Burn severity, tree regeneration, and carbon storage—are reburns different?

Monica G. Turner[1], Brian J. Harvey[2], Winslow D. Hansen[1], and Kristin H. Braziunas[1]

[1]Dept. of Integrative Biology, University of Wisconsin – Madison

[2]School of Environmental and Forest Sciences, University of Washington

Acknowledgements

Summer 2017 field season

- Bill Romme
- Tyler Hoecker
- Zak Ratajczak
- Tanjona Ramiadantsoa
- Jacob Gold
- Shauna Jacobs
- Deirdre Turner
- Nathan Gill
- Ann Olsson
- Kristen Emmett
- Saba Saberi
- Allie Orrego
- Diane Abendroth
- Ron Steffens

Funding

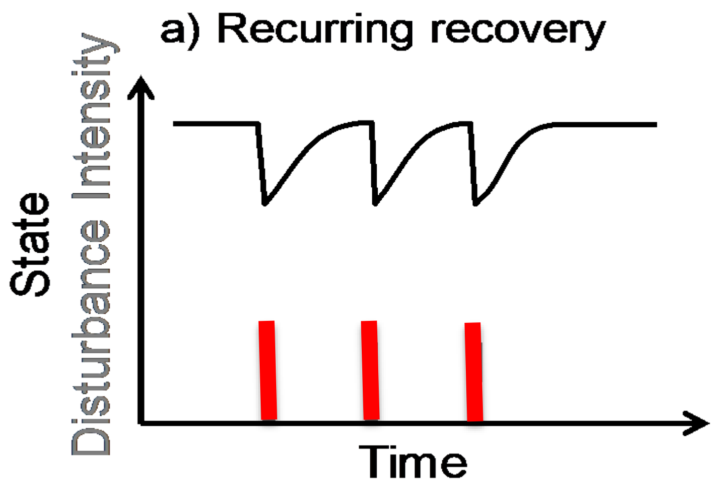
- National Science Foundation RAPID
- Vilas Trust, UW-Madison
- Joint Fire Science Program

Thanks also to

- Yellowstone National Park
- Grand Teton National Park
- UW-NPS Research Center

Forest resilience

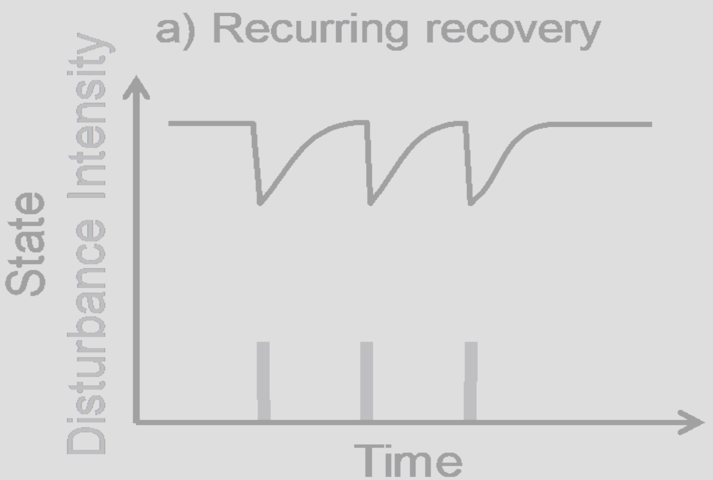
Resilience: capacity of system to tolerate disturbances without shifting to qualitatively different state *(Resilience Alliance 2012)*



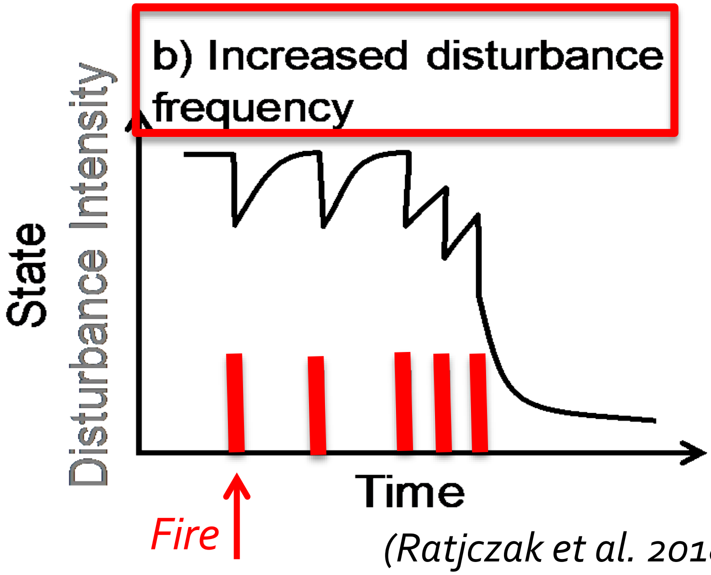
(Ratjczak et al. 2018, TREE)

Forest resilience

Resilience: capacity of system to tolerate disturbance without shifting to qualitatively different state *(Resilience Alliance 2012)*



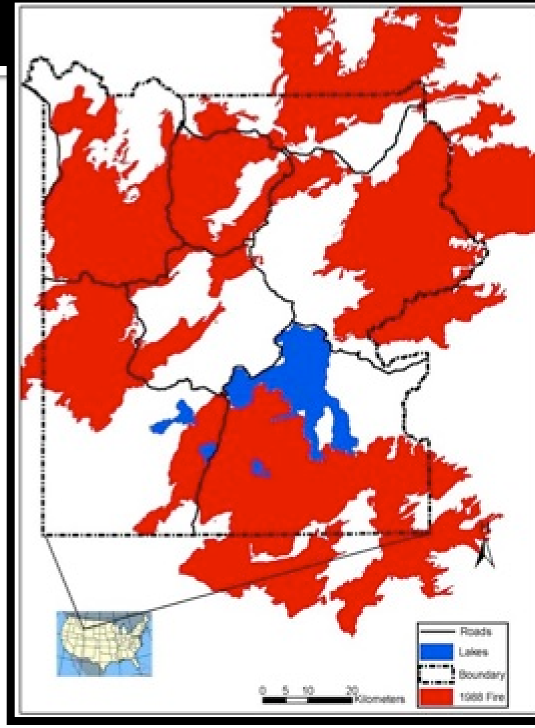
As fire-return intervals shorten, could forest ecosystems "ratchet down" if forests reburn before they recover?

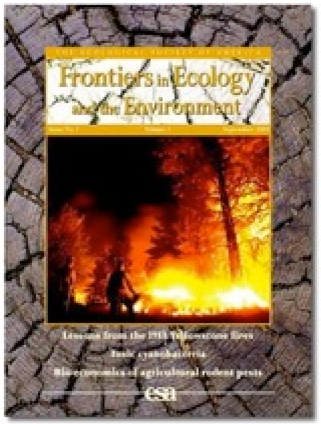


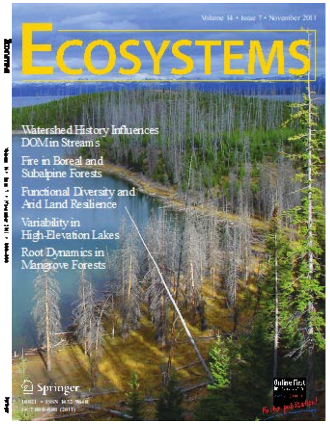
(Ratjczak et al. 2018, TREE)

