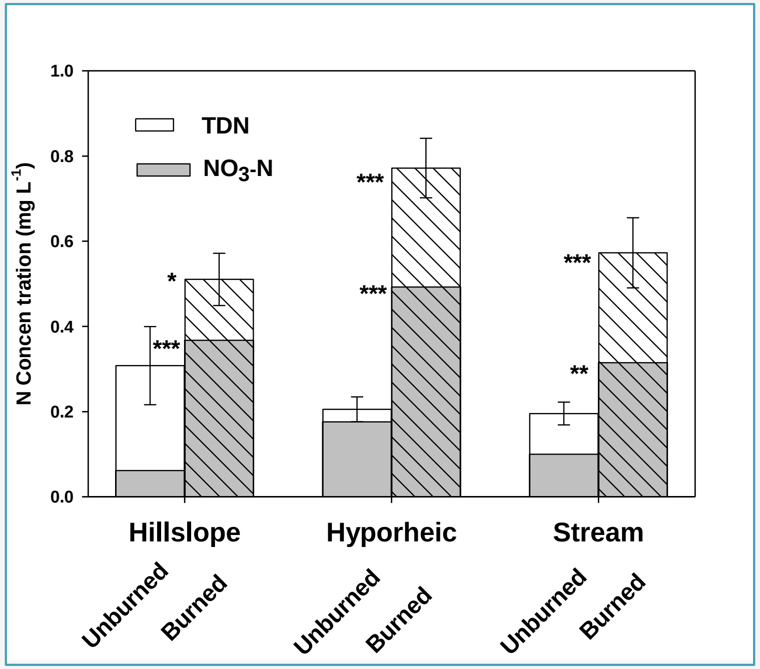
What Explains Lasting Fire Effects?

Higher Soil N Supply or Release



N Supply - Burned Soils

Lower NO_3 & NH_4 along burned hillslopes (*0-10cm soil depth)



