Applying the science of fire to confront challenges facing prescribed burners

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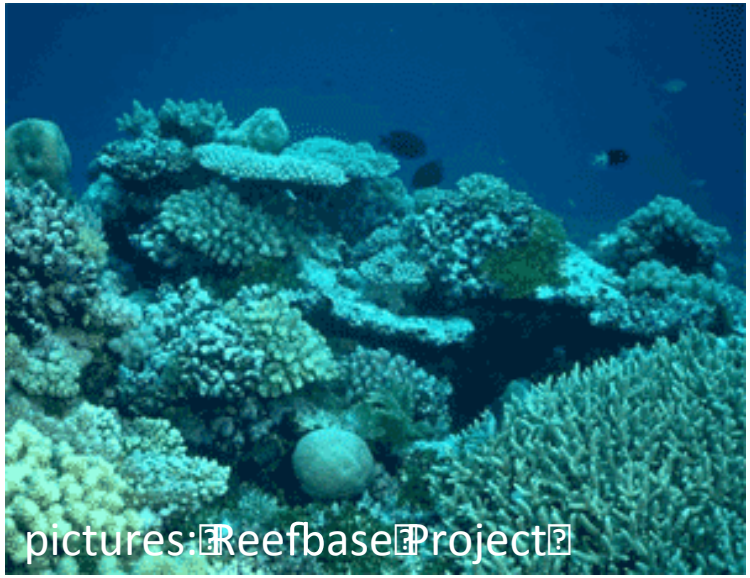
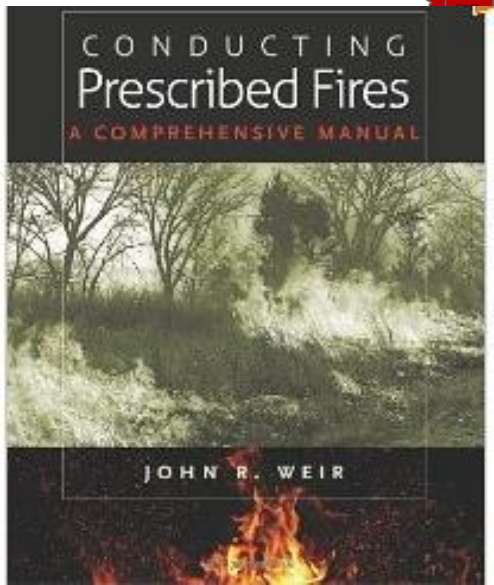
Nebraska Prescribed Fire Council
Kearney, NE
1 December 2015

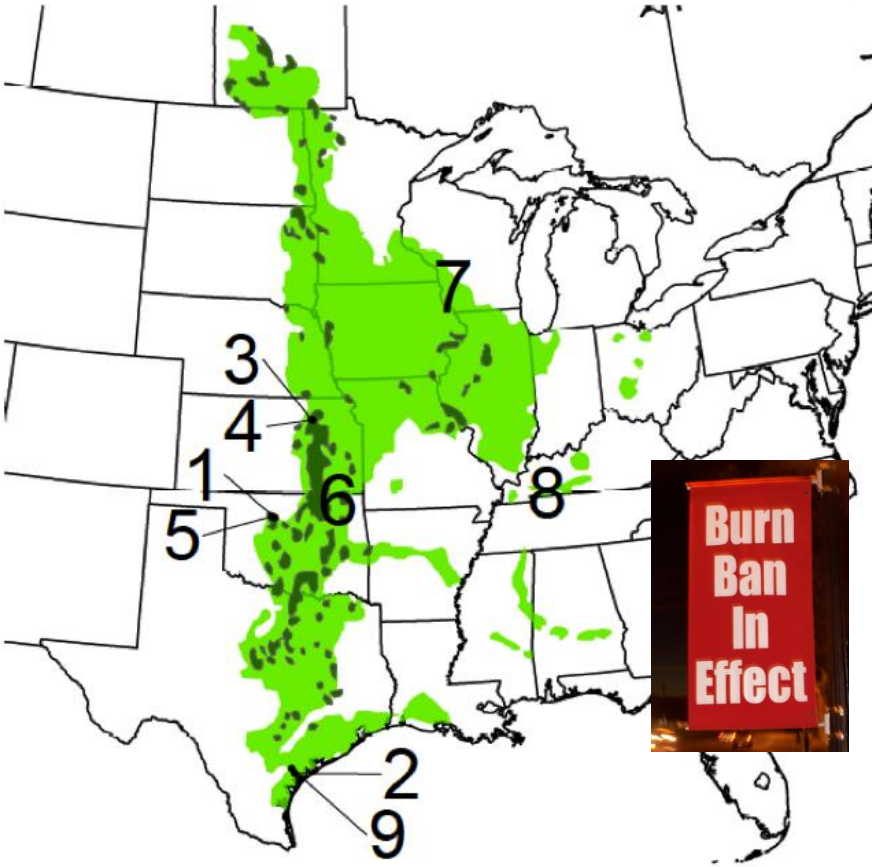
Human activities are contributing to loss of resilience and shifts to less desirable ecological states

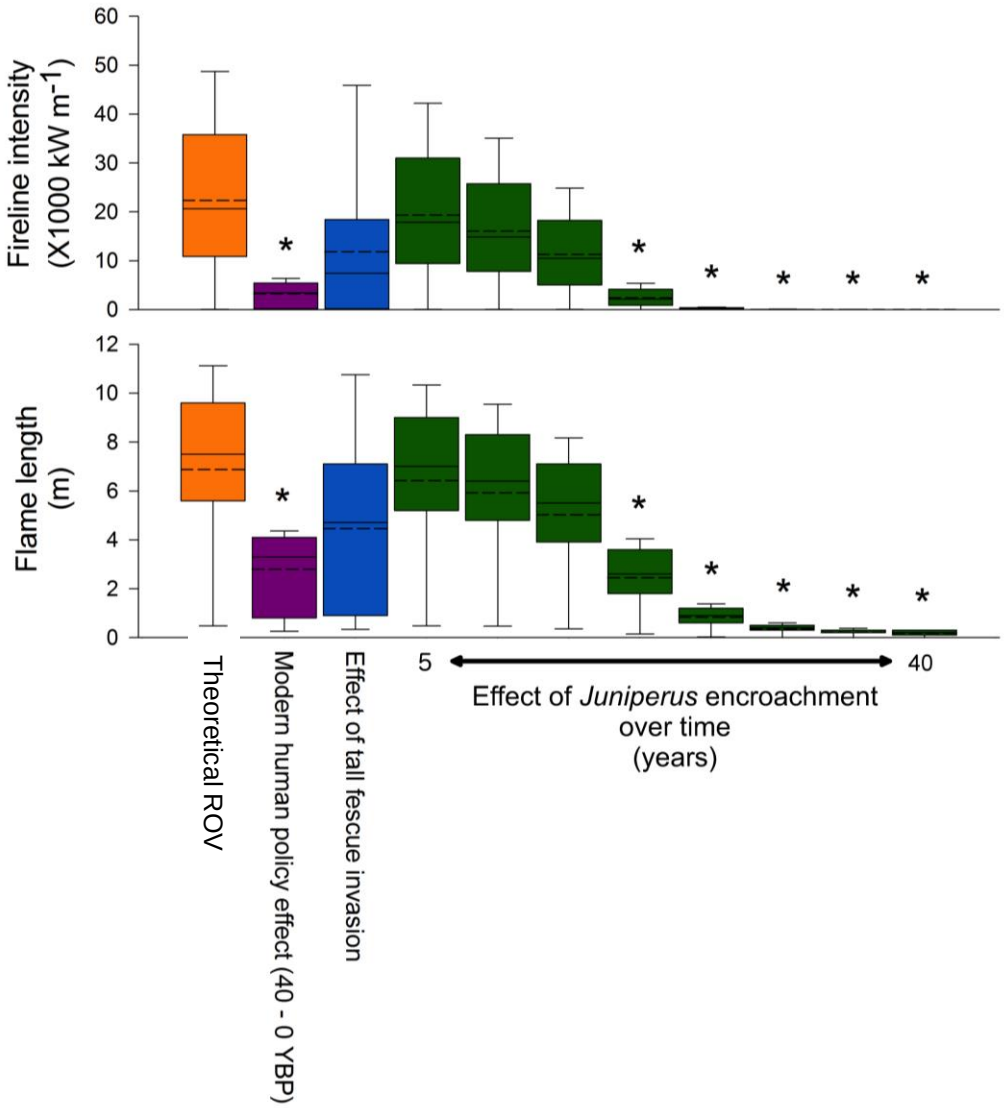


An objective evaluation of the role of fire in structuring the Great Plains has been lacking since settlement