1988 Yellowstone Fires

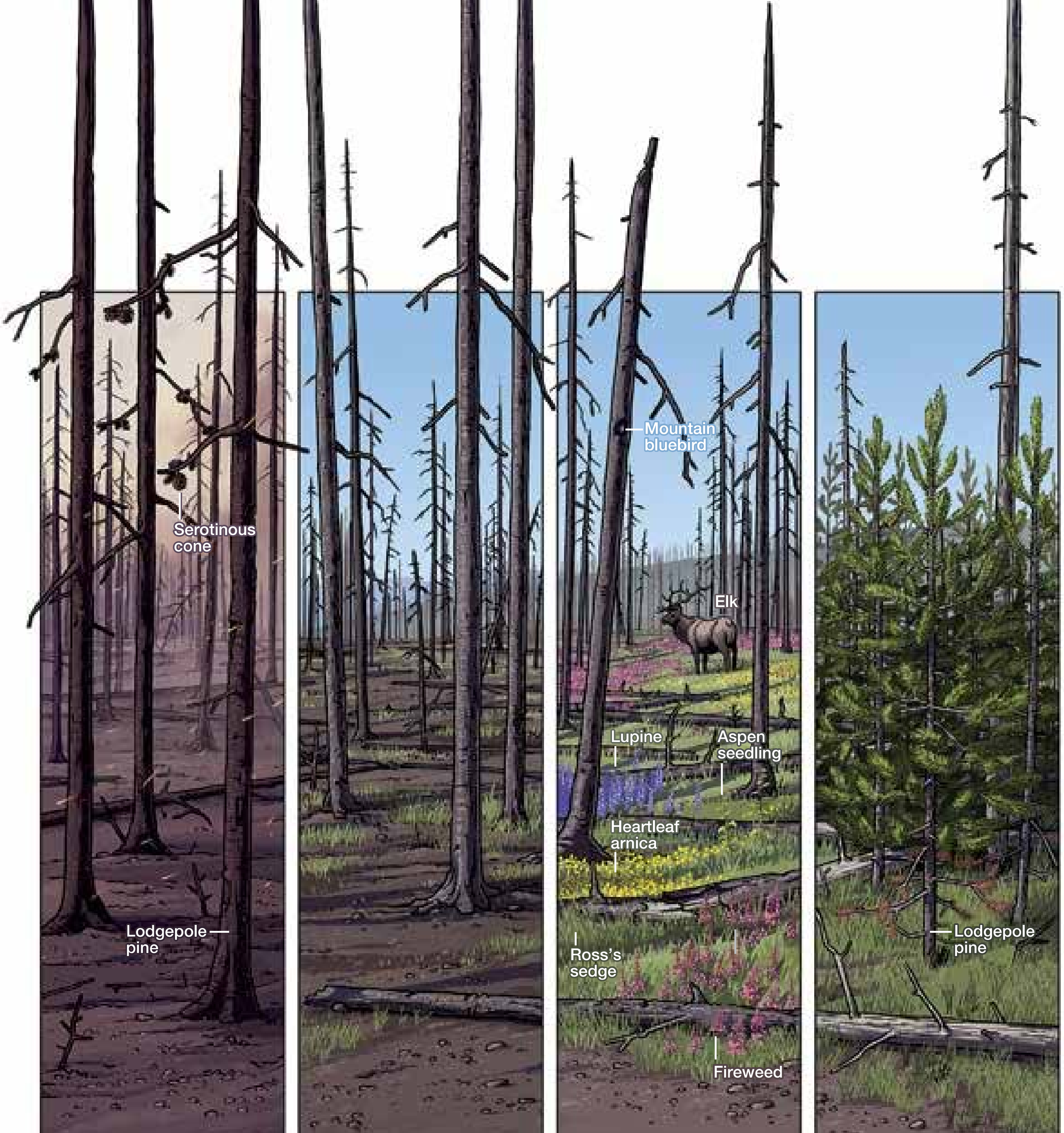
- Consequences well studied
  - Landscape mosaic of fire severity
    - (Turner et al. 1994)
  - Tree regeneration and vegetative cover
    - (Turner et al. 1997, 1999, 2003, 2004; Schoennagel et al. 2003, 2004; Kashian et al. 2004; Turner 2010; Romme et al. 2011; Donato et al. 2016)
  - Plant community composition
    - (Romme et al 2016)
  - Coarse wood dynamics and fuels
    - (Tinker and Knight 2000, 2001, 2004; Nelson et al 2016, 2017)
  - Biomass, primary productivity, decomposition, carbon, nitrogen
    - (Turner et al. 2004, 2007, 2009, 2011, 2016; Kashian et al. 2005, 2006, 2013; Remsburg and Turner 2006, Metzger et al. 2008, Smithwick et al. 2009, Copenhaver and Tinker 2014)





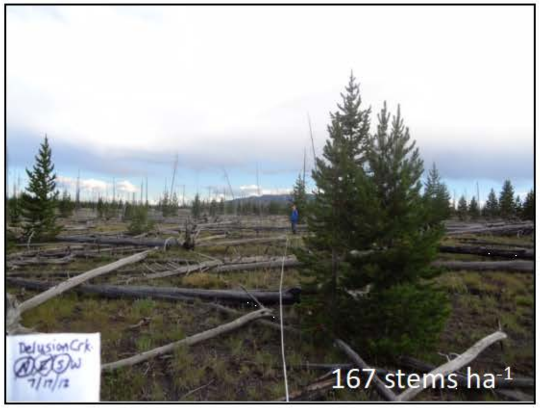


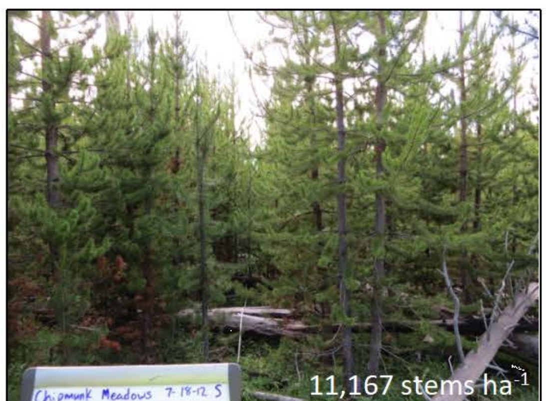
Vegetation recovered very rapidly



National Geographic
March 2016
Source info: M.G. Turner

After 25 yrs…stand development





Postfire year 24 lodgepole pine stem density

After 25 yrs…fuels

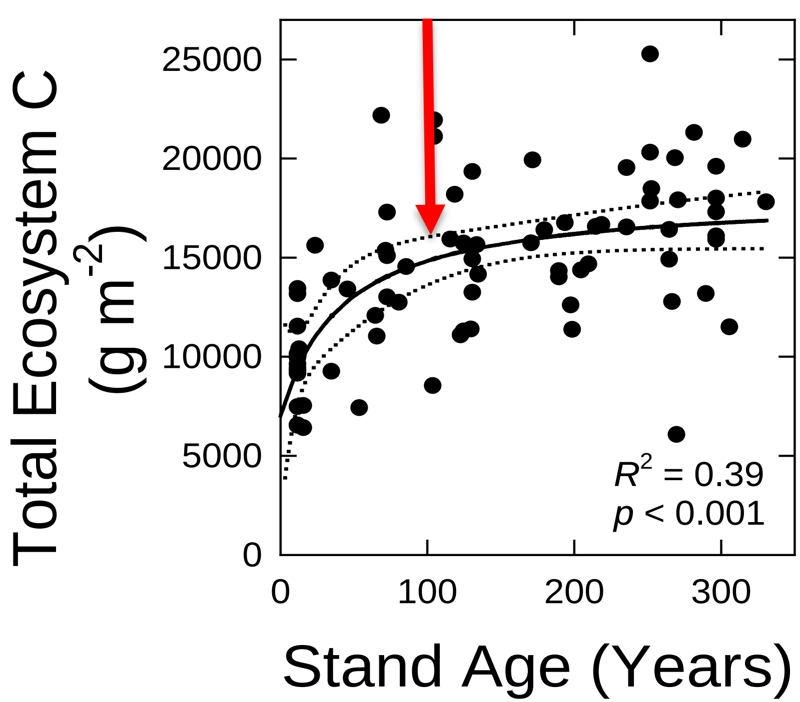
- Meet or exceed fuels in mature forest
  - Available canopy fuels (8.5 Mg/ha)
  - Canopy bulk density (0.25 kg/m^3)
  - Total surface fuels (123 Mg/ha)
- Fuels can support fire
  - 76% of stands have 1000-hr fuels > levels associated with high-severity surface fire
  - 63% of stands have canopy fuels > levels associated with active crown fire potential

(Nelson et al. 2016, Ecol Applica; Nelson et al. 2017, IJWF)