Lower soil C & N

in hi severity patches

N Release - Burned Soils

Higher N release

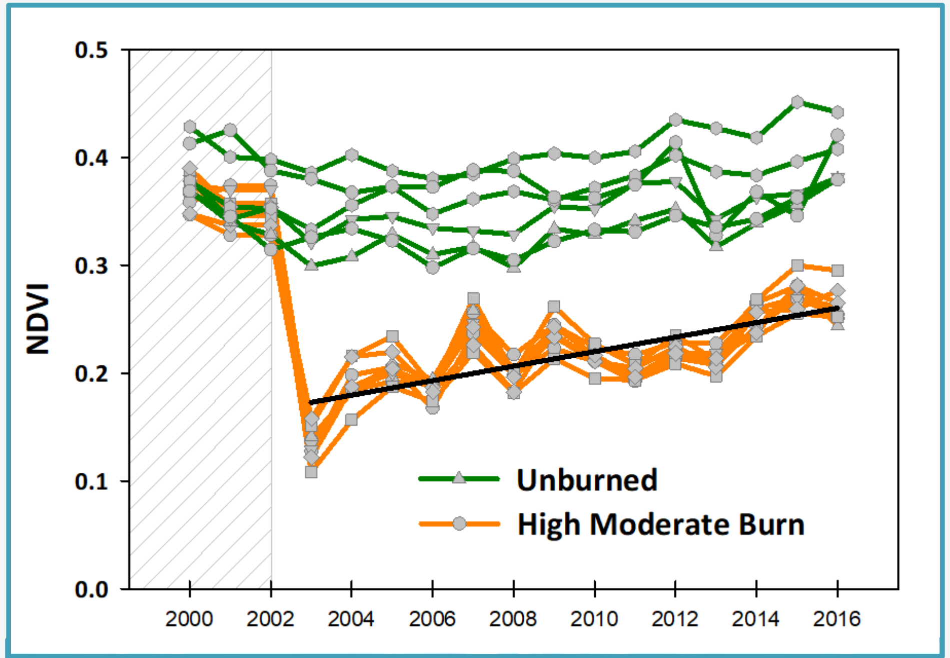
2 to 4x more TDN

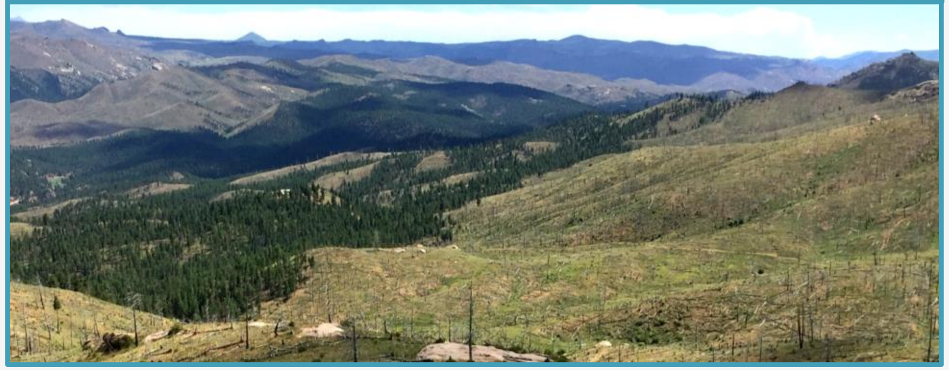
3 to 6x more NO_3-N

(*leached below 50 to 100 cm)

What Explains Lasting Fire Effects?