Departures from historical fire regimes:
Fire intensity

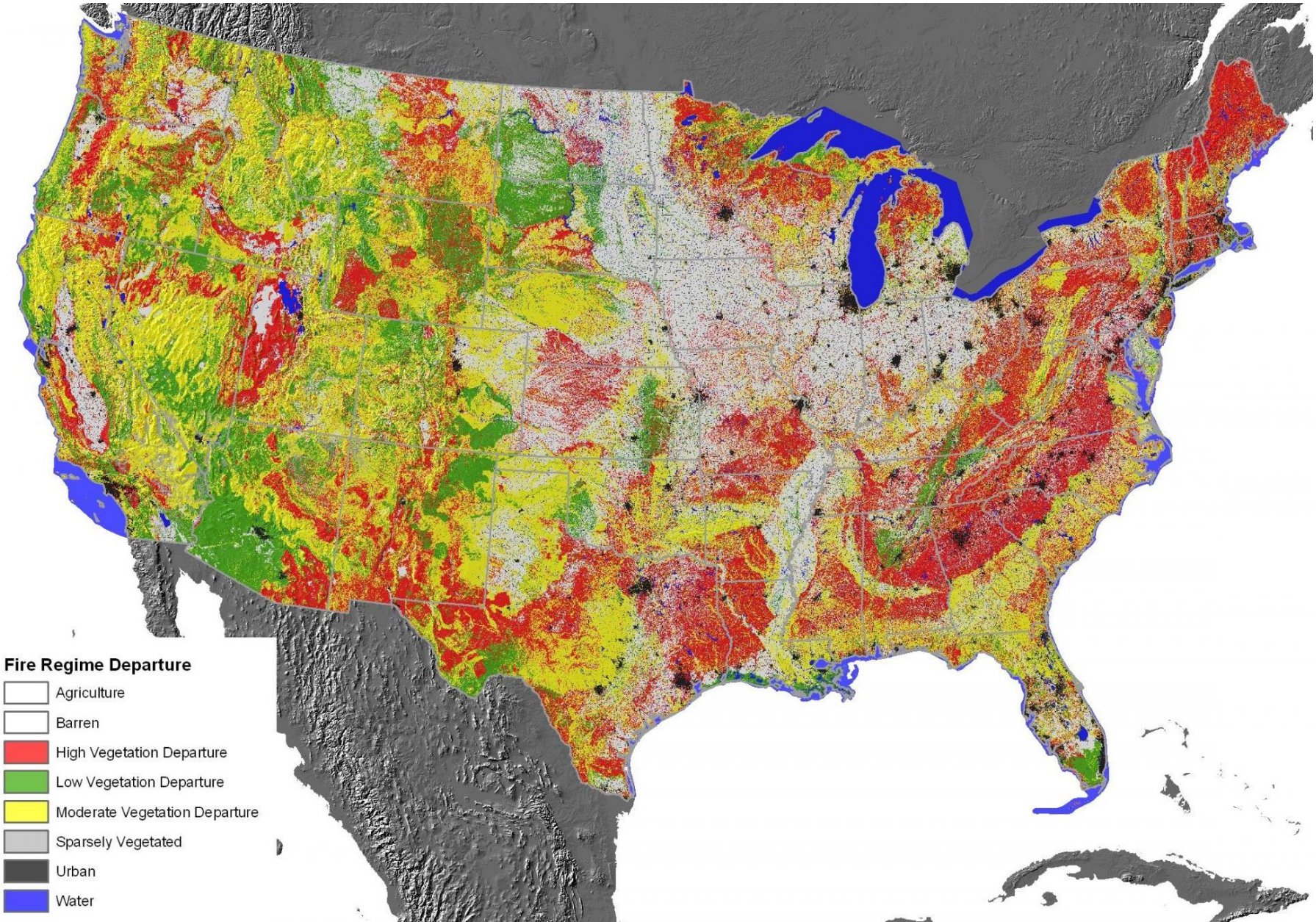




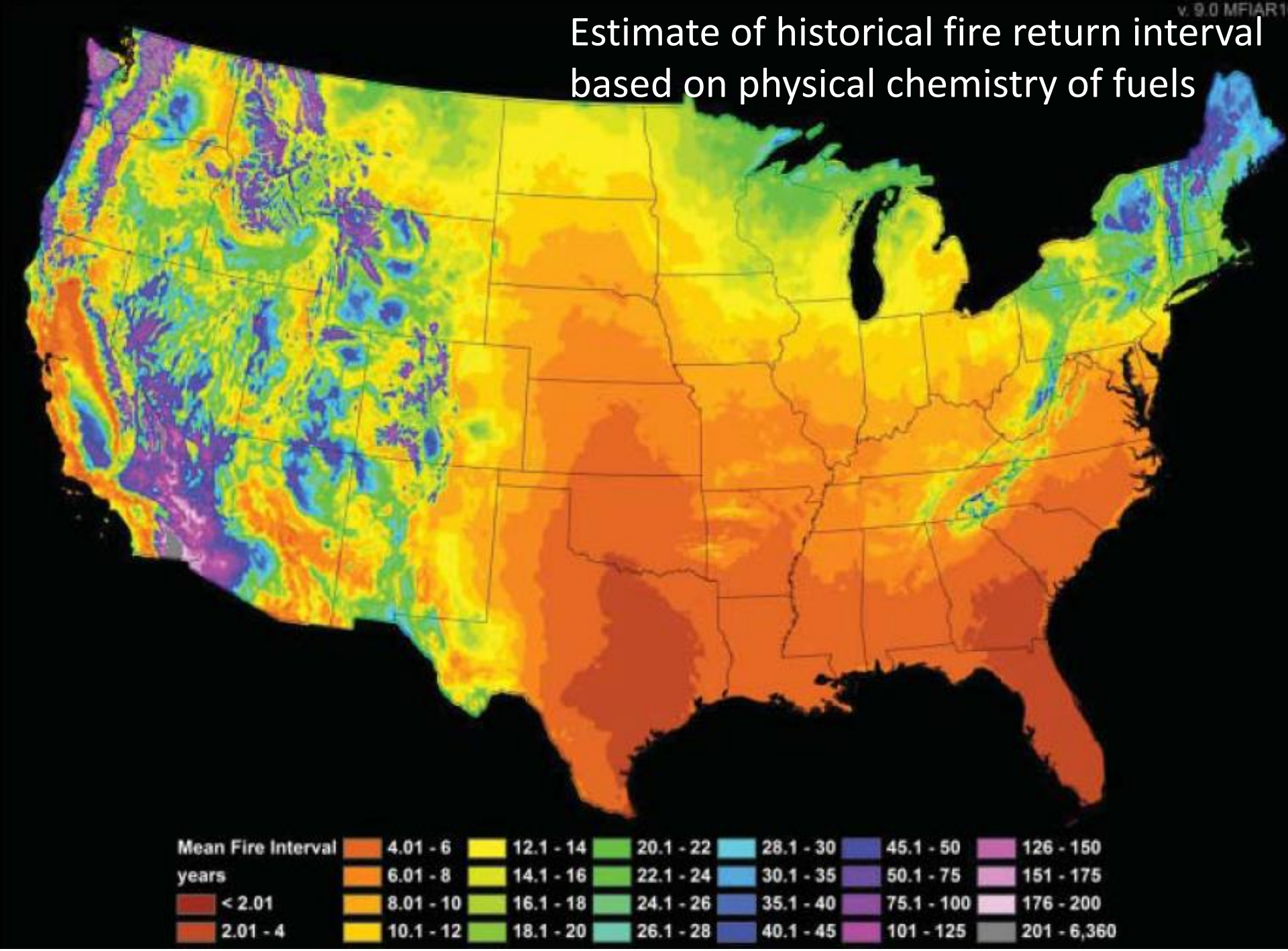
Only 9 empirical studies have measured fire behavior in tallgrass prairie

Twidwell et al. 2015 *Ecosystems*

Departures from historical fire regimes:
Fire return interval

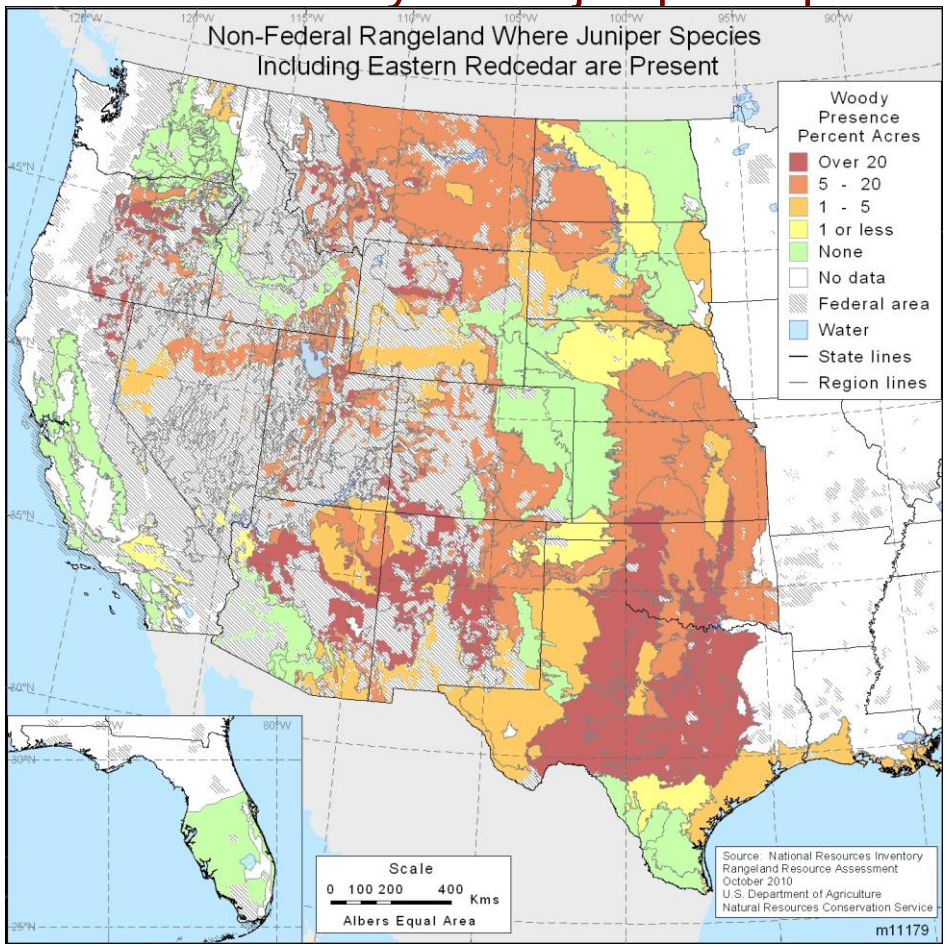


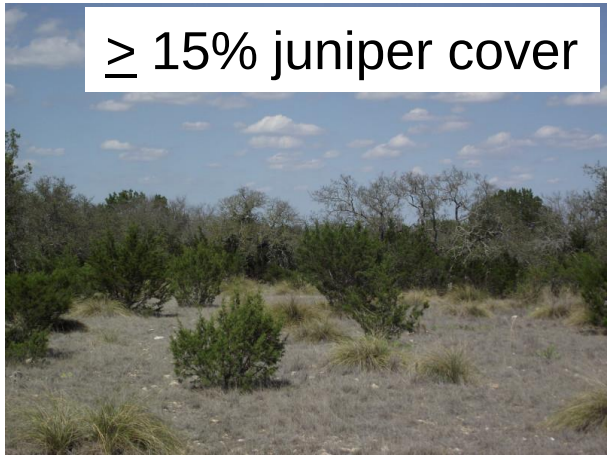
Estimate of historical fire return interval based on physical chemistry of fuels



Juniper invasion is moving north, transforming the Great Plains due to human changes in fire

Everywhere juniper is present



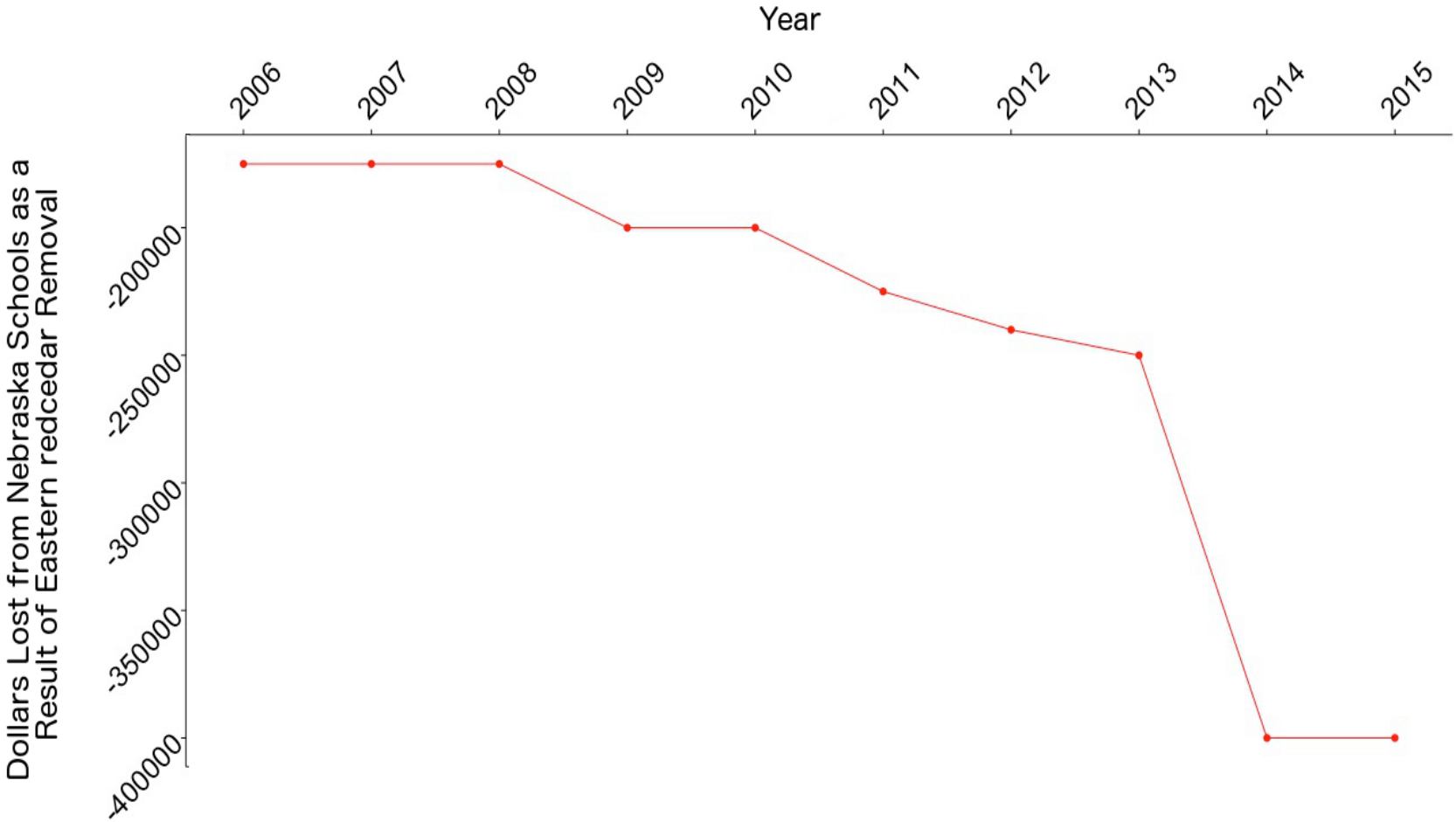


Maps from USDA NRCS NRI

Pictures from D Twidwell and NE LCRA

Simplifying fire regimes leads to ‘surprise’ that is often undesirable

Decline in $ available for NE schools due to ERC invasions

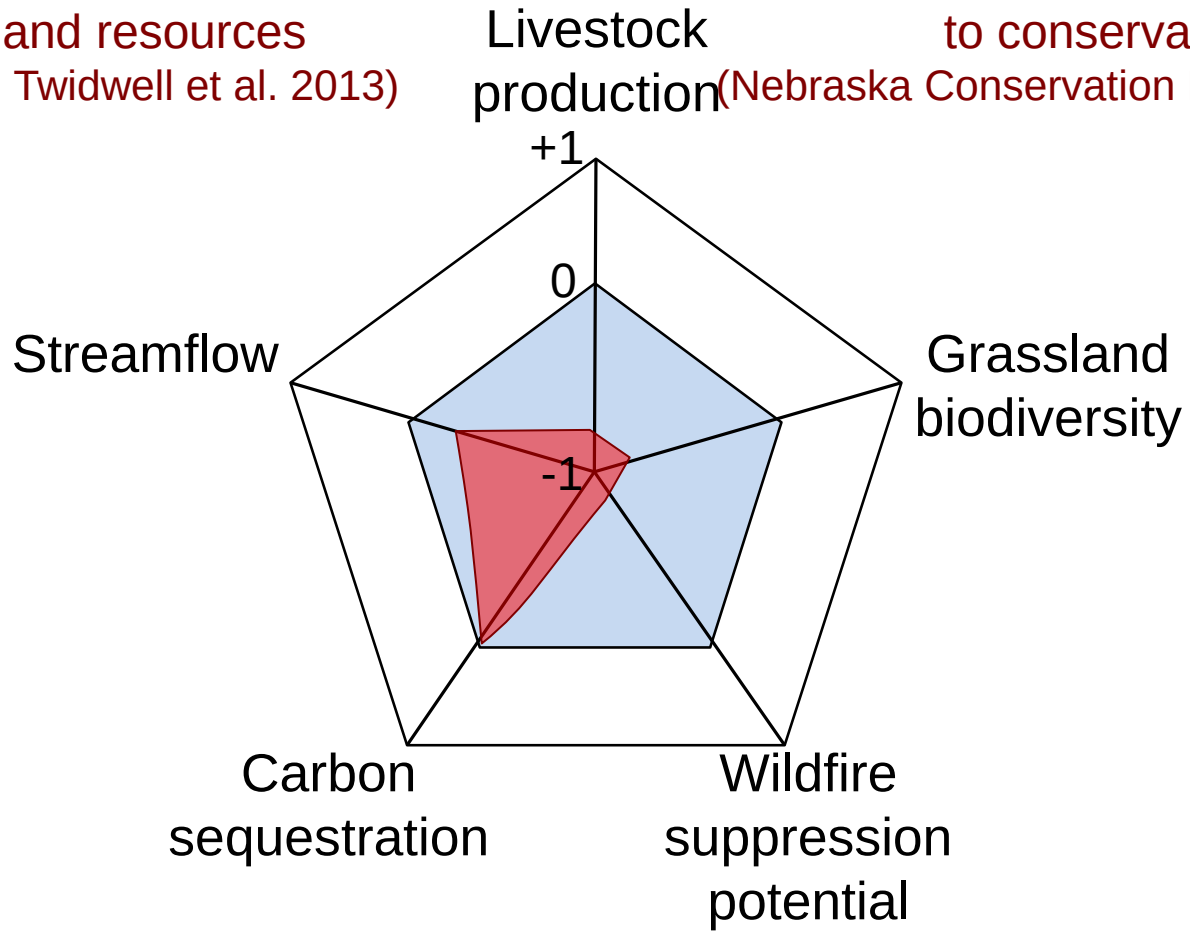


Student team project in Ecosystem Monitoring and Assessment 444/844

Ecosystem service assessment following rangeland to juniper woodland state change