Long-interval fire

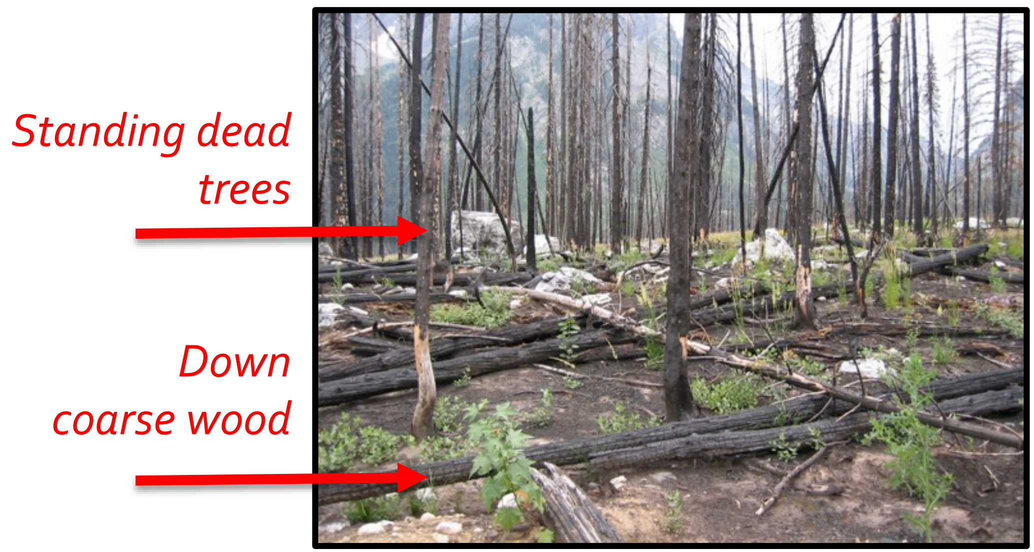
(Turner et al. 1997, Ecol. Monogr.; Turner et al. 2004, Ecosystems; Turner 2010, Ecology)

90% of carbon stocks recovered in 100 yrs



(Kashian et al. 2013, Ecol Monogr)

Only ~16% coarse wood lost

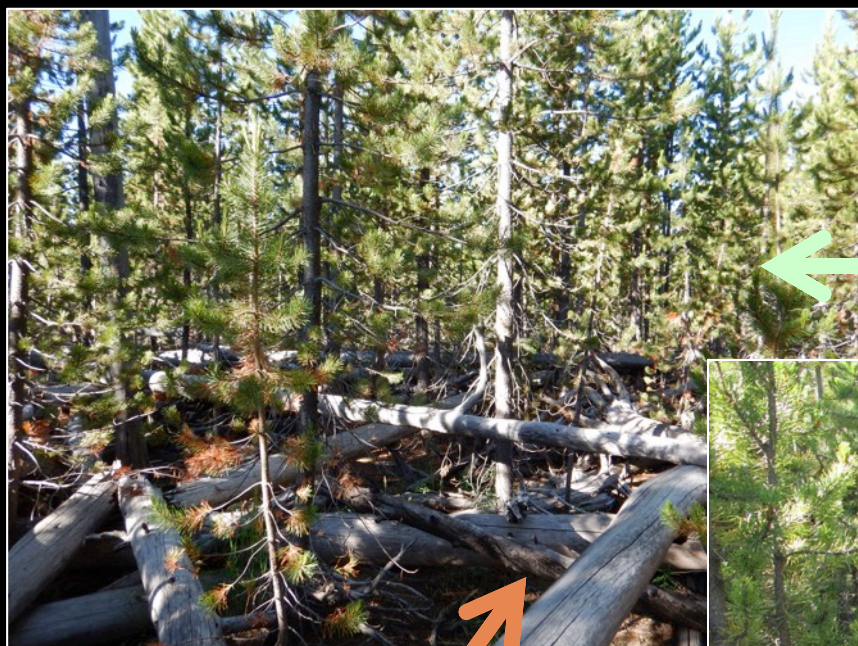


(Tinker & Knight 2000, 2001, 2004)

Short-interval fire?

Reburn ?

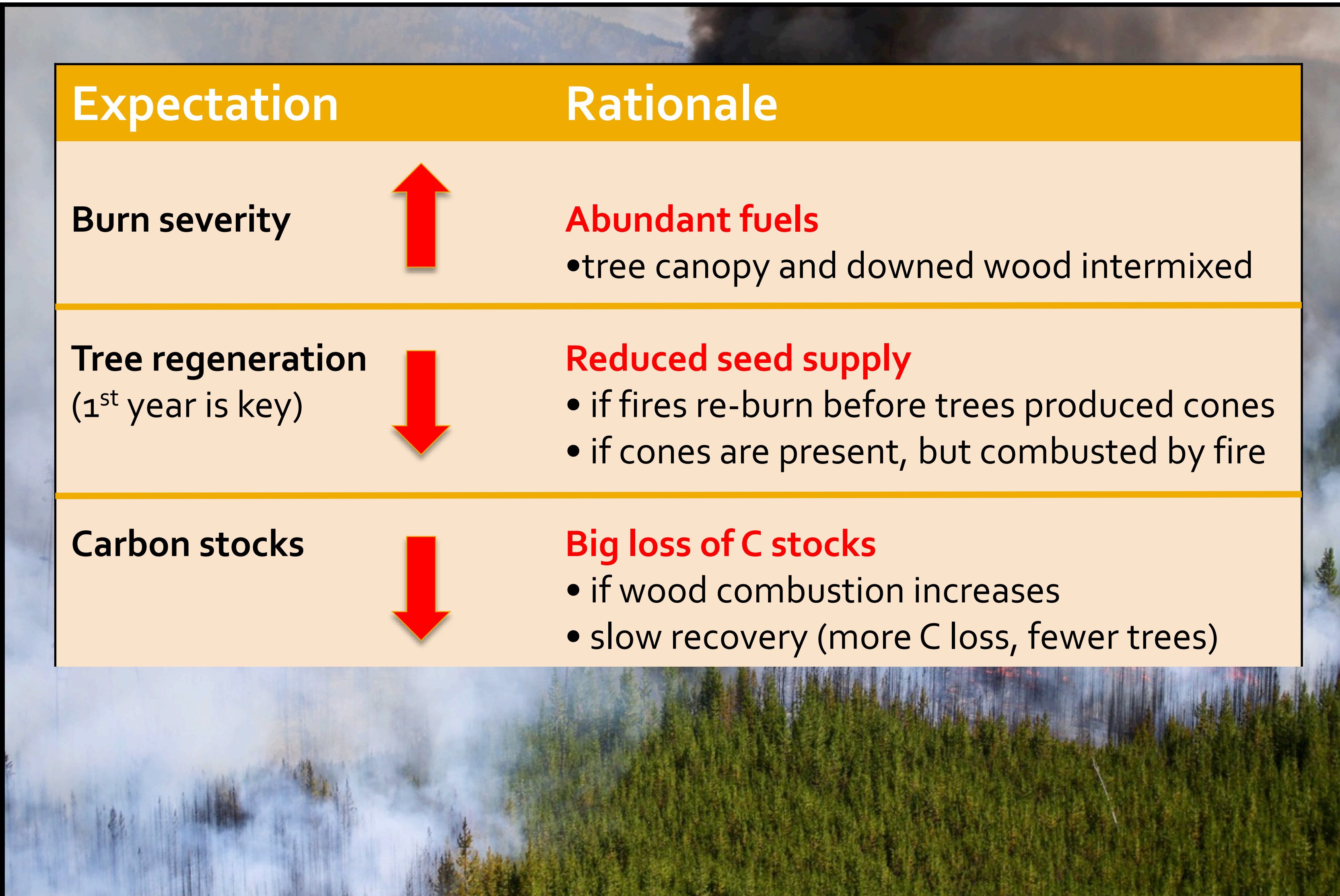
Fuels in young lodgepole pine forests



Dense canopy fuels, low to the ground

Abundant coarse wood (snags from 1988 fire)

Short-interval fire and forest resilience



Expectation		Rationale
Burn severity	↑	**Abundant fuels** •tree canopy and downed wood intermixed
Tree regeneration (1^{st} year is key)	↓	**Reduced seed supply** • if fires re-burn before trees produced cones • if cones are present, but combusted by fire
Carbon stocks	↓	**Big loss of C stocks** • if wood combustion increases • slow recovery (more C loss, fewer trees)