Vegetation Recovery





*May-June NDVI; 10 m DEM; Burned = Mod/Hi patches

Hayman Fire

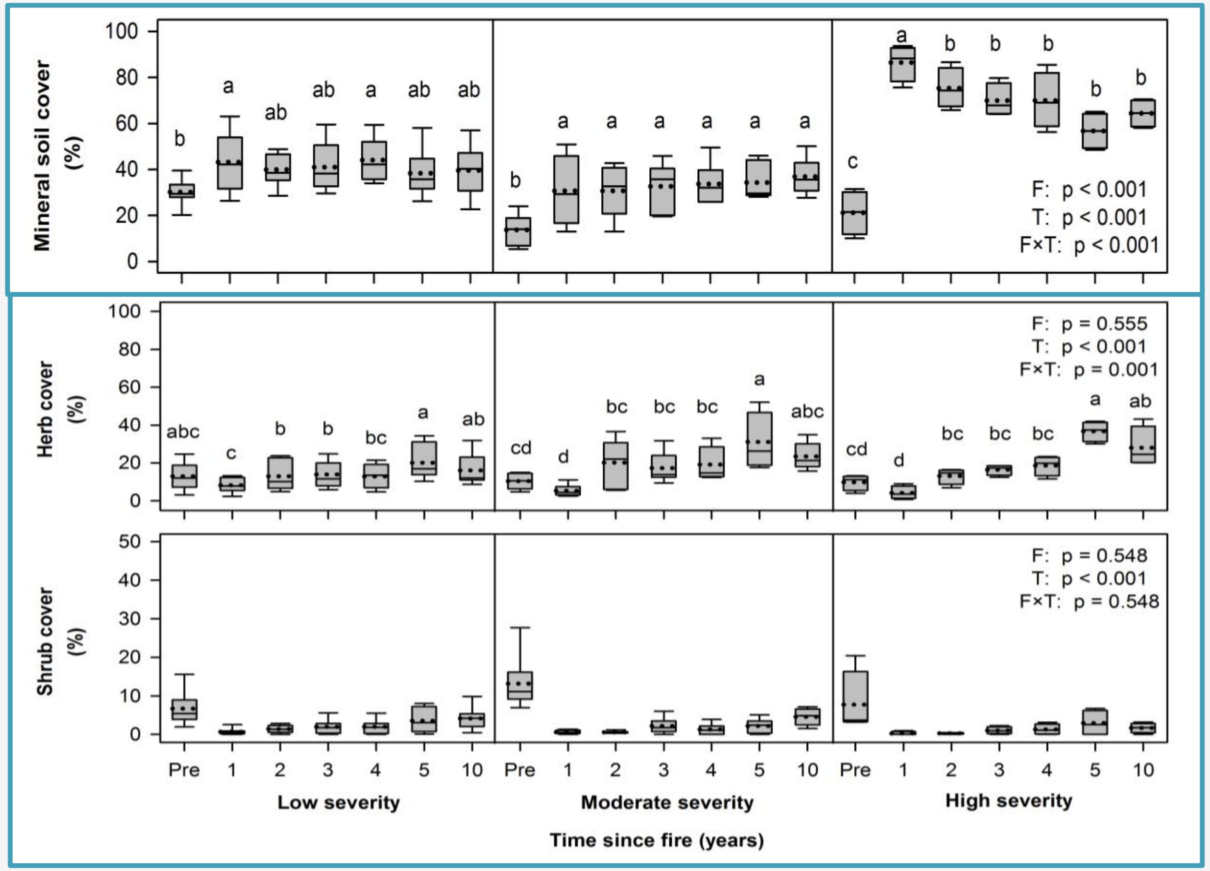
50% of pre-fire vegetation after 14 yrs

Soil Cover

2x above pre-fire

Plant Cover

Varies by plant type



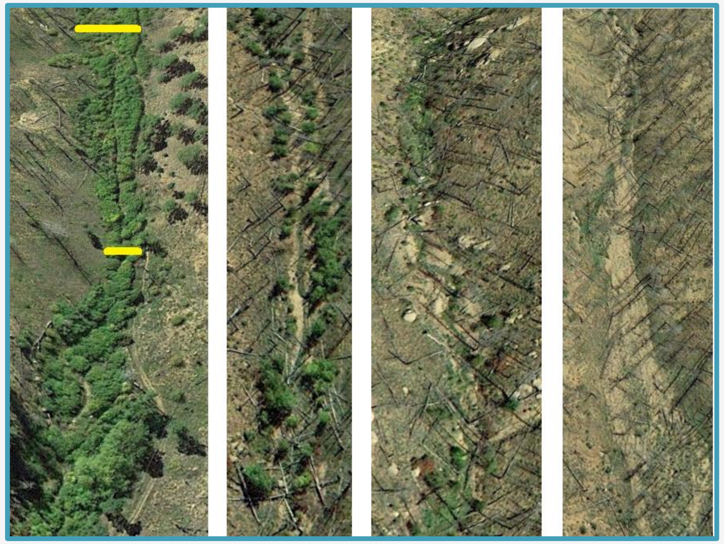
Fornwalt et al. 2018 *Forests*

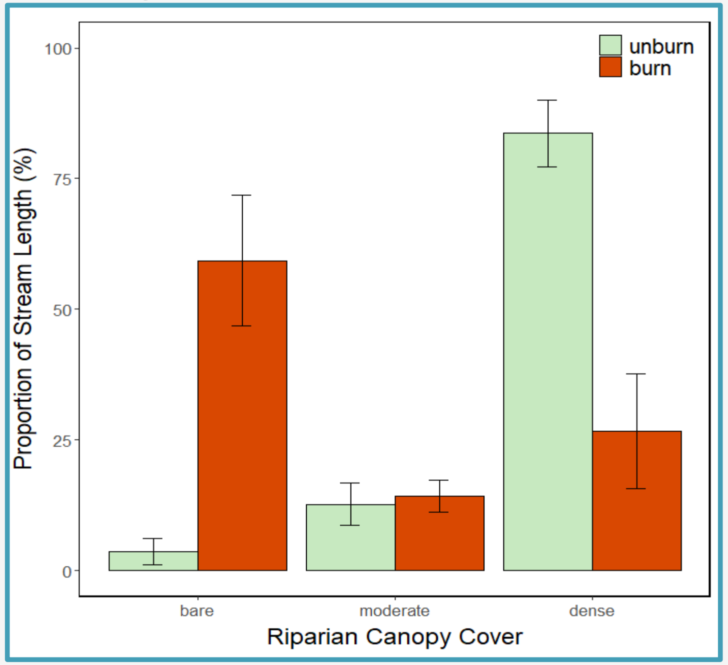
Post-Fire Vegetation Cover

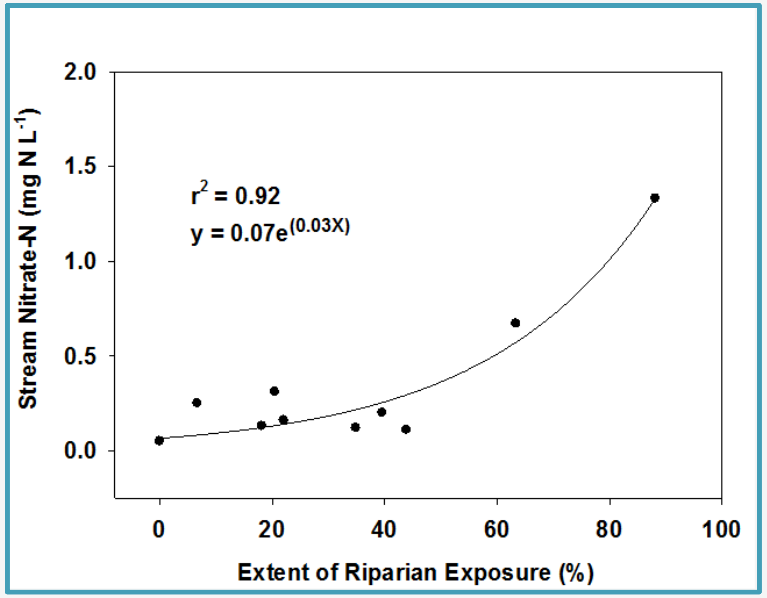
Nutrient retention much lower in extensively burned watersheds