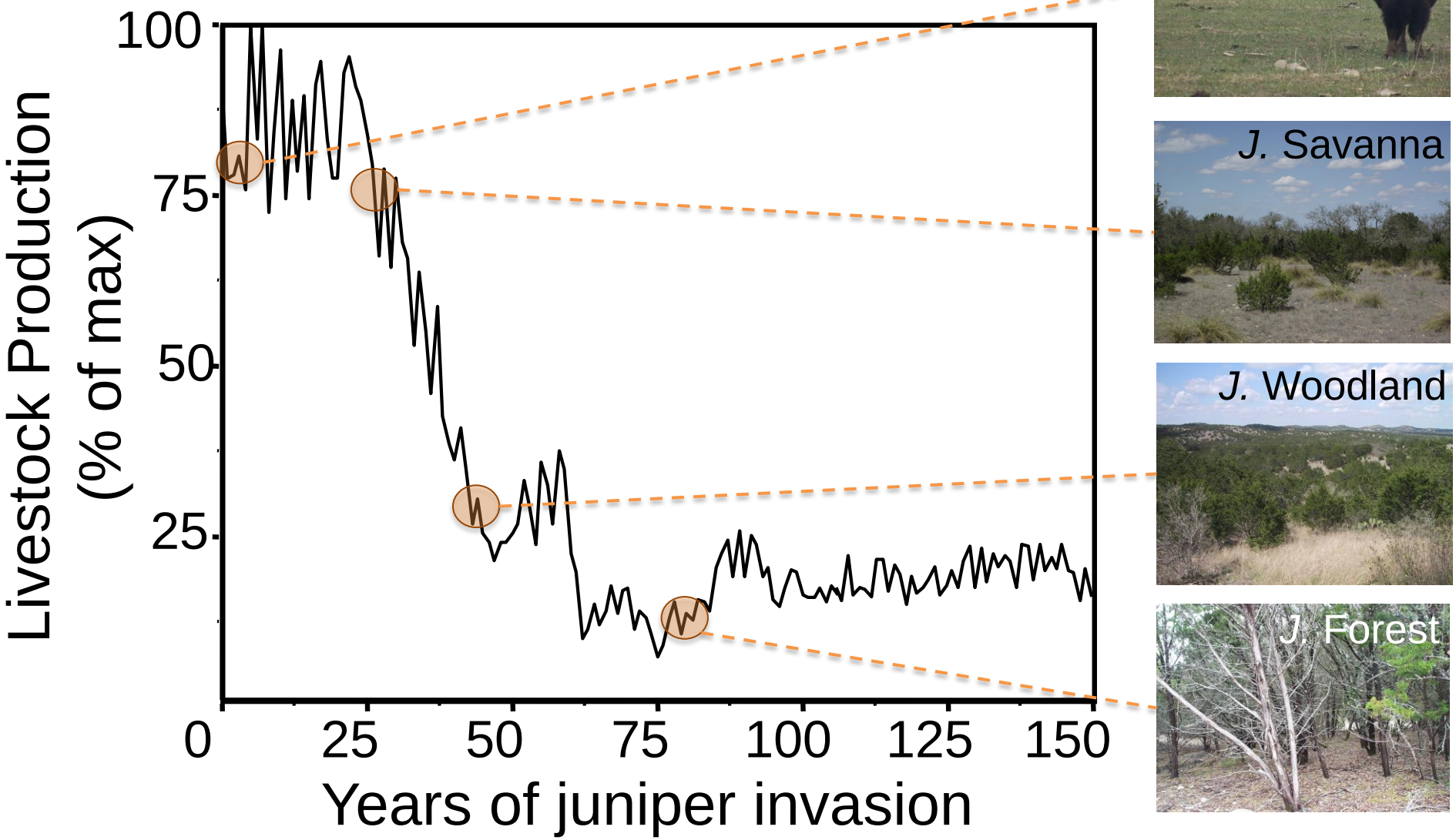
Juniper invasions: one of the greatest threats to rangeland resources
(Engle et al. 2008; Twidwell et al. 2013)

Juniper invasions: the greatest threat to conservation in Nebraska
(Nebraska Conservation Roundtable, 2014)



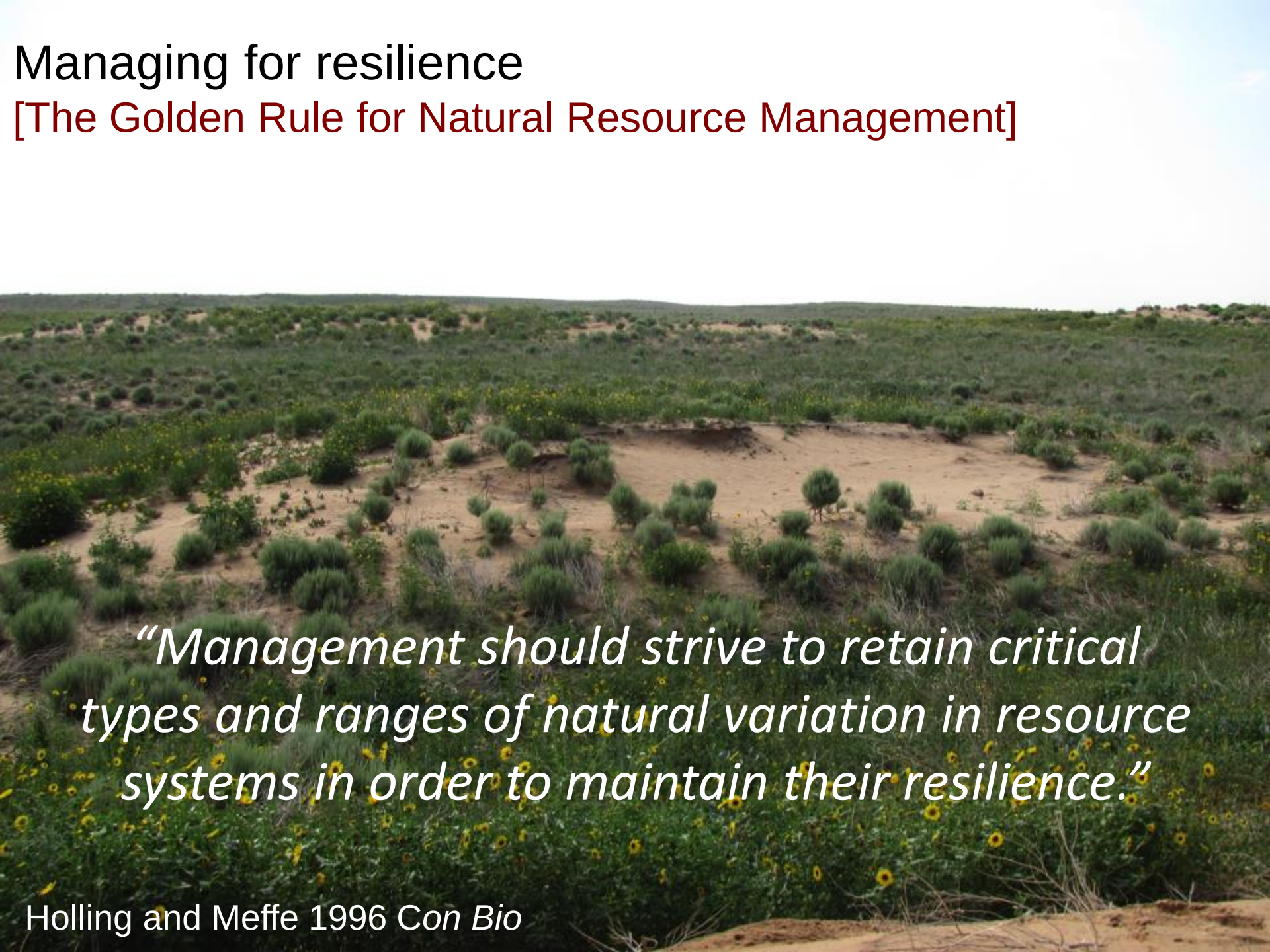
based on review by Twidwell et al. 2013
Frontiers in Ecology and the Environ.

Livestock productivity declines due to juniper conversion of grasslands: the result of managing for yield – and not for resilience



Managing for resilience

[The Golden Rule for Natural Resource Management]



"Management should strive to retain critical types and ranges of natural variation in resource systems in order to maintain their resilience."

Holling and Meffe 1996 C*on Bio*

Implementing new studies across the Great Plains that consider critical ROV in fire regimes

Extreme fire experiments

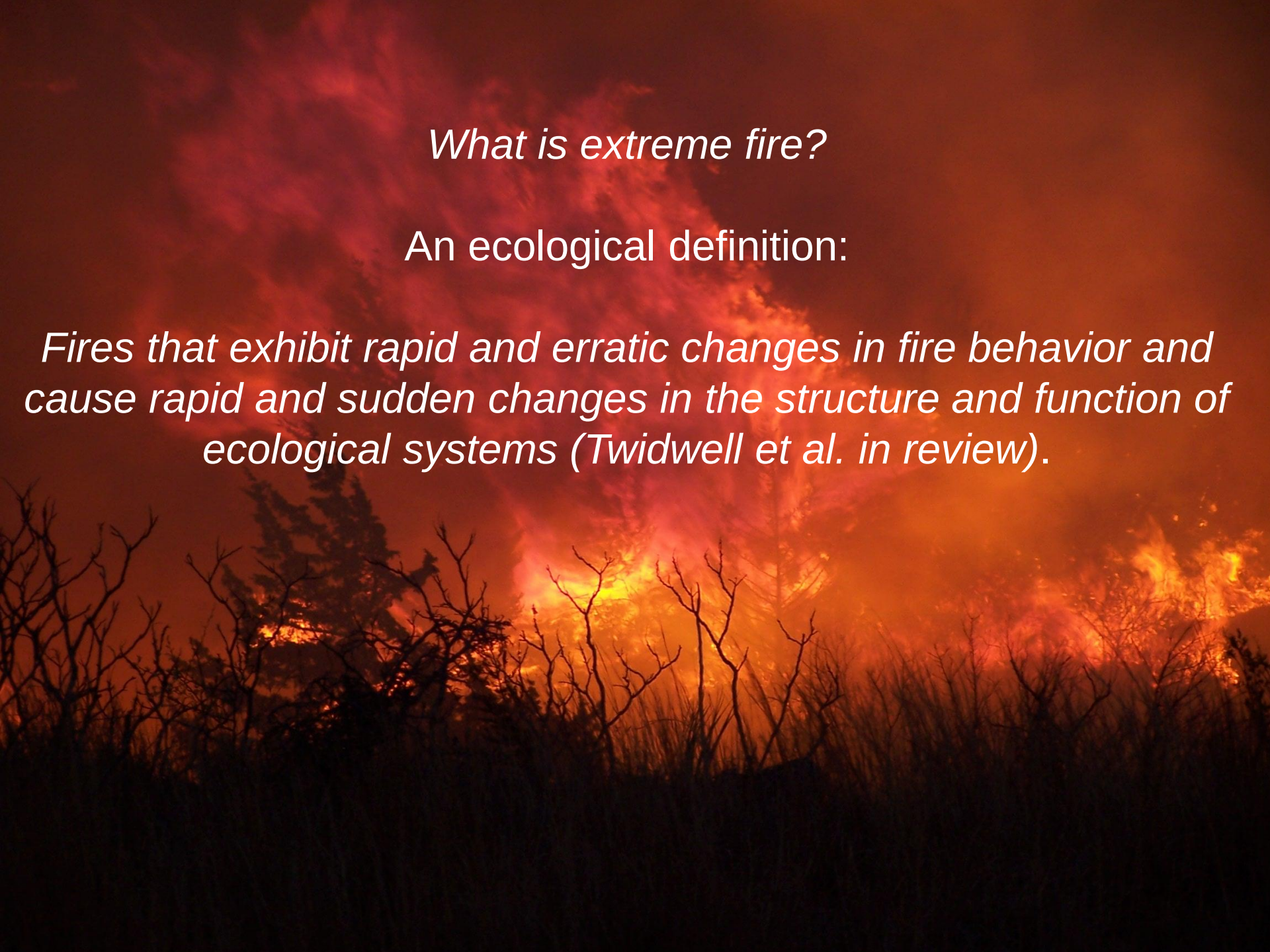
What is extreme fire?

Has been used commonly in the U.S. wildland fire community since the 1950s (Potter and Werth 2011)

Describes atypical behavior in high intensity fires that lead to blow-ups, fire storms, fire whirls and other forms of erratic fire behavior (Byram 1954).

“Fire spread other than steady surface spread, especially when it involves rapid increases” (Werth et al. 2011)

“‘Extreme’ implies fire behavior characteristics that ordinarily preclude direct control actions” (NWCG 2012)



What is extreme fire?