2016 Yellowstone Fires

Area burned ~ 40,000 ha

Short-interval fire = 18,000 ha

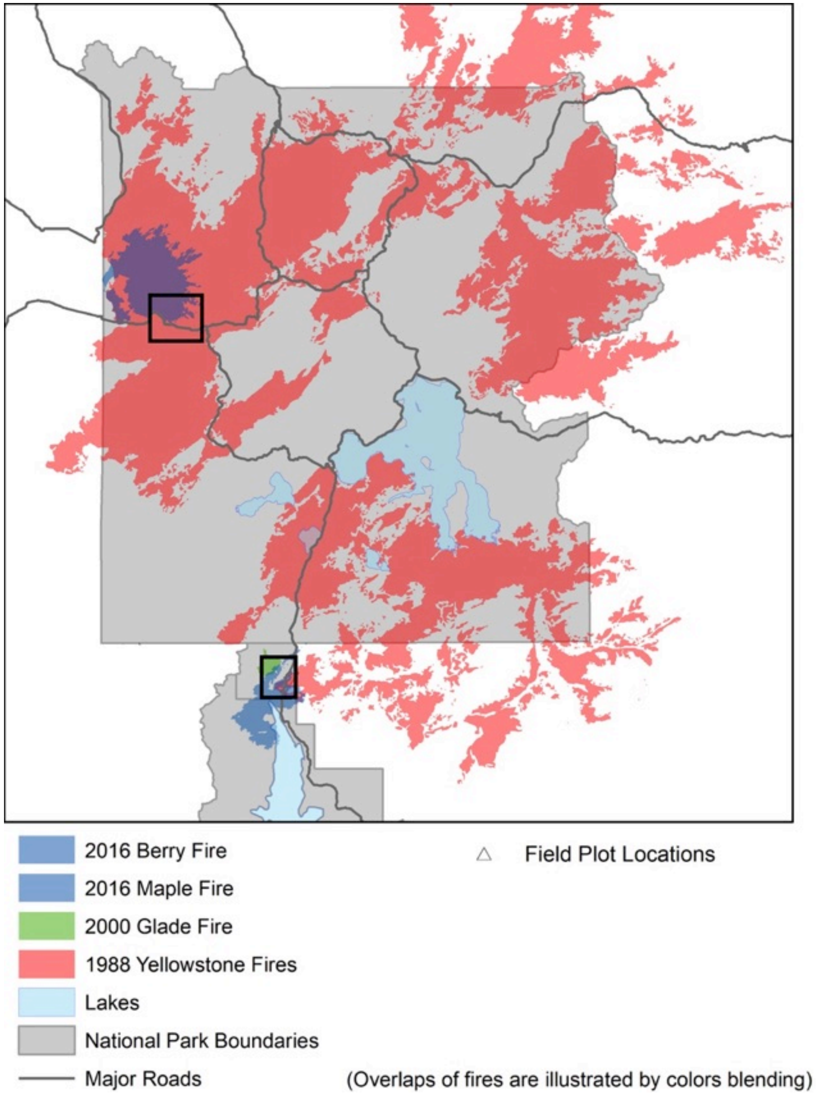
Maple Fire burns 28-yr old lodgepole pine in July 2016 (NPS photo)

Summer 2017 field campaign (*n* = 27 plots)

Sites: *n* = 3 (16 or 28 yr FRI)

Maple Fire

Berry Fire



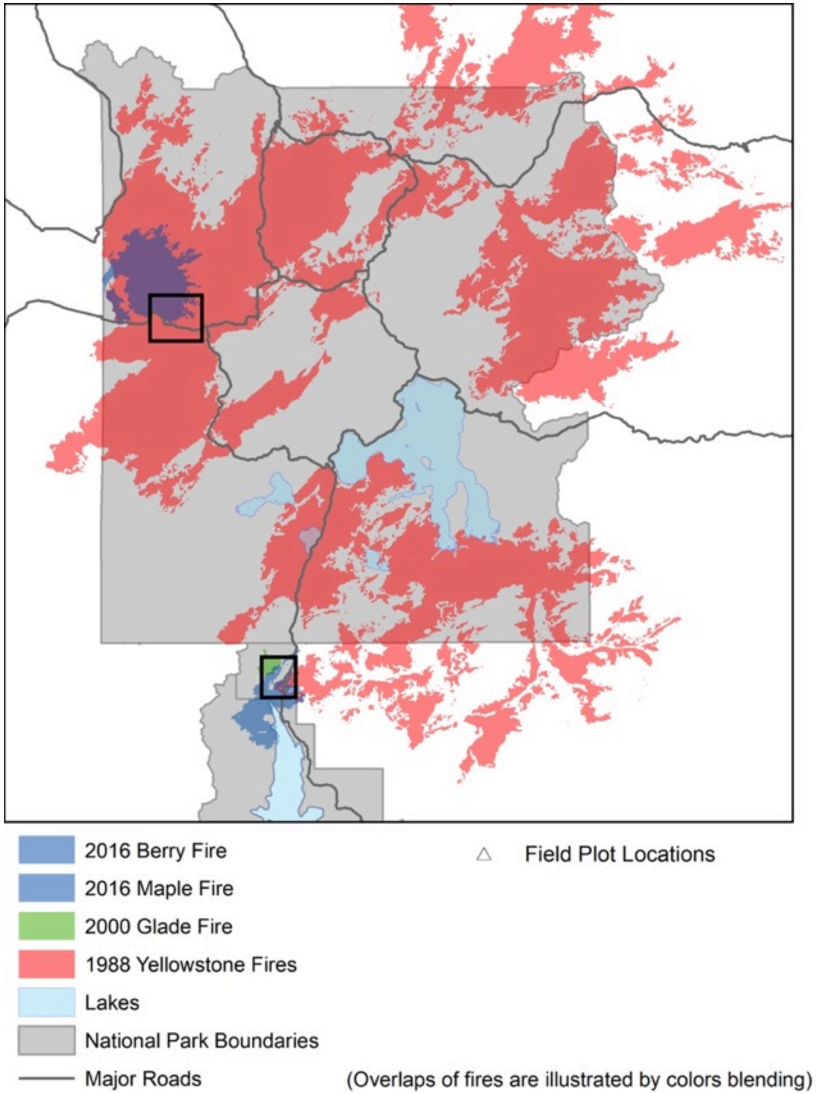
Summer 2017 field campaign (n = 27 plots)

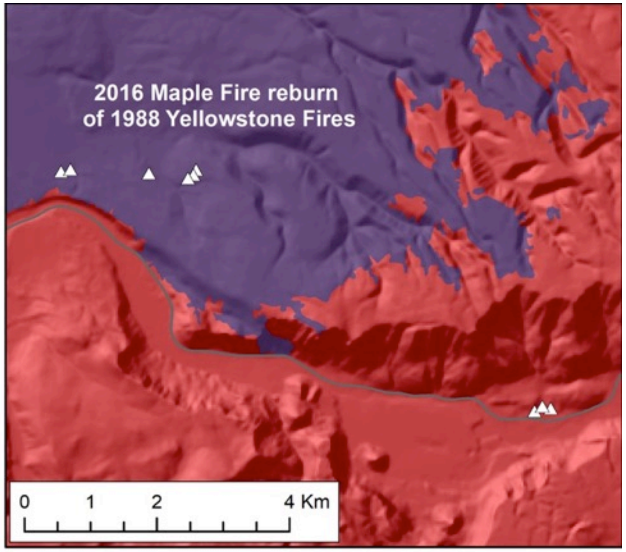
Sites: n = 3 (16 or 28 yr FRI)

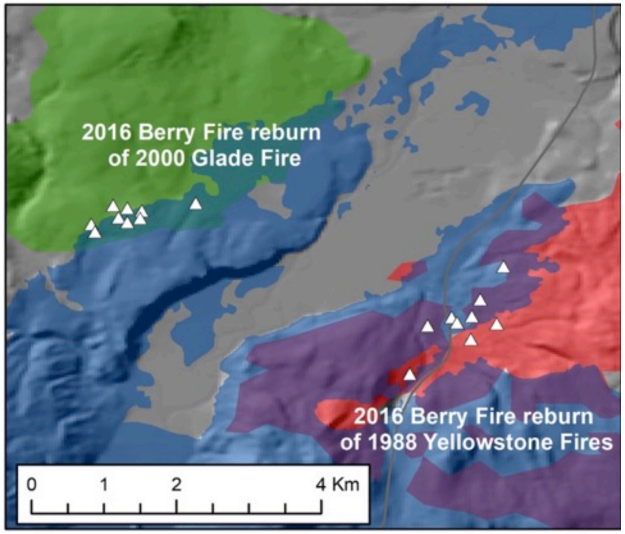
Plots per site: n = 6 stand-replacing reburns, n = 3 not reburned