>90% retention in unburned vs < 50% in burned

Prolonged effects relate to vegetation recovery and riparian cover







Stream N Relates to Riparian Cover

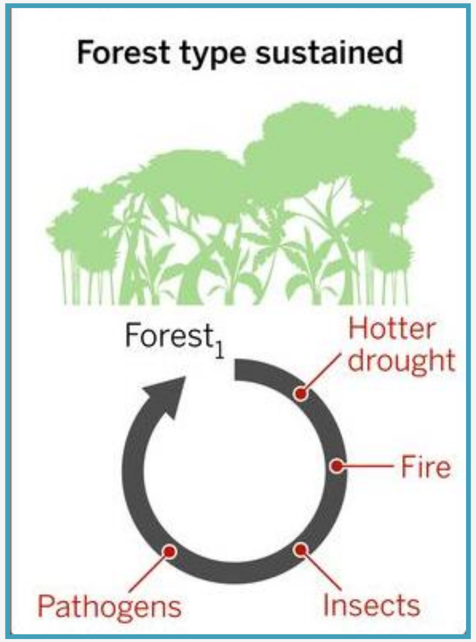
Decreased N uptake & C input

Increased stream temperature and light

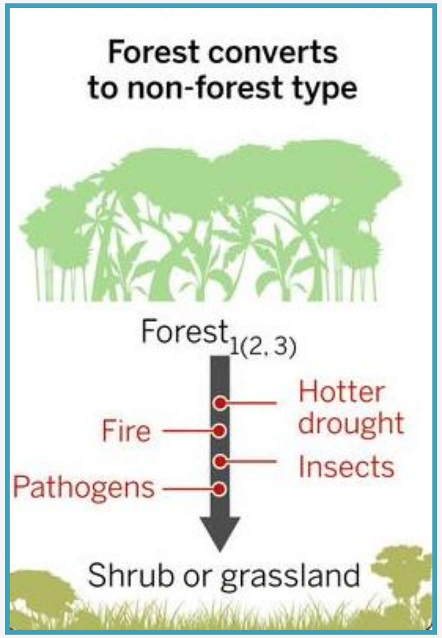
Rhoades et al. 2019, Ecosystems

MEGA- & MULTIPLE DISTURBANCES

WILDFIRE ACTIVITY & RECOVERY



Sparse tree regeneration 16 yrs after the Hayman Fire



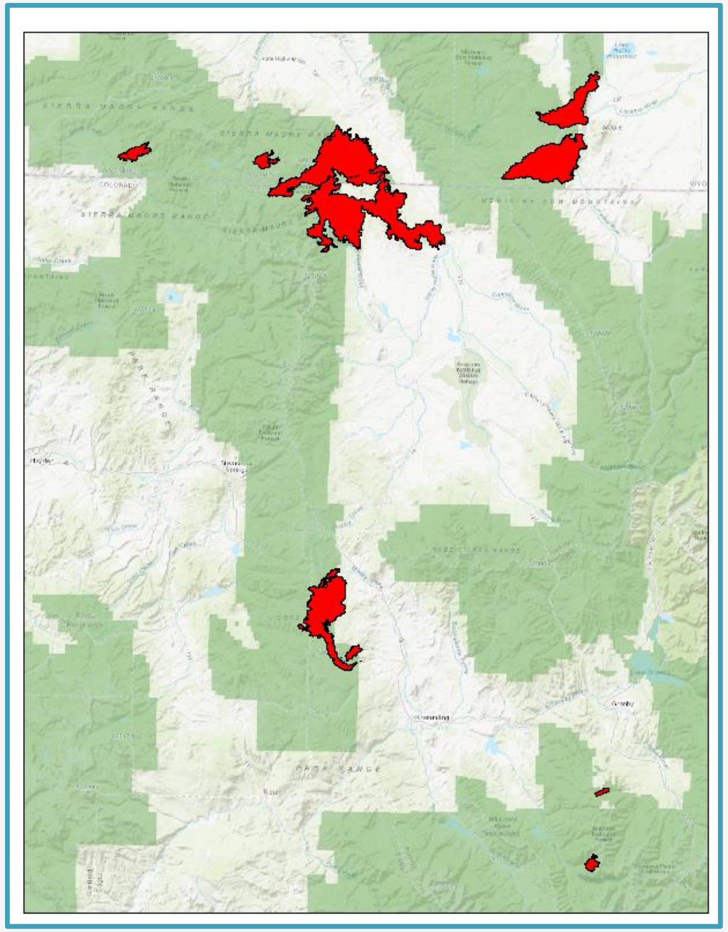
Additive Pressures – Severe, repeated or frequent wildfires directly or in combination with drought, insects or factors, push some forests beyond thresholds of sustainability.