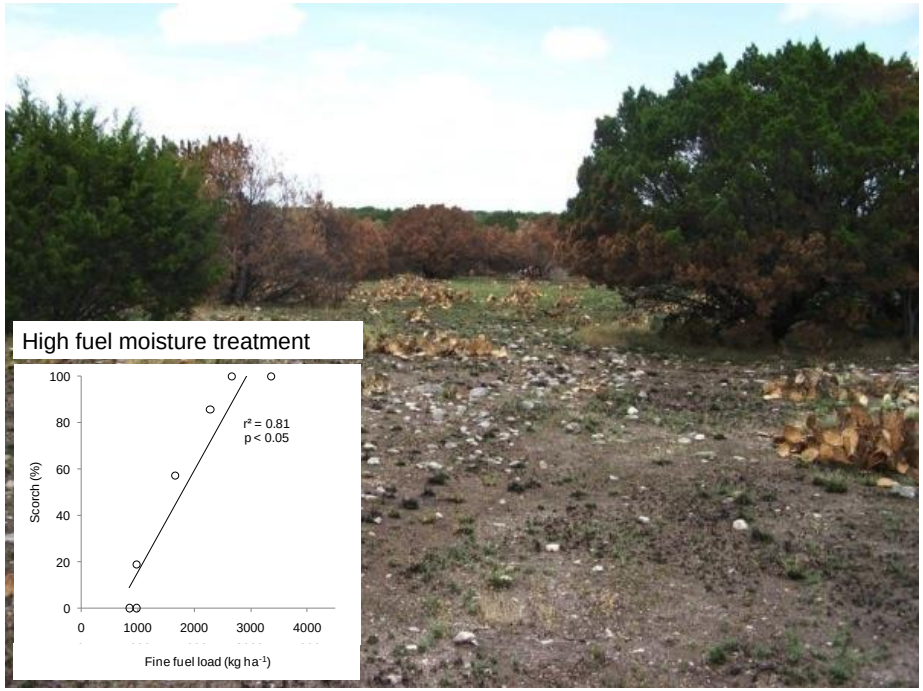
An ecological definition:

Fires that exhibit rapid and erratic changes in fire behavior and cause rapid and sudden changes in the structure and function of ecological systems (Twidwell et al. in review).

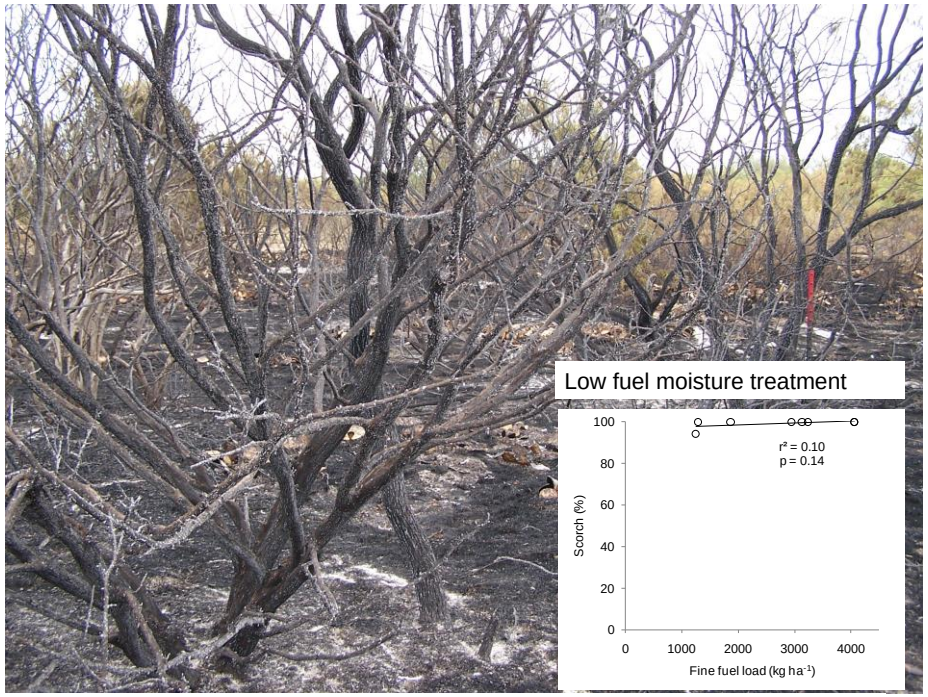
Juniperus Extreme Fire Experiment I

High vs. Low FFM conditions in the growing season

Typical prescribed fire prescriptions do not overcome the resilience of juniper woodland to fire



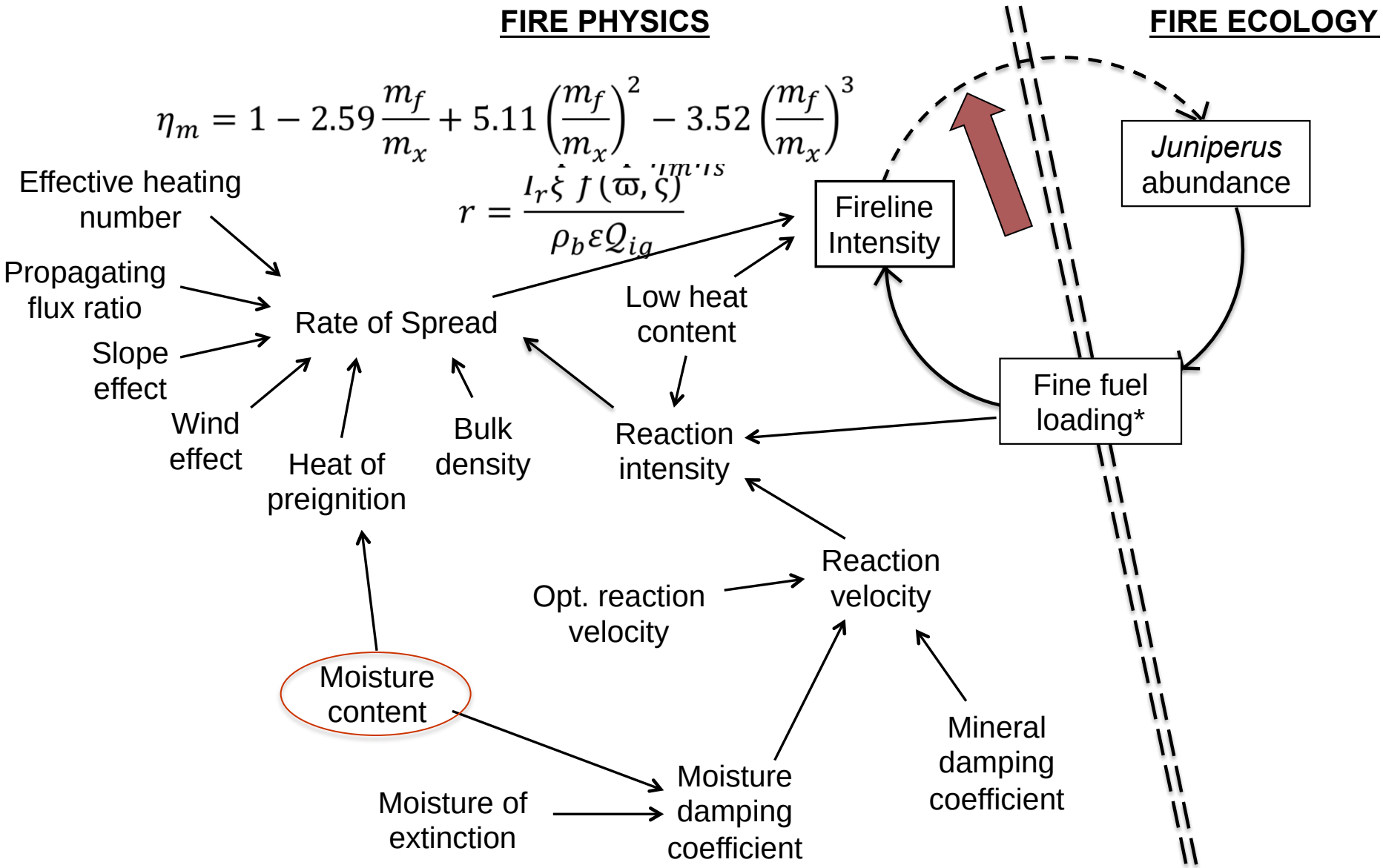
30% mortality of mature juniper when FFM = 21%



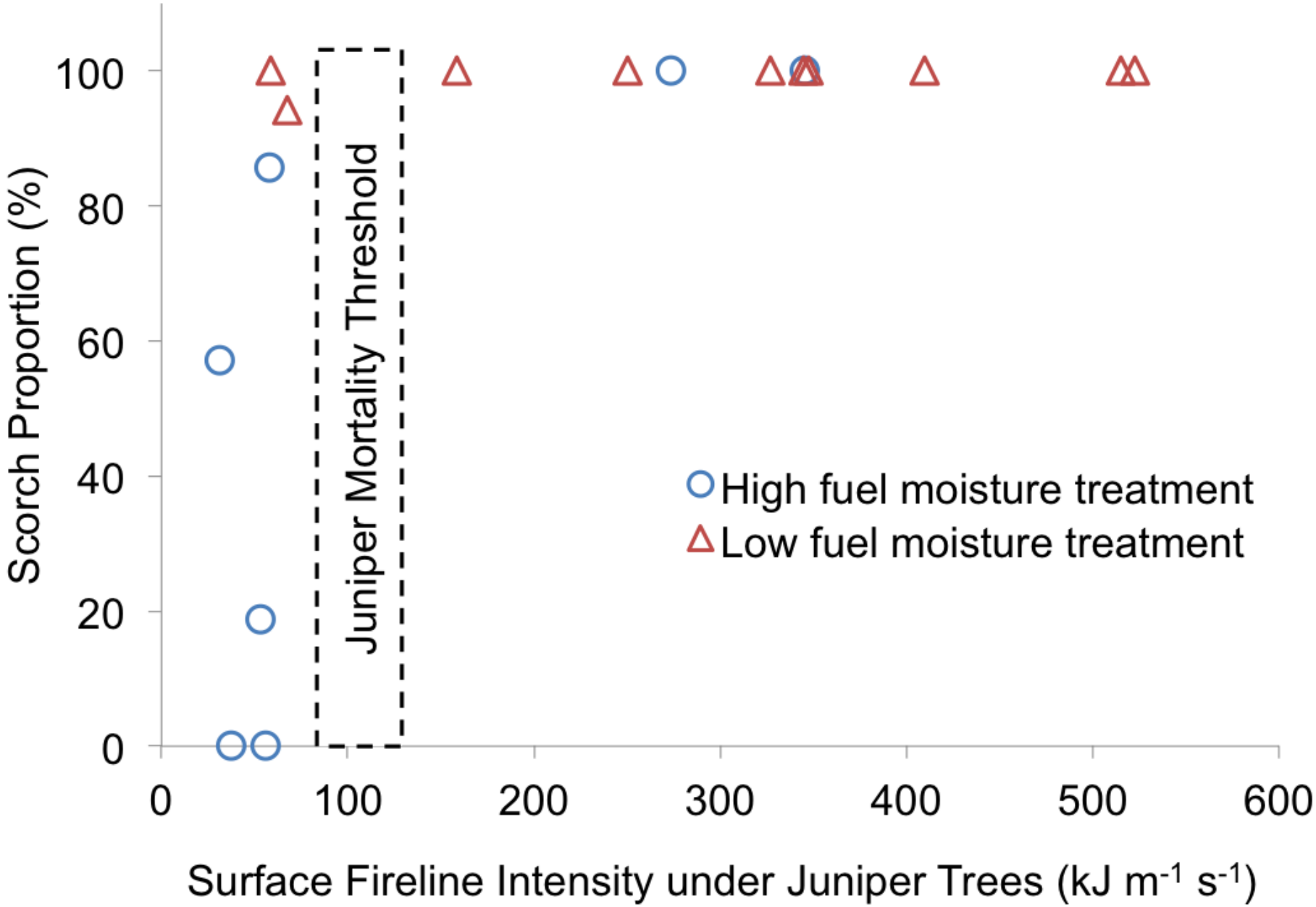
100% mortality of mature juniper when FFM = 4%