Maple Fire

Berry Fire







Field sampling (50 x 50 m plots)

- **Burn severity**

  (30-m diameter circular plot)
  - % cover of char, soil, live vegetation
  - Char height, bole scorch, on trees
  - Pre- vs postfire stems & stumps
- **Tree regeneration**

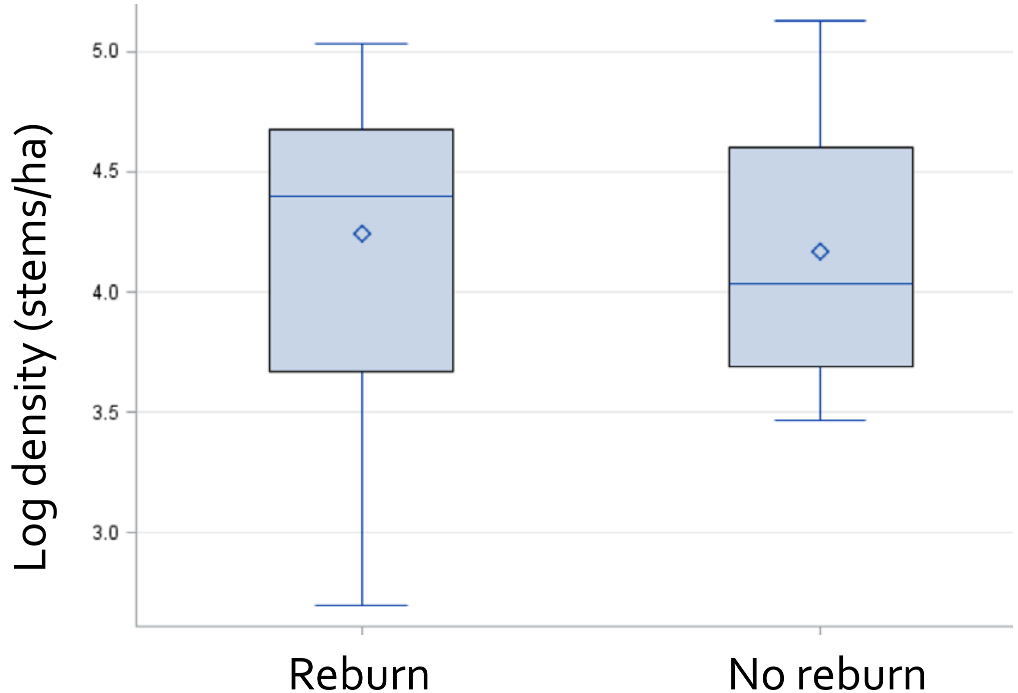
  (three 50 x 2 m belt transects)
  - Postfire tree seedlings
- **Carbon stocks**
  - Downed coarse wood % cover, biomass

    (>7.5 cm diameter; line and planar intercept, three 30-m transects)
  - Live and dead aboveground C pools

    (local allometric equations)

Within sites: Stand structure similar in plots that did and did not reburn

- Mean down coarse wood = 82 Mg/ha
- Mean tree density = 36,300 stems/ha
  (range 500 – 108,000)



No reburn

Results: Burn severity

- Typical for stand-replacing fire
  - Bole scorch = 98 ± 2%
  - Char height = 0.85 ± 0.06 of tree ht
  - Charred surface = 64 ± 6%

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- Typical for stand-replacing fire
  - Bole scorch = 98 ± 2%
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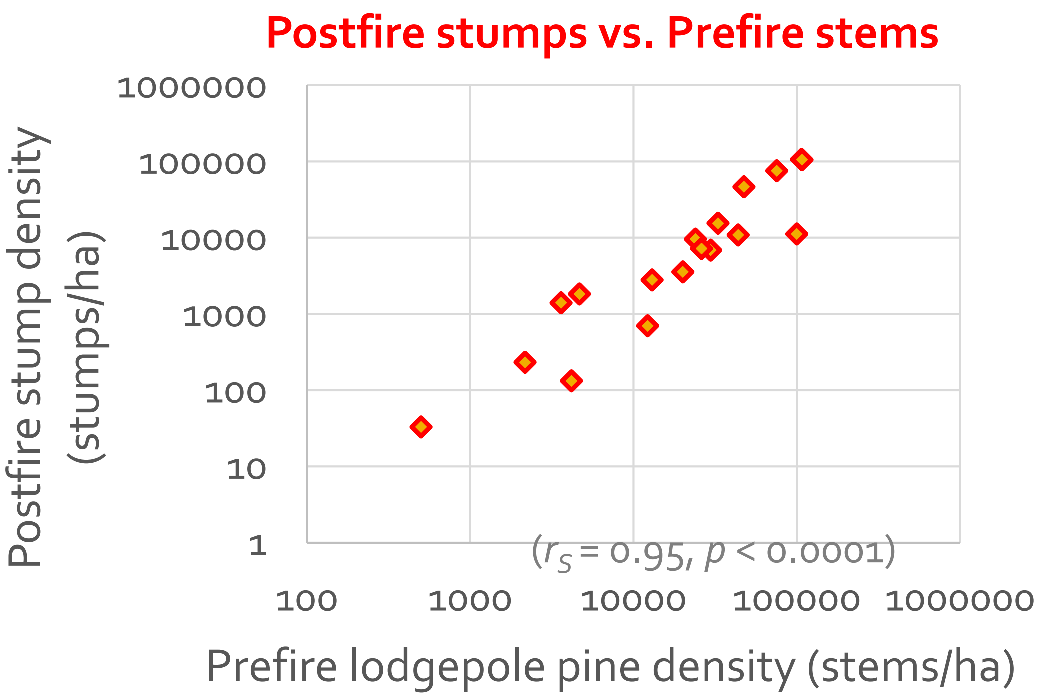
  - Charred surface = 64 ± 6%

- **BUT**...also included **much** higher burn severity than observed in any other fires ***(Crown +)***
  - Nearly complete combustion

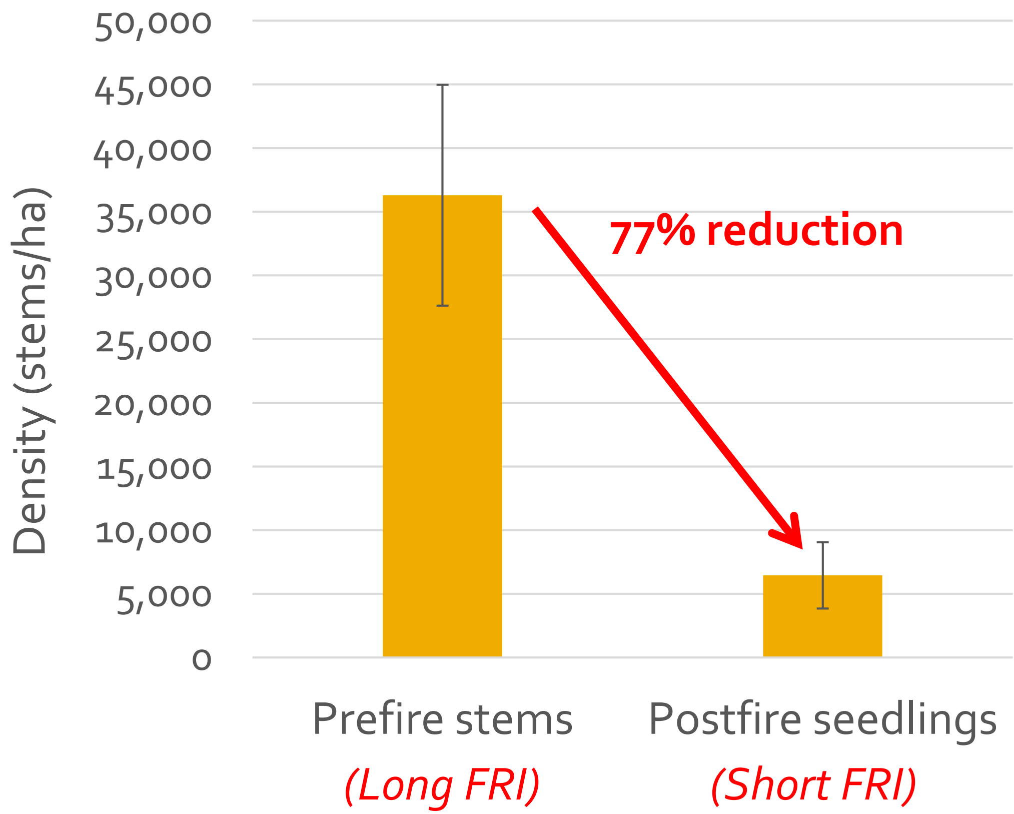
Stem combustion:
the more you had, the more you lost