Harvey et al. PNAS

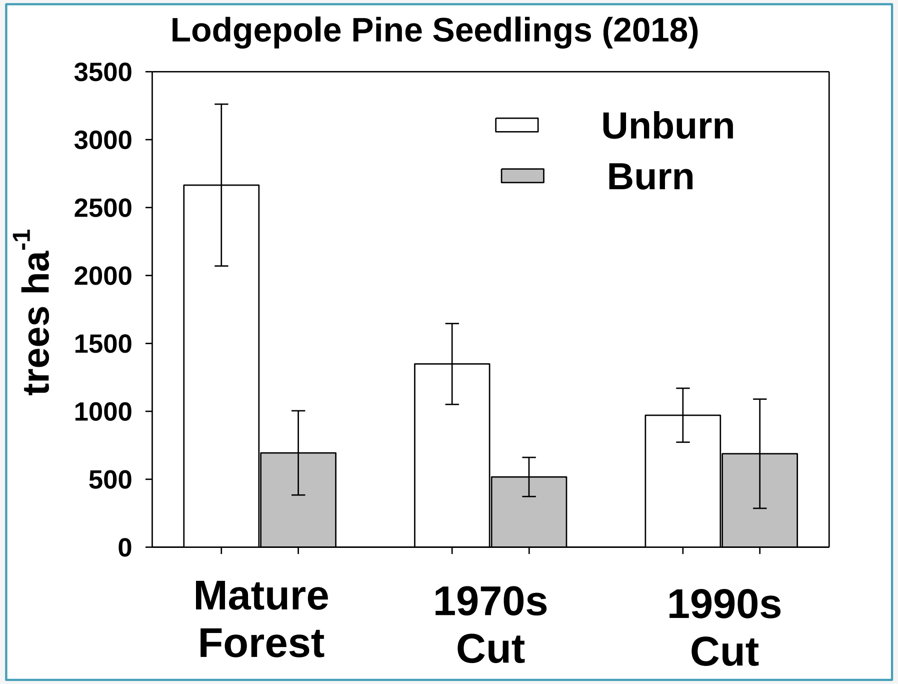
Millar and Stephenson; Aug 2015. Science

New Challenges

Wildfire + Extensive Tree Mortality



Fire	Date	Acres
Church's Park	3/10/10	500
Beaver Crk	6/19/16	37,381
Snake	9/10/16	2,300
Broadway	8/14/16	2,121
Ryan	9/15/'18	28,585
Badger Crk	6/10/'18	20,310
Silver Crk	6/19/'18	20,120
Keystone	7/3/'17	2,527
Sugarloaf	6/28/'18	1,280