Twidwell et al. 2009 *REM*; Twidwell et al. 2013 *J App Eco*

Toward applying biophysical fire models in management



Twidwell et al. 2013 *J Applied Ecology*

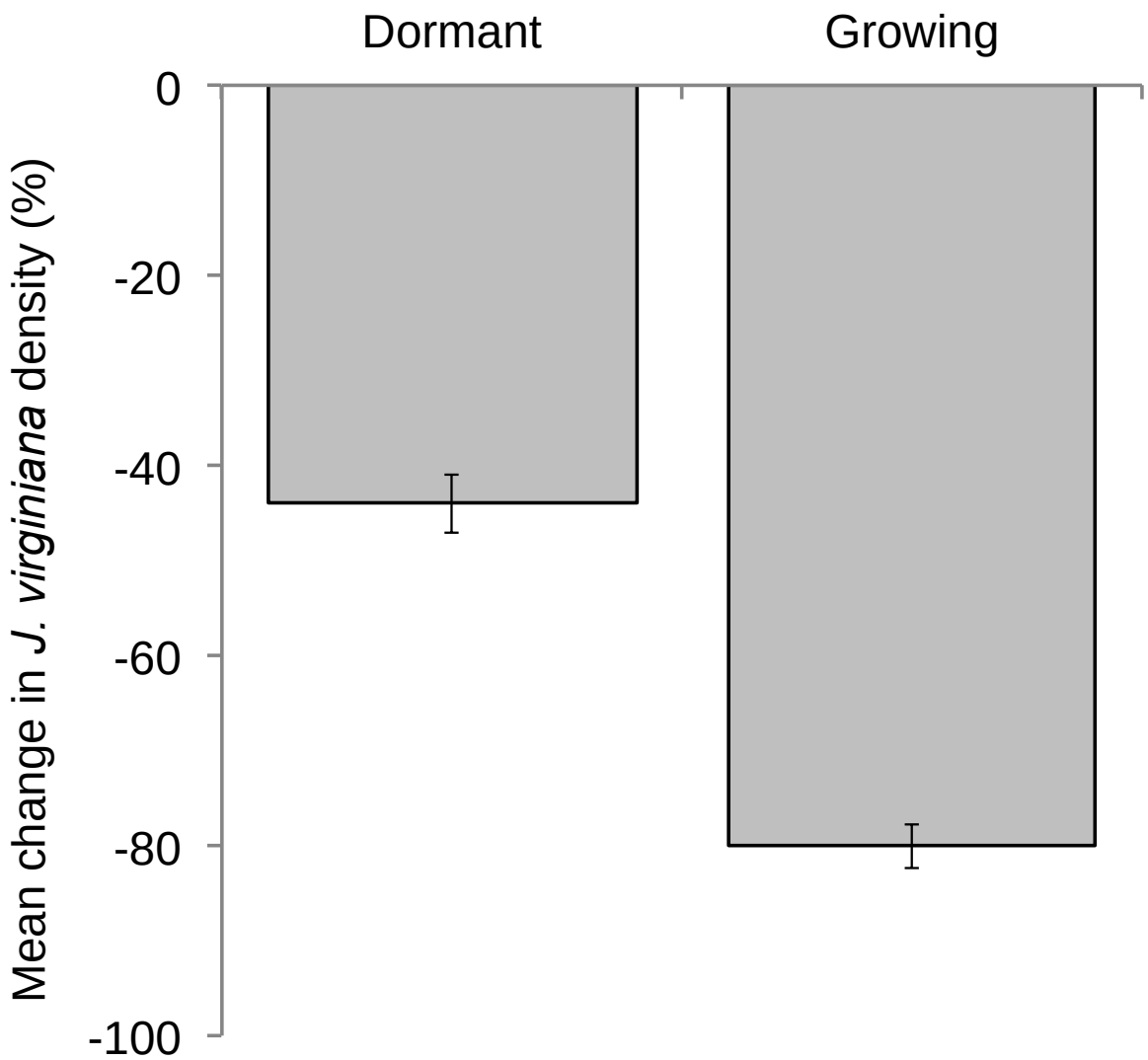


Twidwell et al. 2013 *J Applied Ecology*

Extreme Fire Experiment II

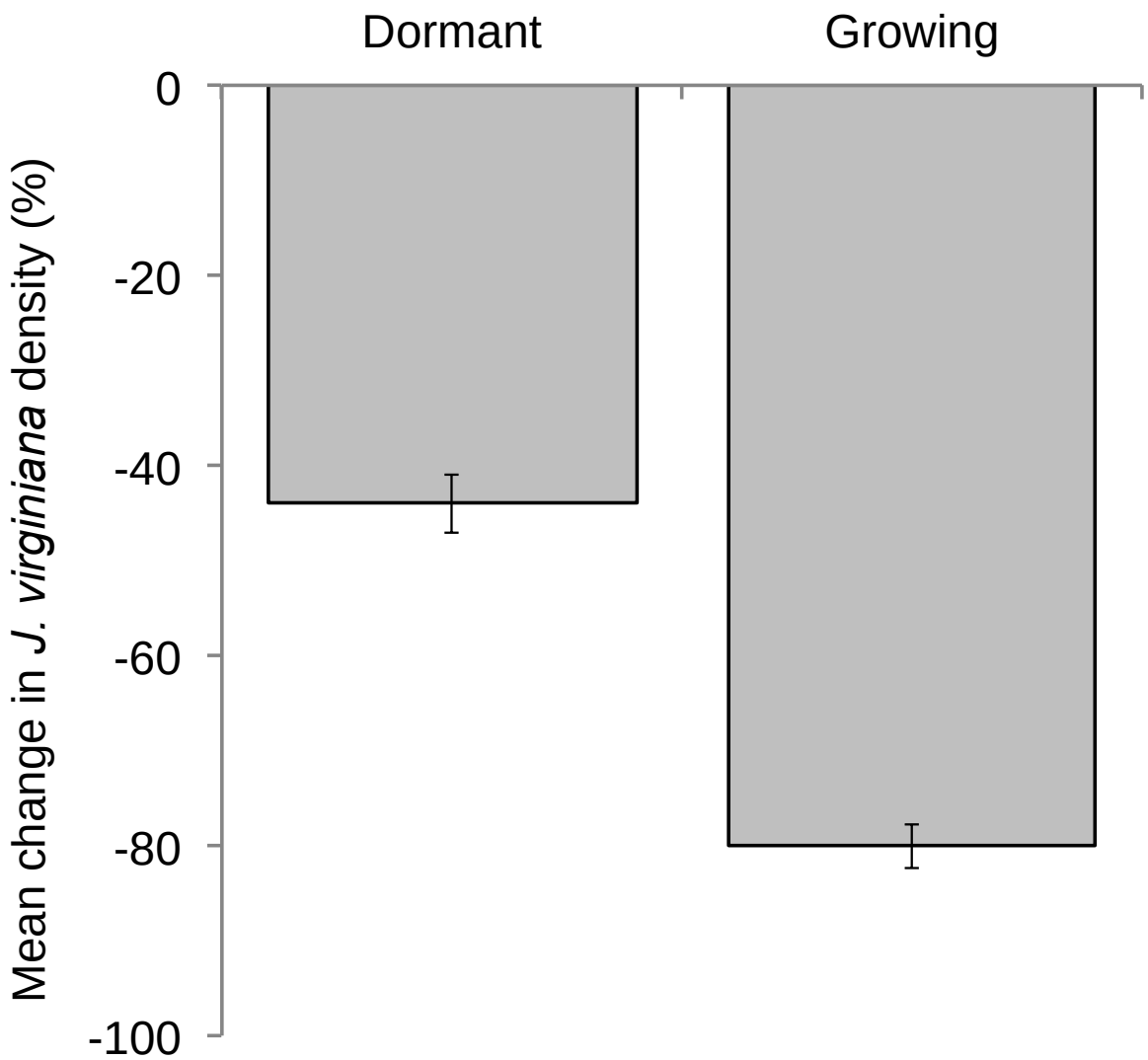
Growing vs. Dormant Season Experiment while targeting equivalent fire intensities

Resilience of *J. virginiana* to fire is lower in the growing season



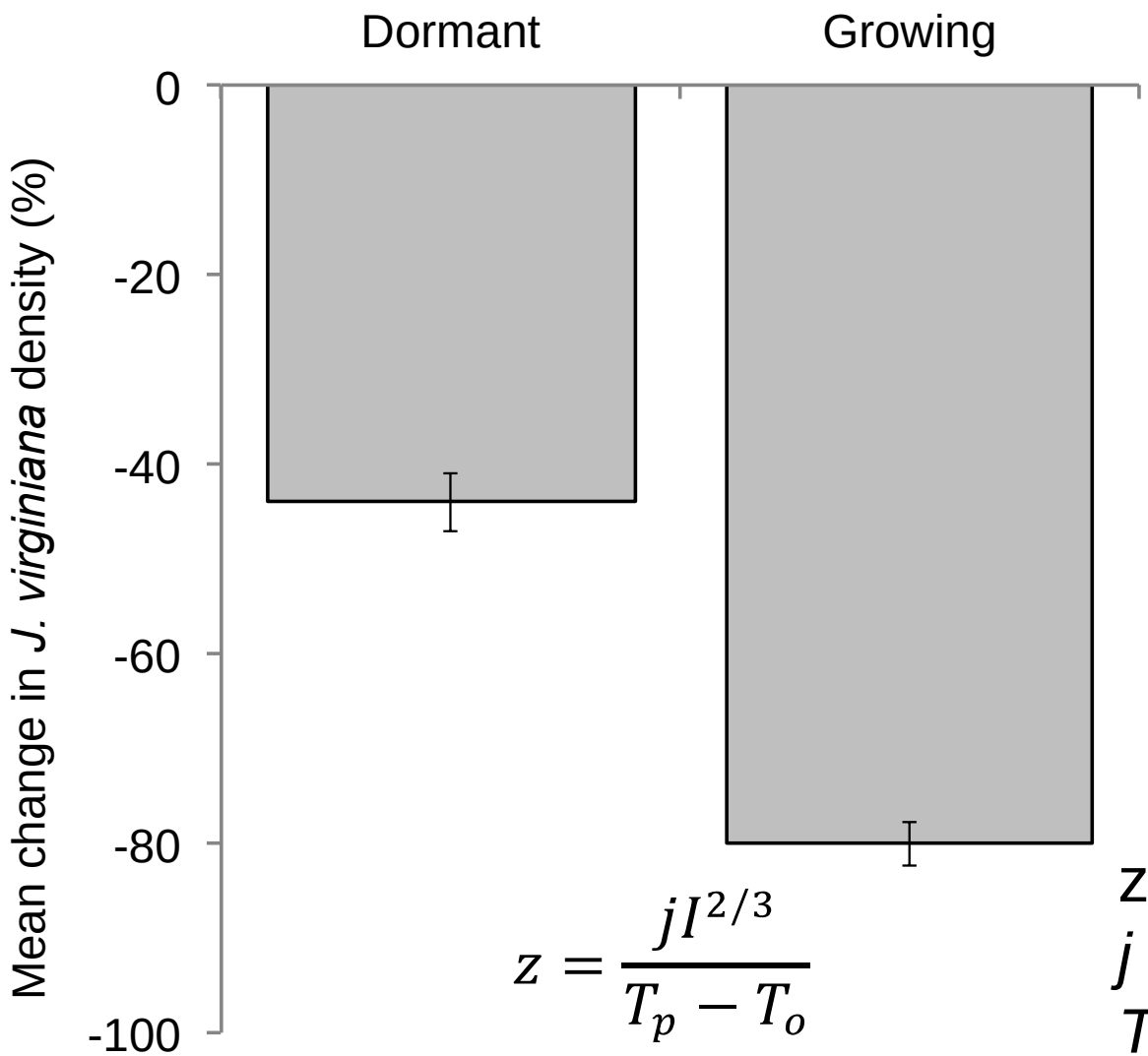
Twidwell et al. *in prep.*

~~Resilience of *J. virginiana* to fire is lower in the growing season~~



Twidwell et al. *in prep.*

~~Resilience of *J. virginiana* to fire is lower in the growing season~~



$$z = \frac{jI^{2/3}}{T_p - T_o}$$

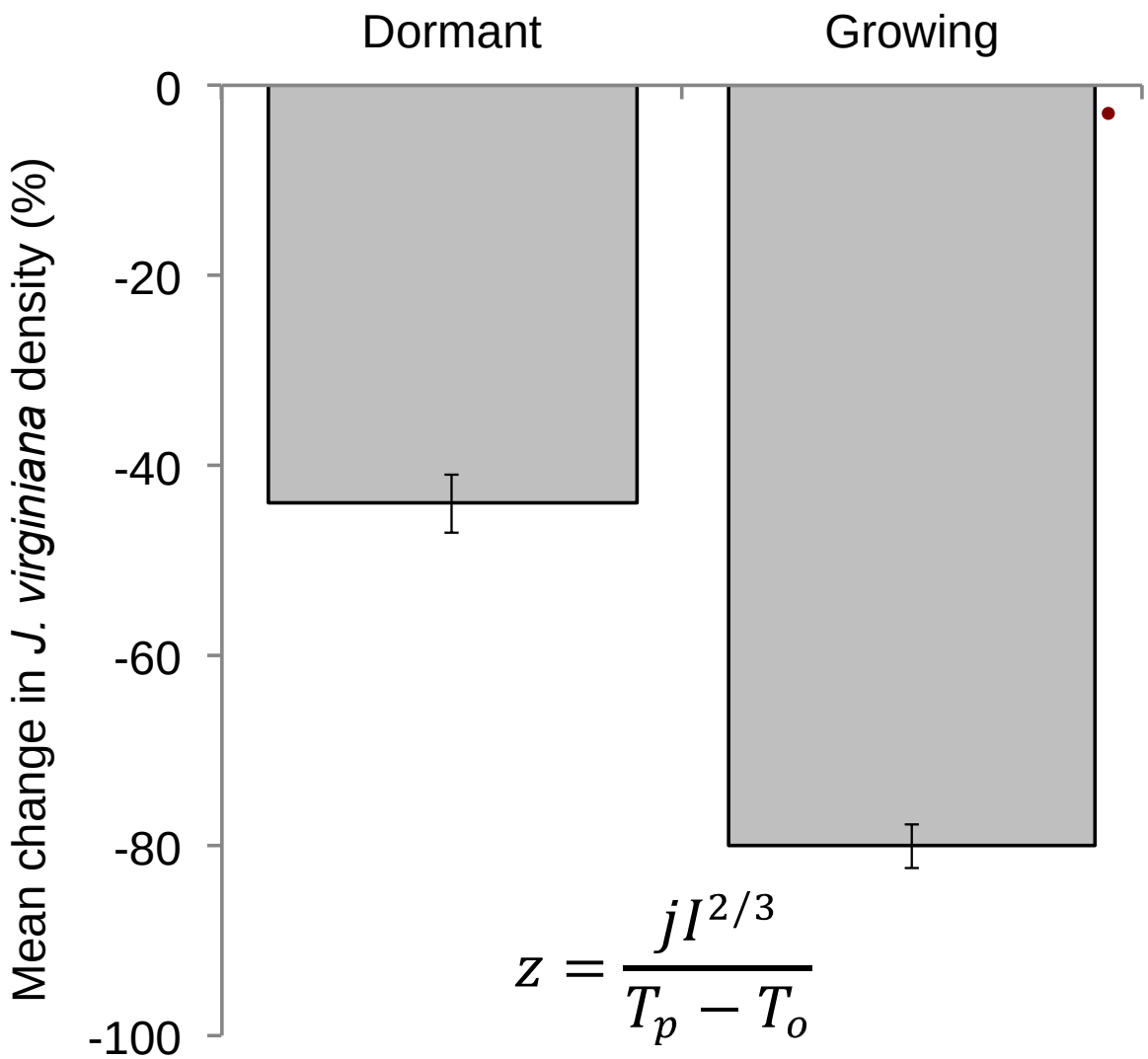
Surface fireline intensities were similar between growing and dormant season treatments.