Dense packing of small trees → *Crown fire +*



Results: Tree regeneration

- Less regeneration with reburn (short FRI)
  - But trees present on all plots (633 to 39,600 seedlings/ha)



Results: Tree regeneration

Greater decline with higher prefire density
(r = –0.73, p = 0.0006)

Sparse → sparse

Prefire stems = 500/ha
Postfire seedlings = 1100/ha

Dense → sparse (–99%)

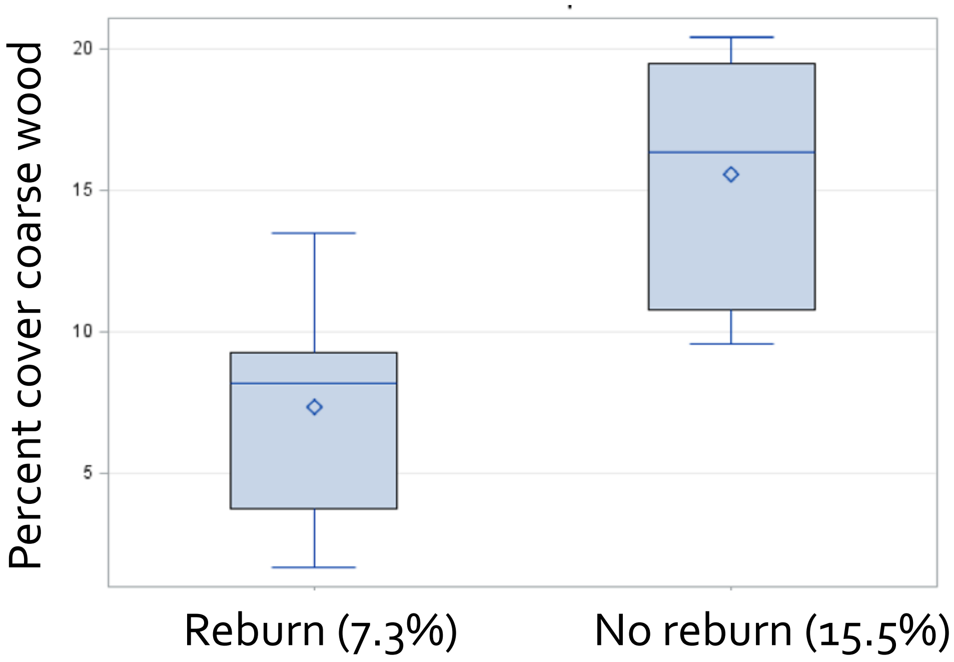
Prefire stems = 105,533/ha
Postfire seedlings = 833/ha

Results: Tree regeneration

More tree seedlings with more cones still present after reburns
(r = 0.62, p = 0.0059)

Results: Down coarse wood

- Coarse wood **% cover** reduced by ~half in reburns

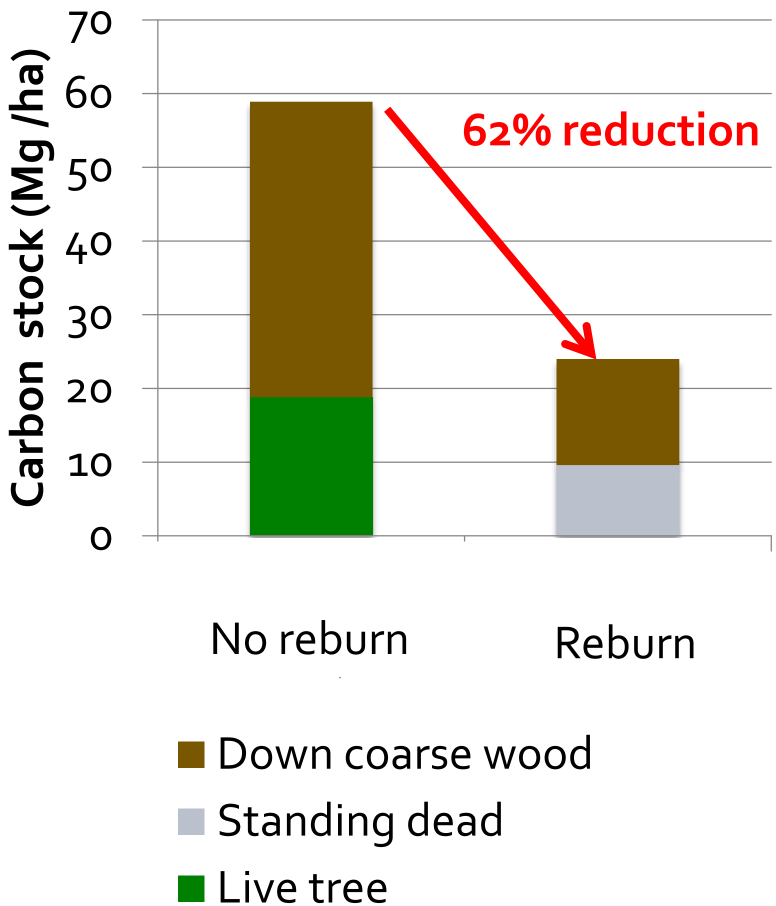


Results: Down coarse wood

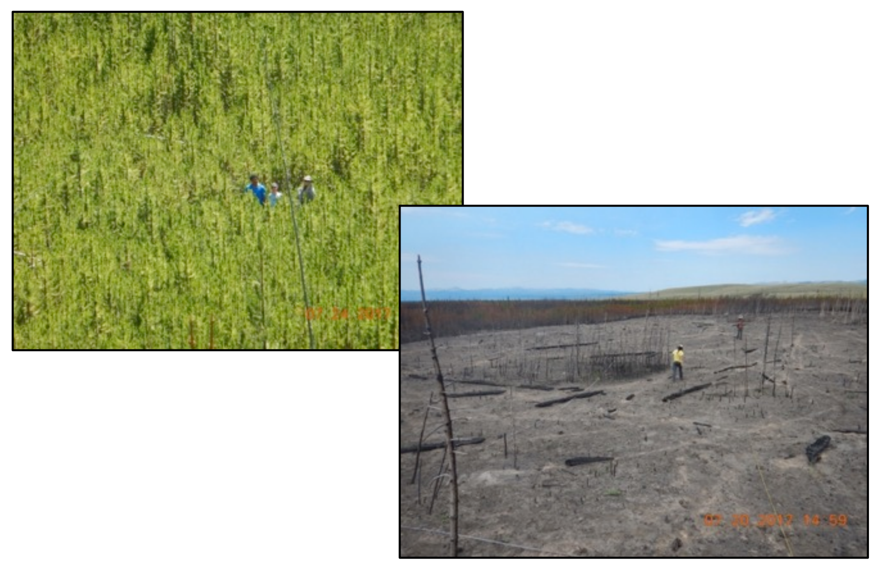
- Coarse wood **biomass** reduced by two-thirds in reburns
  - **Much** more combusted with short FRI

Fire interval	Percent lost	Biomass lost
Long (> 100 yrs) *(Tinker & Knight 2000)*	16%	~10 Mg/ha
Short (16-28 yrs) *(this study)*	65%	53 Mg/ha

Results: Aboveground C stocks



- **Amount** of C loss (Mg/ha) unrelated to prefire tree density or biomass
- **Percent** of C loss greater with small-diameter trees
  - Declines ranged from 32-96%



Longer-term consequences?