Beaver Creek Fire

Low density of new trees

Hi severity + lo serotiny

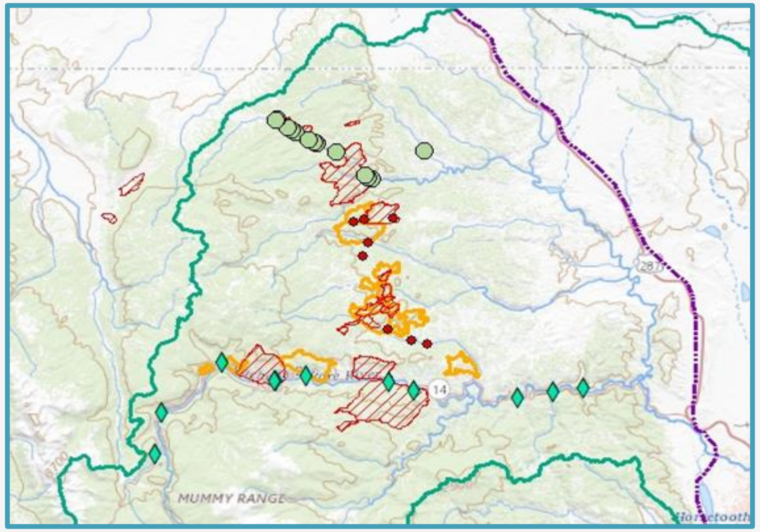
* Regen varies acoss fires

New Challenges

Reducing Fuels, Protecting Watersheds

NoCo Fireshed Partnership

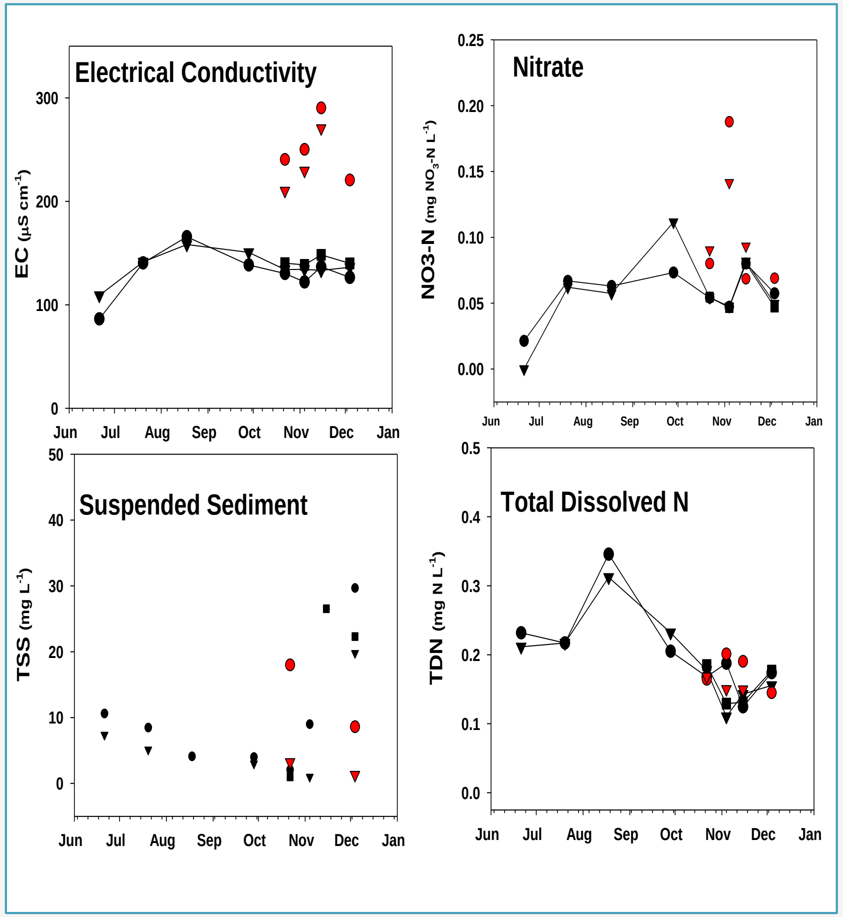
Increasing the pace and scale of prescribed burning on all lands



Citizen Science Monitoring

Evaluating water quality following prescribed burning in the Upper CLP to inform management activities

Prescribed Fire on Water Quality



Tributary within Elkhorn Rx Fire

Initial increase: nitrate-N, EC, pH, TSS other analytes.

Likely to fluctuate as snow melt, rains mobilize ash, sediment, nutrients, C from exposed soils.

Wildfire Effects on Water, Watersheds

Long-term changes in nutrients and C are significant and Common

CAtchments with extensive & moderate extent of severe wildfire

These signify shifts watershed nutrient retention

Source of persistent change in Stream N

High Soil N Supply = **No**	Burned and unburned soils similar
Low In-stream Uptake = **No**	Algal production higher in burned streams
Low Soil N Demand = **Yes**	High N release in leachate and low cover in burned

Implications and Challenges for Management

Revegetation/Restoration efforts may speed water quality recovery

Many unknowns regarding multiple disturbances (ie. Fire + Bugs, drought, harvest)

Knowledge Gap: How to conduct prescribed fires to protect watersheds

THANKS!

7^{th} Annual Poudre River Forum
Loveland, CO; 28 February 2020

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