Temperature was 22° C higher in the growing season fire treatment

z = crown scorch height
j = 4.4713 (constant)
T_p = lethal temp foliage
T_o = ambient air temp

Twidwell et al. *in prep.*

~~Resilience of *J. virginiana* to fire is lower in the growing season~~

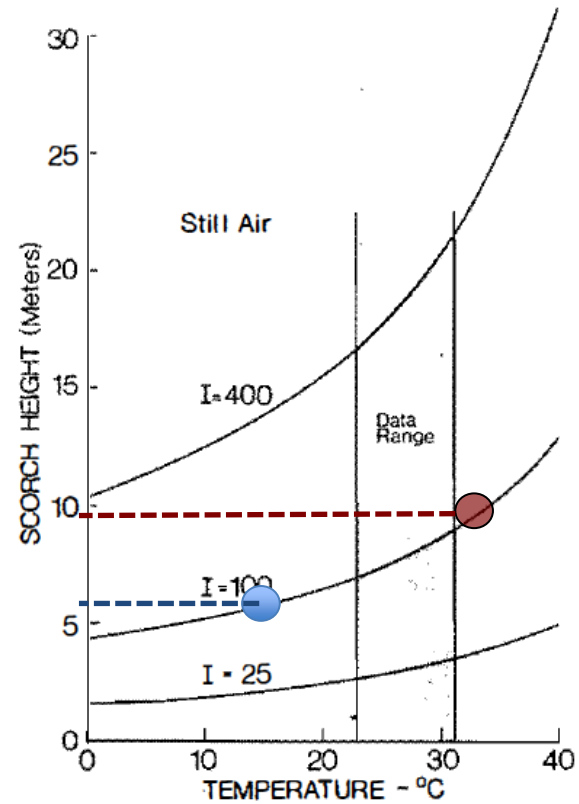


$$z = \frac{jI^{2/3}}{T_p - T_o}$$

Twidwell et al. *in prep.*

To exceed mortality thresholds:

- Lower air temperatures require higher intensity fires
- Higher air temperatures require less intensity



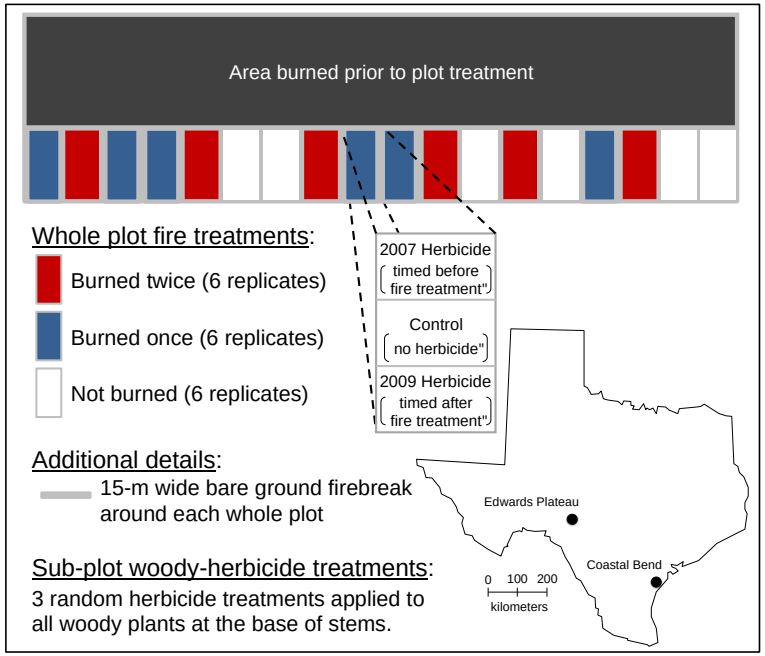
Van Wagner 1973
Can J For Res

Extreme Fire Experiment III

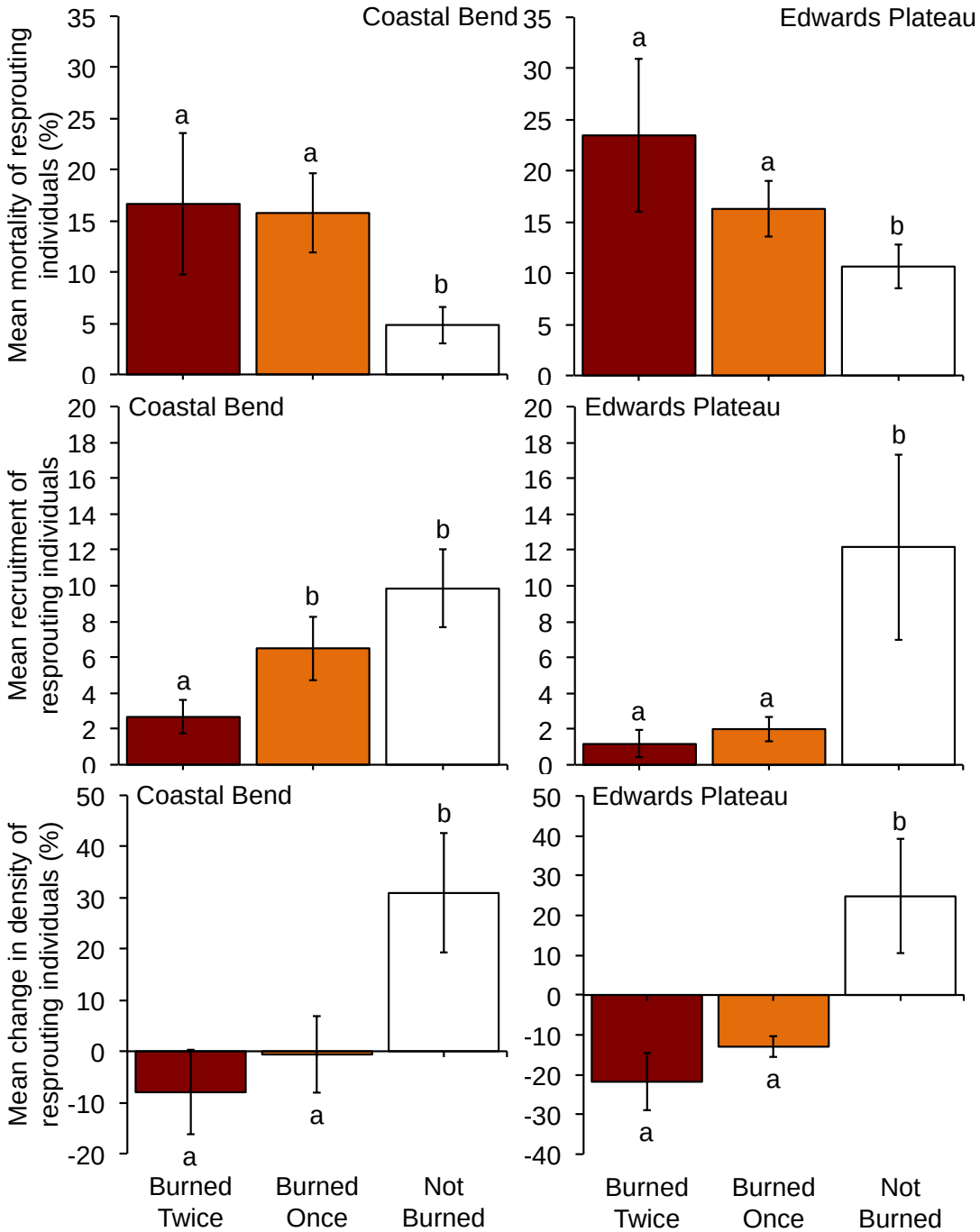
Resprouting shrublands

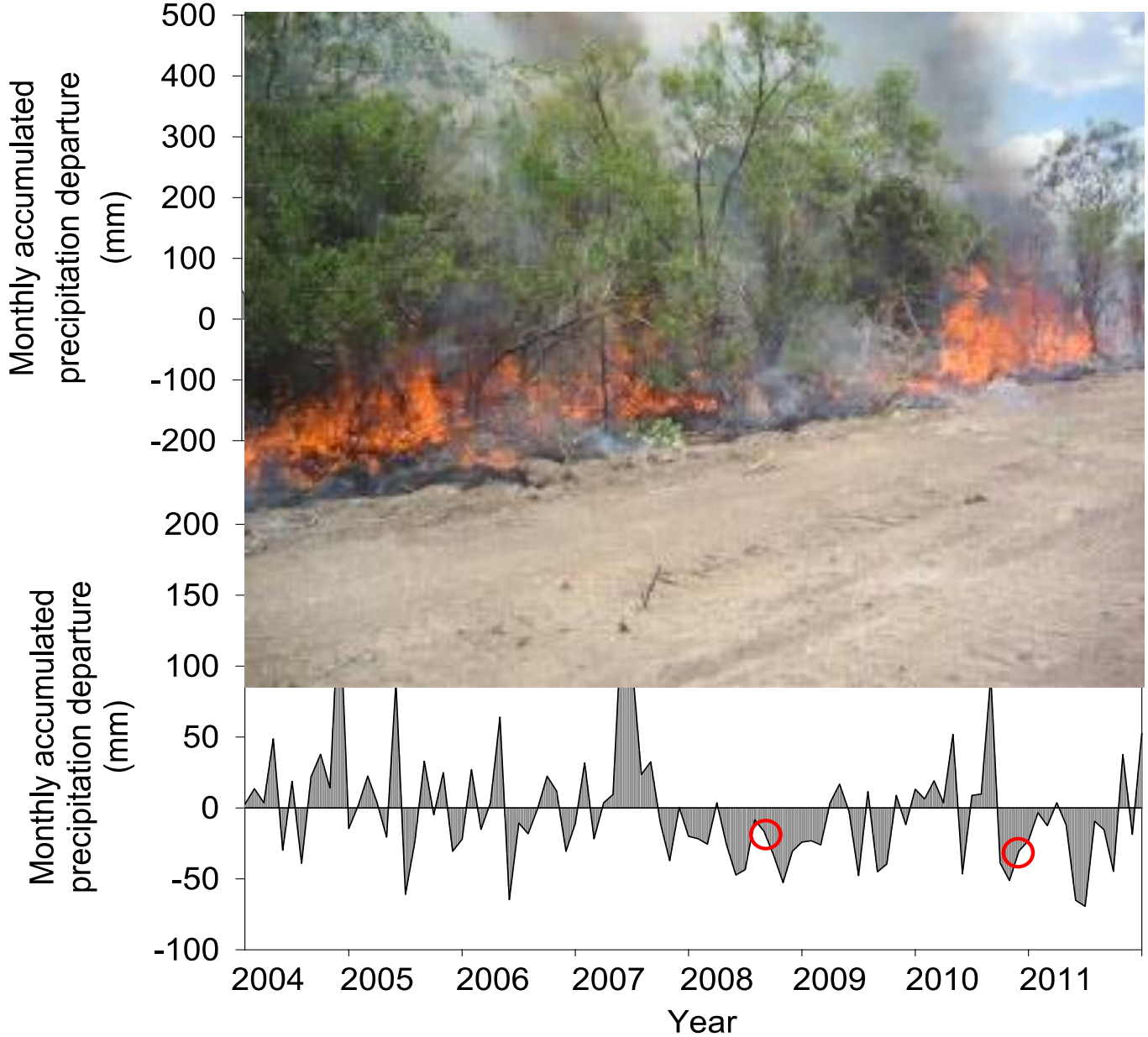
High intensity fires during severe droughts killed significant levels of mature resprouting woody species

(Twidwell et al. *in review*)

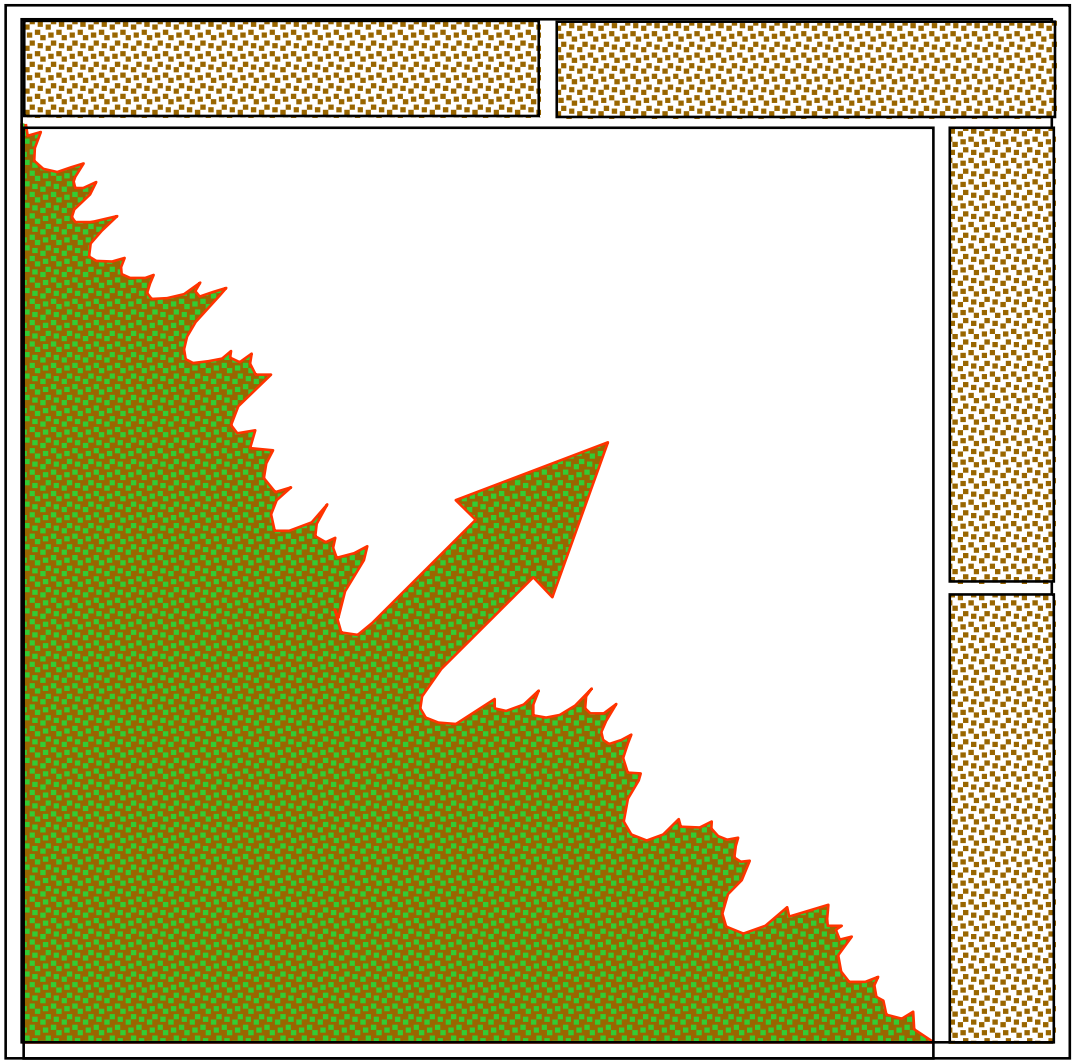


Adapted from Twidwell et al. 2012




Monthly accumulated precipitation departure (mm)
500
400
300
200
100
0
-100
-200
Monthly accumulated precipitation departure (mm)
200
150
100
50
0
-50
-100
2004
2005
2006
2007
2008
2009
2010
2011
Year