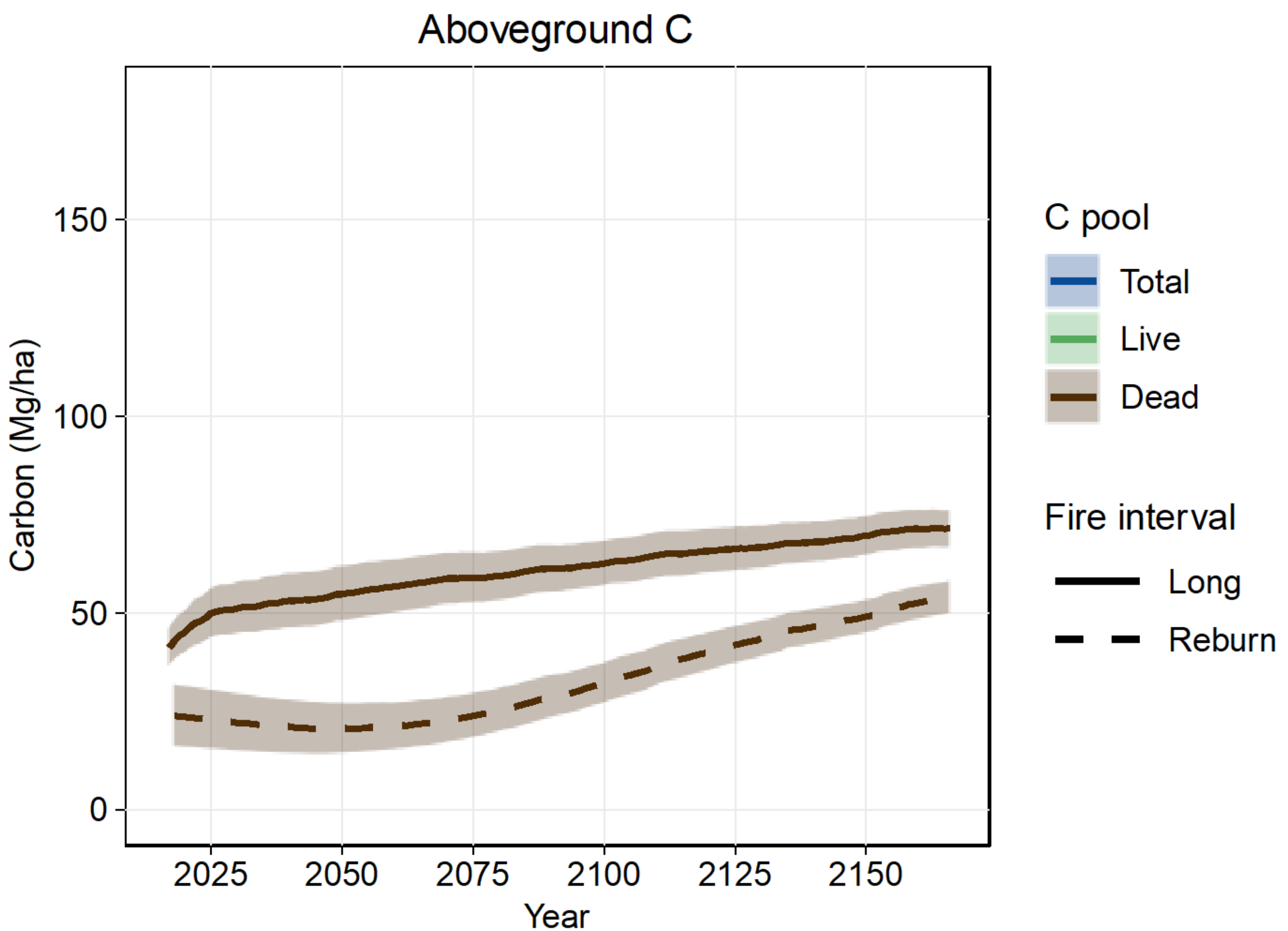
- **iLand**: Individual-based forest landscape and disturbance model *(Seidl et al. 2012 Ecol Modelling, 2014 Eco Apps)*
  - **Parameterized, well tested for Greater Yellowstone**

    (Hansen et al. 2018 Ecology, Braziunas et al. in revision FEM)
  - **Simulated the reburned stands (1-ha) for 150 yrs**
    - With and without the 2016 reburn
    - Historical climate (1980-2017), random with replacement
    - No subsequent disturbances
    - **Compare aboveground live and dead C stocks**

http://iland.boku.ac.at/

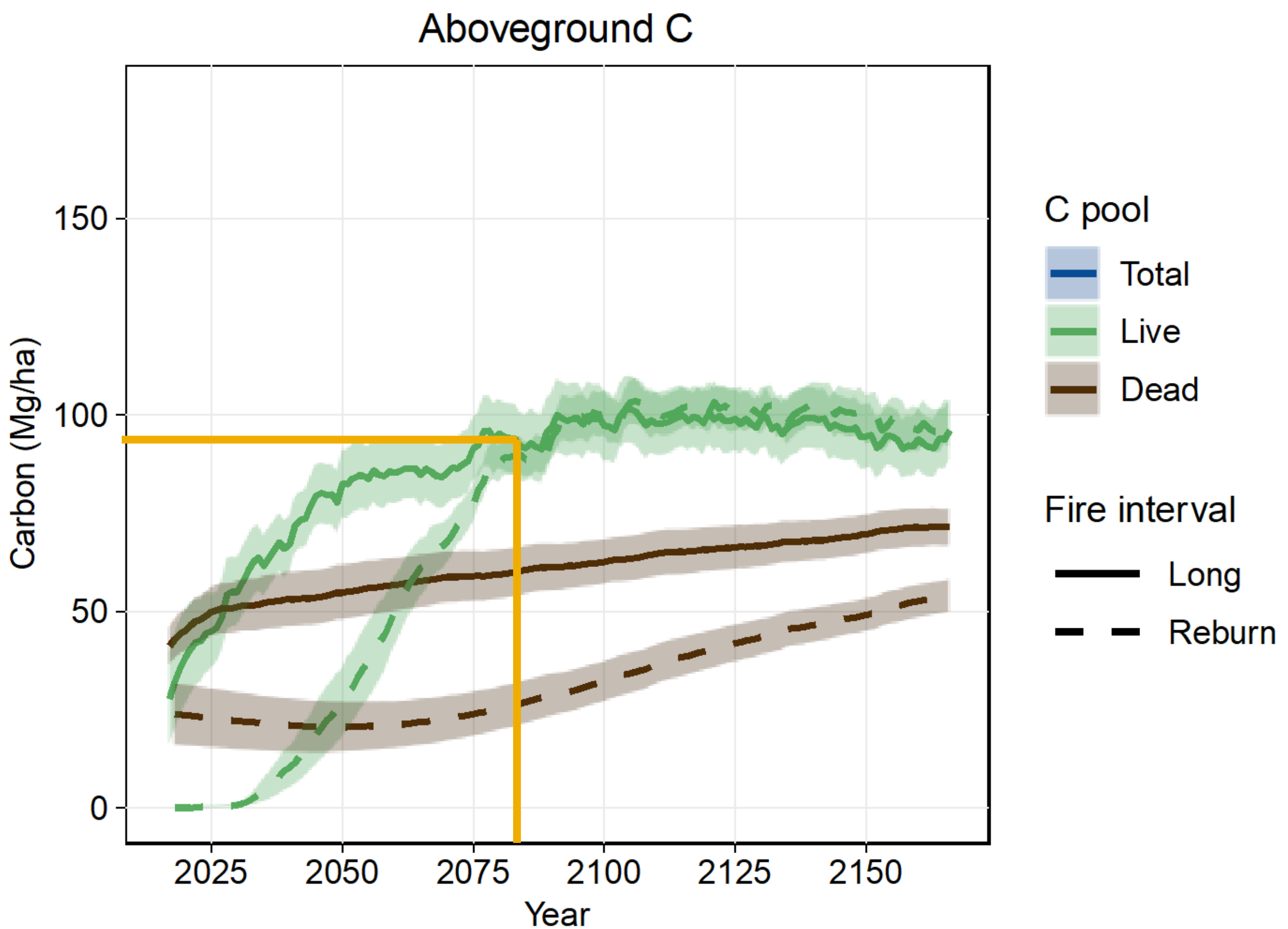
Results: Aboveground C stocks

Down coarse wood does not recover in 150 yrs



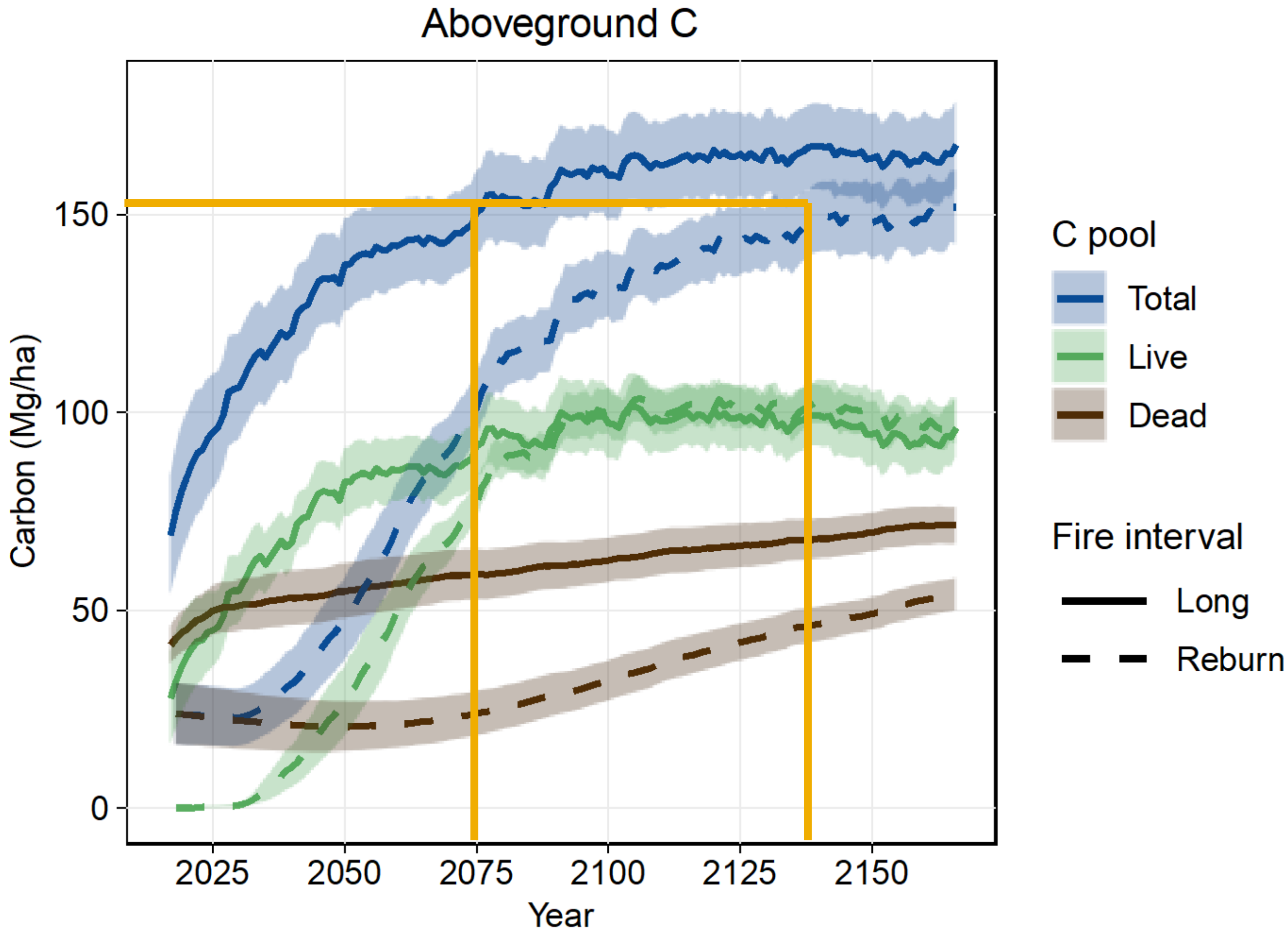
Results: Aboveground C stocks

Recovery of live tree C takes ~60 yrs



Results: Aboveground C stocks

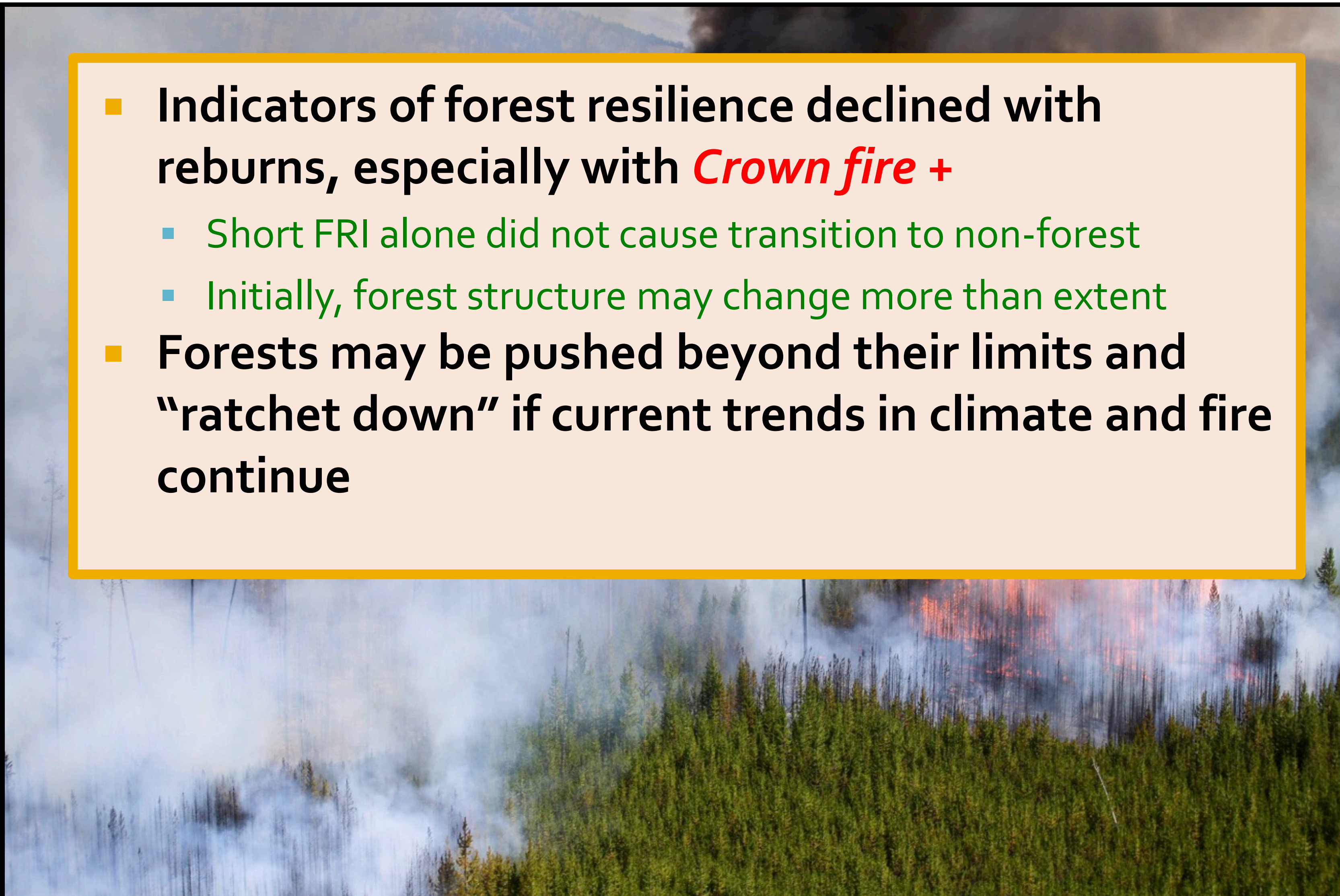
Aboveground C recovery takes > 65 yrs



Summary

Expectation		Rationale
Burn severity	↑	✓ **More extreme burn severities** ***Crown fire* +** not observed in previous fires
Tree regeneration (1st year is key)	↓	✓ **Slower rates of recovery** Much lower regeneration density
Carbon stocks	↓	✓ **More loss, slower recovery of C stocks** Over 65 more years needed to recover aboveground C from prior long-interval fire

Conclusions



- **Indicators of forest resilience declined with reburns, especially with *Crown fire* +**
  - Short FRI alone did not cause transition to non-forest
  - Initially, forest structure may change more than extent
- **Forests may be pushed beyond their limits and “ratchet down” if current trends in climate and fire continue**


Thank you