Applying ember transport models to improve landscape fire designs



Rules-of-Thumbs
in Rangelands

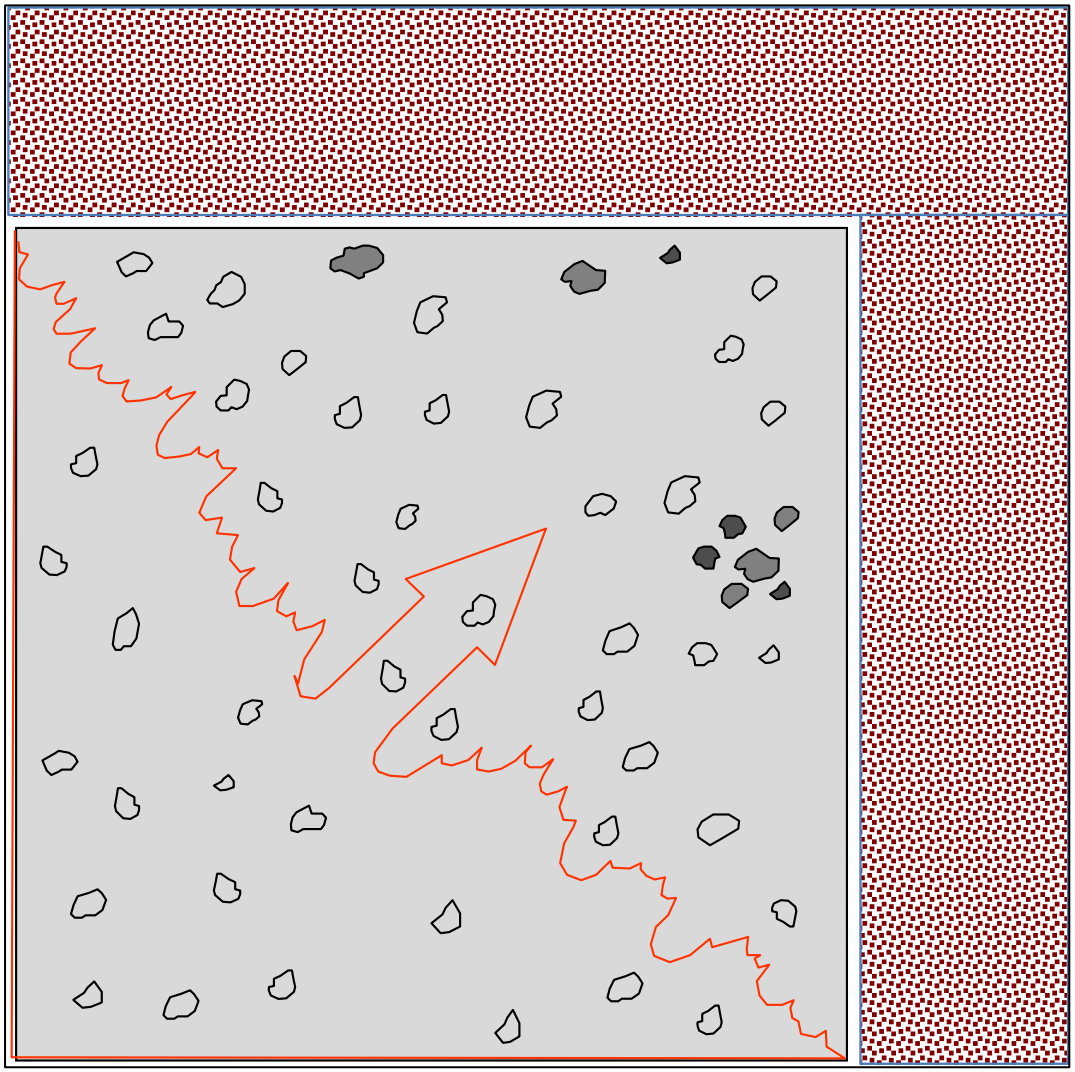
Spot-fire distance in
non-volatile,
rangeland fuels

100 ft. perimeter buffer

Use when winds are
less than 20 mph
(but recommend not
exceeding 15 mph)

- Wright 1974

Applying ember transport models to improve landscape fire designs



Rules-of-Thumbs
in Rangelands

Spot-fire distance in
volatile,
rangeland fuels

400 ft. perimeter buffer

Use when winds are
less than 20 mph
(but recommend not
exceeding 15 mph)

- Wright 1974

Rules-of-Thumbs in Rangelands Oversimplify Physical Models of Spot-Fire Transport and Occurrence

The maximum distance between a source of firebrands (e.g., a burning tree) and a potential spot fire is dependent on 6 phenomena.

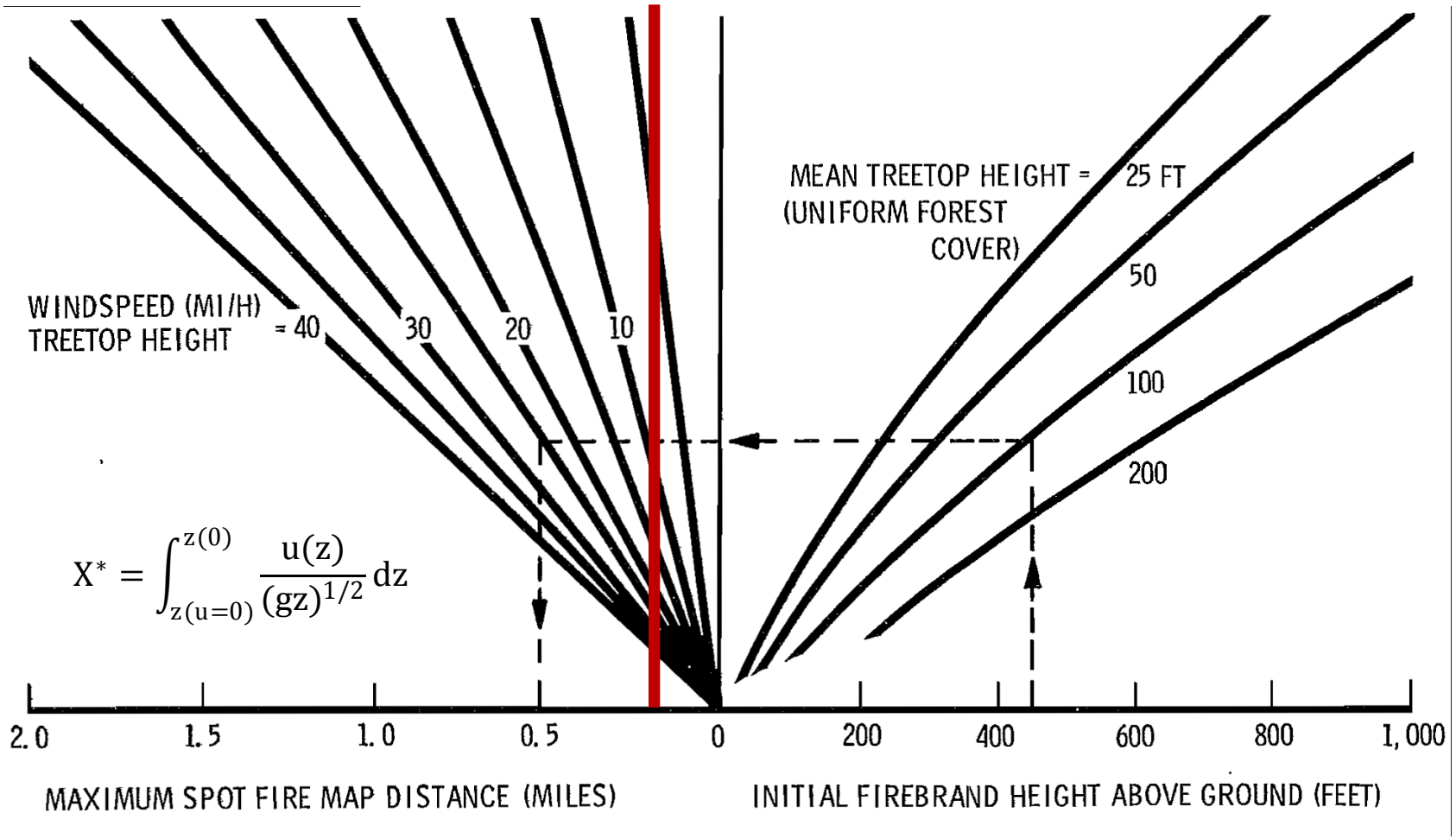
1. The structure of the flame that provides the initial lofting of a firebrand particle.
2. The structure of the buoyant plume established by the flame – this determines the height of the airborne particle.
3. The rate at which the firebrand particle burns as it moves through the atmosphere.
4. The trajectory of the firebrand as it moves through the flame and plume.
5. The structure of the surface winds over variable terrain.
6. The trajectory of the firebrand as it moves through the surface winds.

$$X^* = \int_{z(u=0)}^{z(0)} \frac{u(z)}{(gz)^{1/2}}\,dz$$

Albini 1979, 1981, & 1983

Applying ember transport models to improve landscape fire designs

Predicting maximum spot fire distance in flat terrain



$$X^* = \int_{z(u=0)}^{z(0)} \frac{u(z)}{(gz)^{1/2}}\,dz$$

Albini 1979

Applying ember transport models to improve landscape fire designs

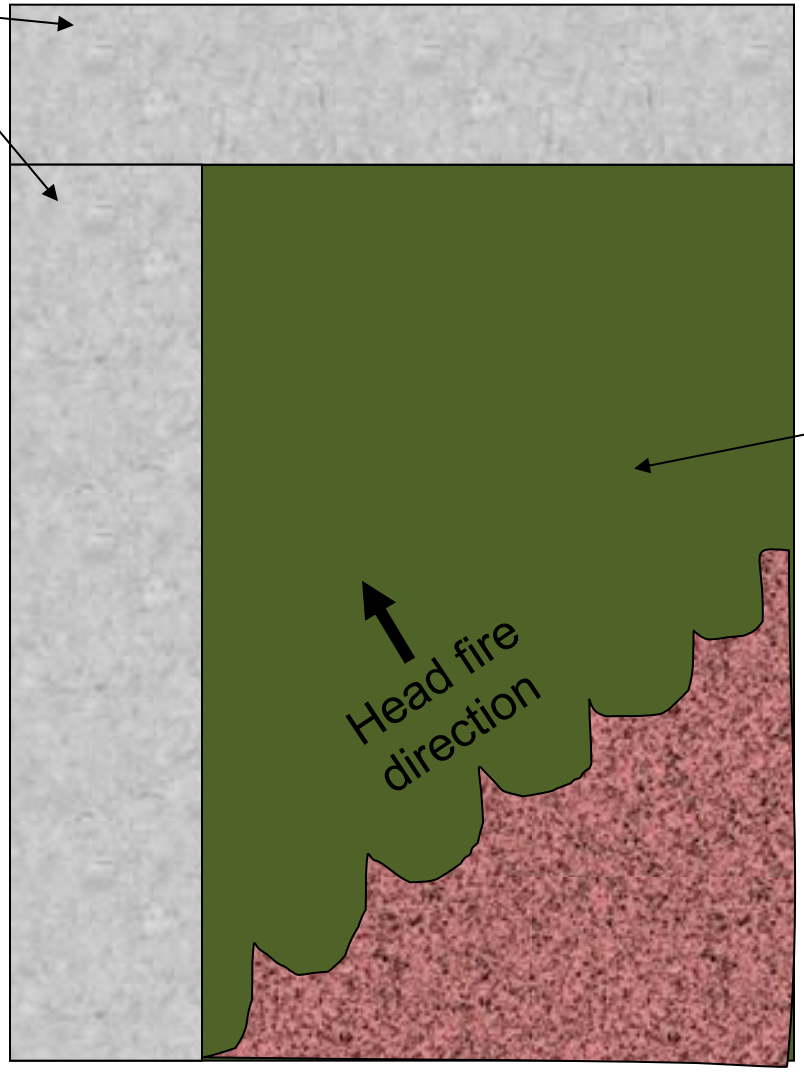
<u>Perimeter buffer</u>:

Burned under moderate conditions.

Livestock are used to maintain low fuel load.

Distance determined by (no slope):

$$X^* = \int_{z(u=0)}^{z(0)} \frac{u(z)}{(gz)^{1/2}} dz$$



Burned in extreme fire conditions to reduce volatile fuels while also meeting restoration objectives

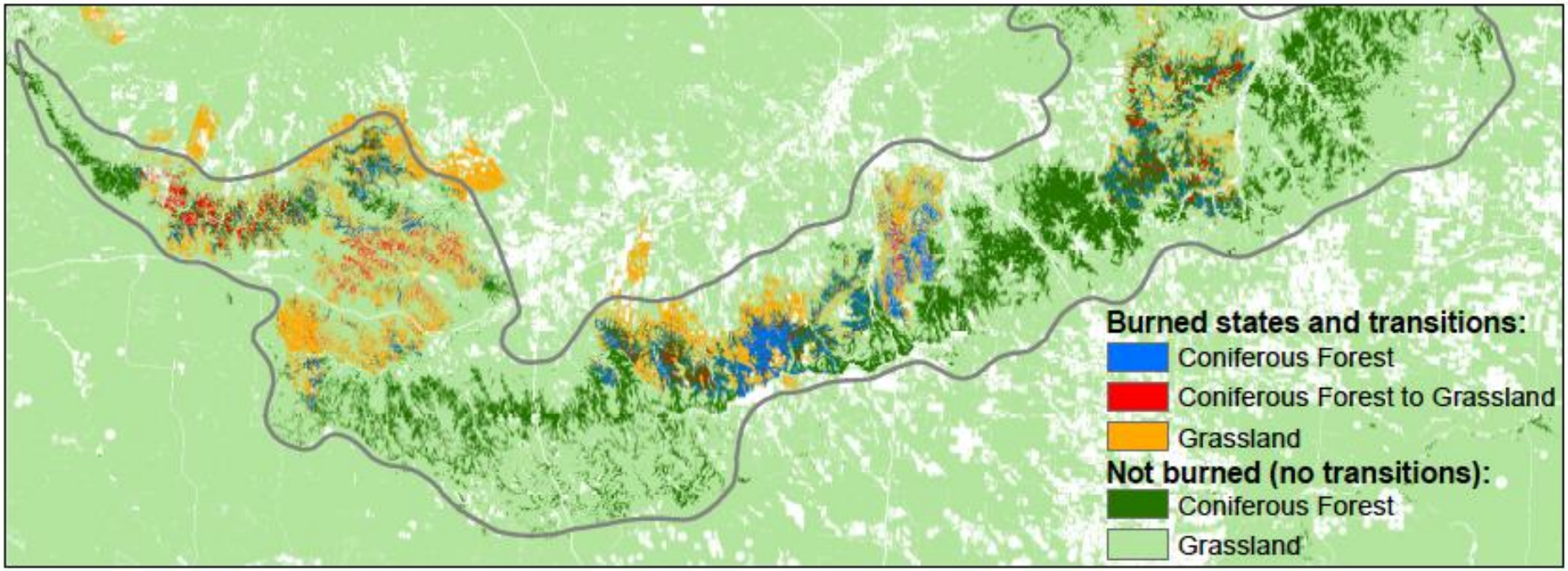
Extreme Fire Experiment IV

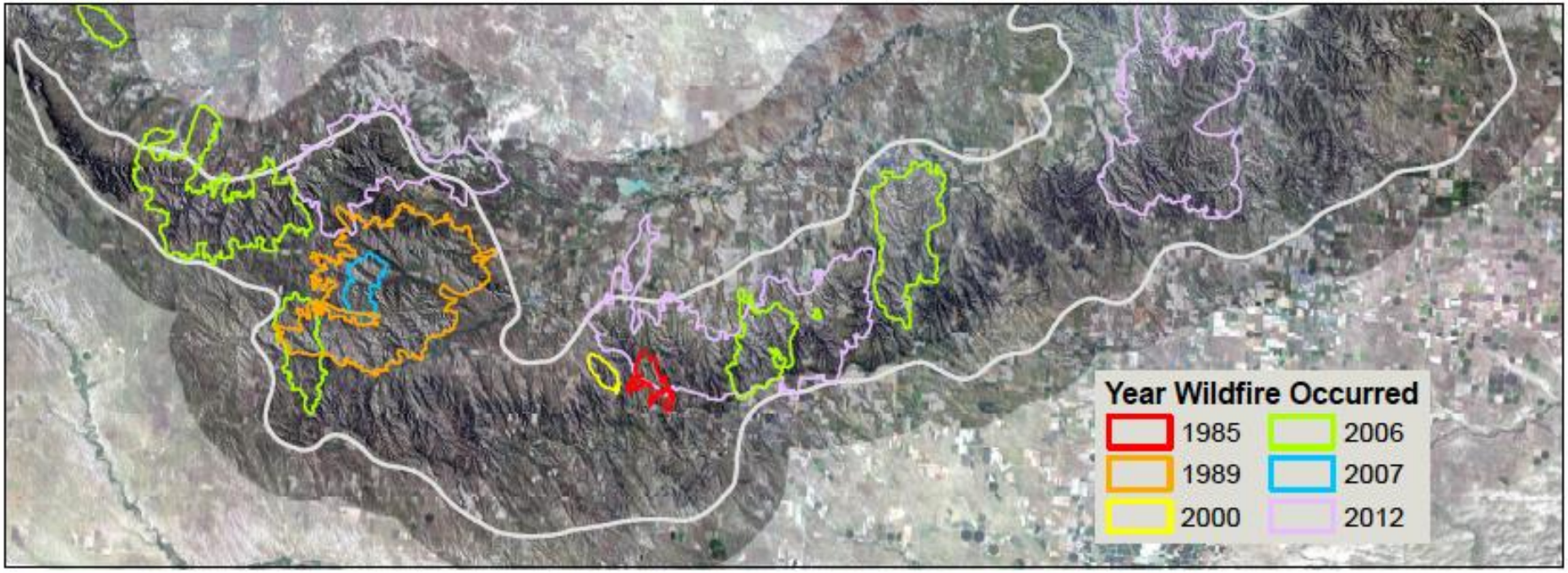
Fire and the spatiotemporal complexity of ecological states in Pine Ridge BUL

1912

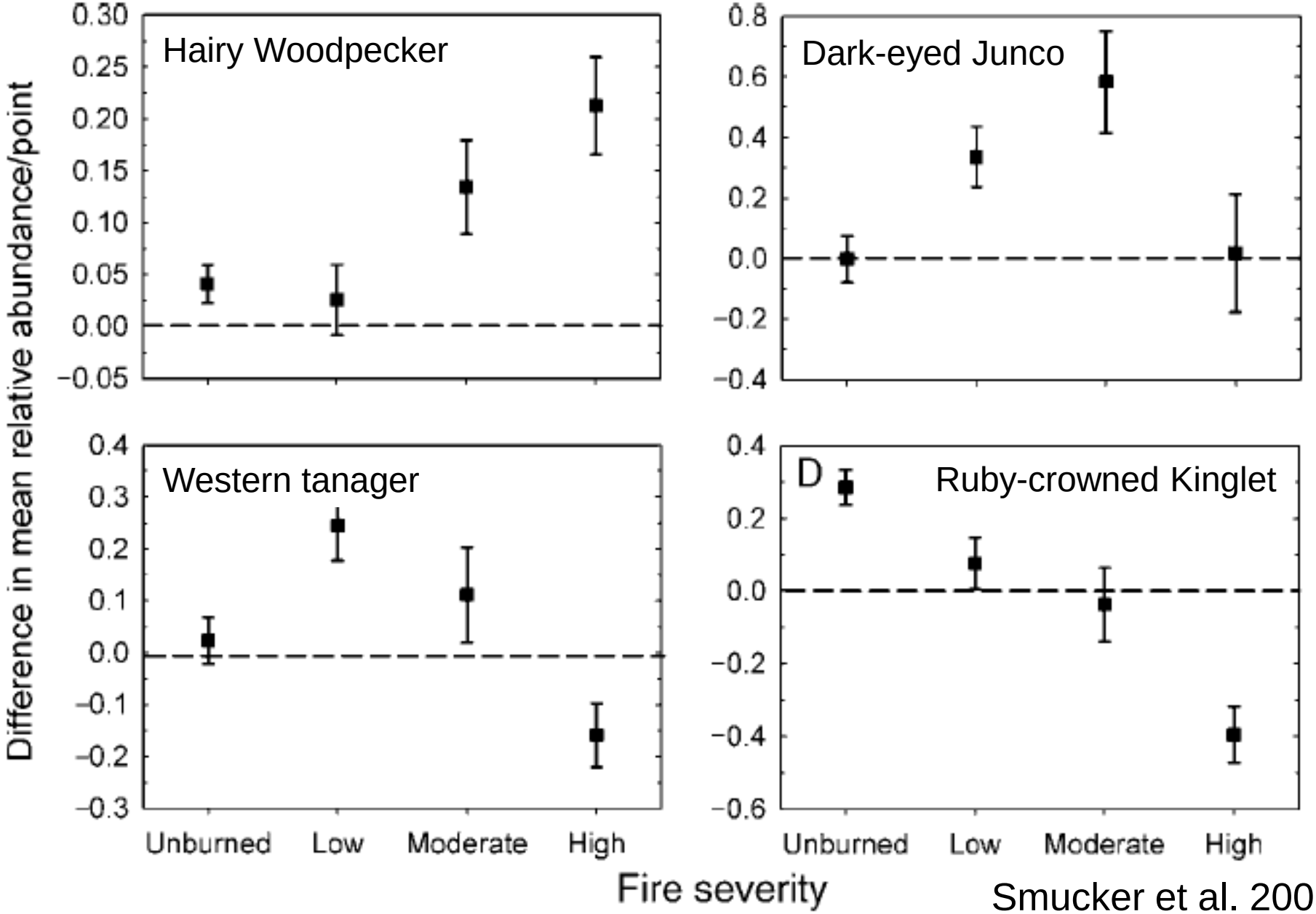
1999

Photo by NGPC


Burned states and transitions:
Coniferous Forest
Coniferous Forest to Grassland
Grassland
Not burned (no transitions):
Coniferous Forest
Grassland


Year Wildfire Occurred
1985
1989
2000
2006
2007
2012

Bird abundances following wildfires of different severity in mixed *Pinus* communities

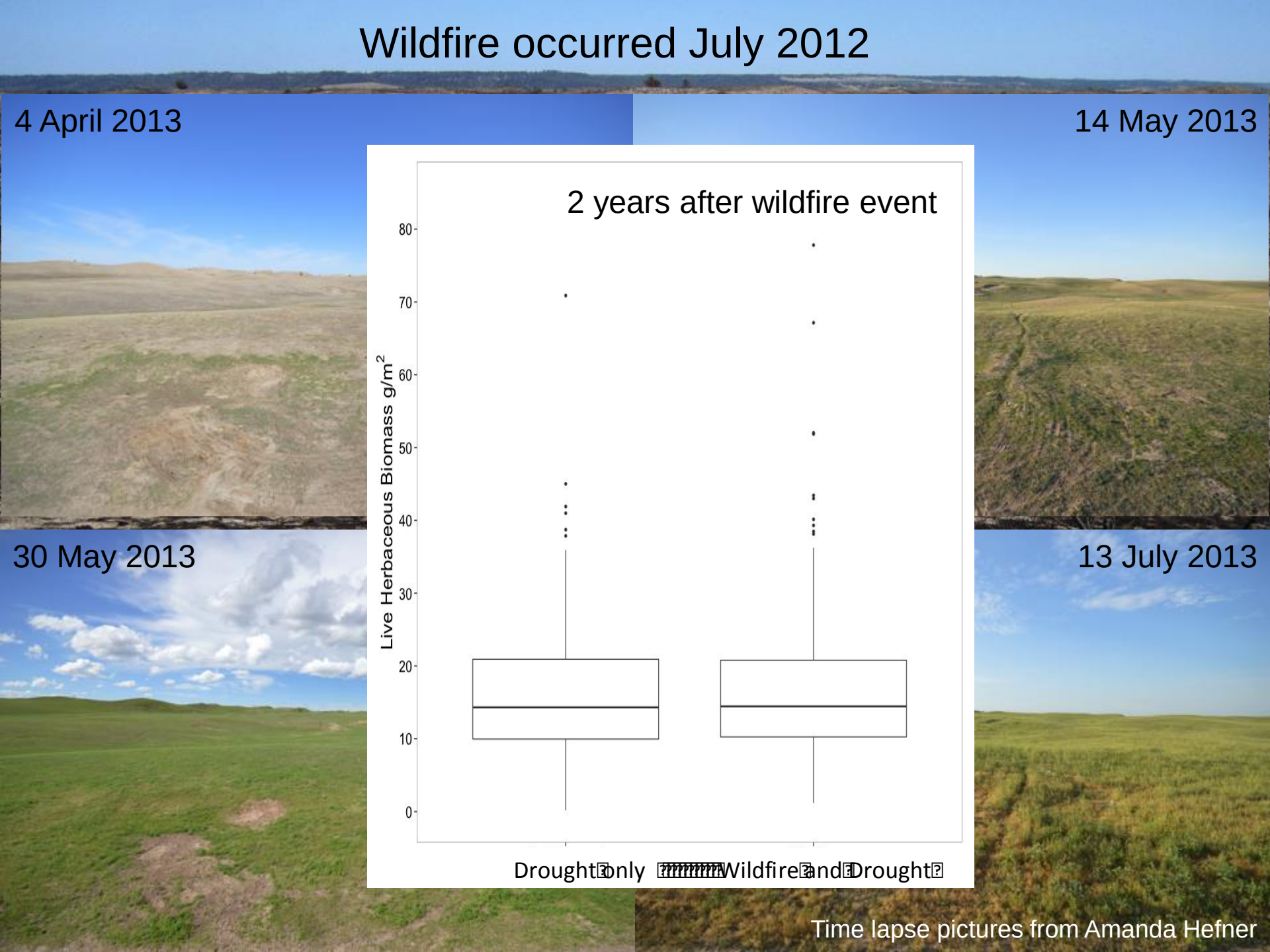


Smucker et al. 2005

Extreme Fire Experiment V

Fire in the Sandhills

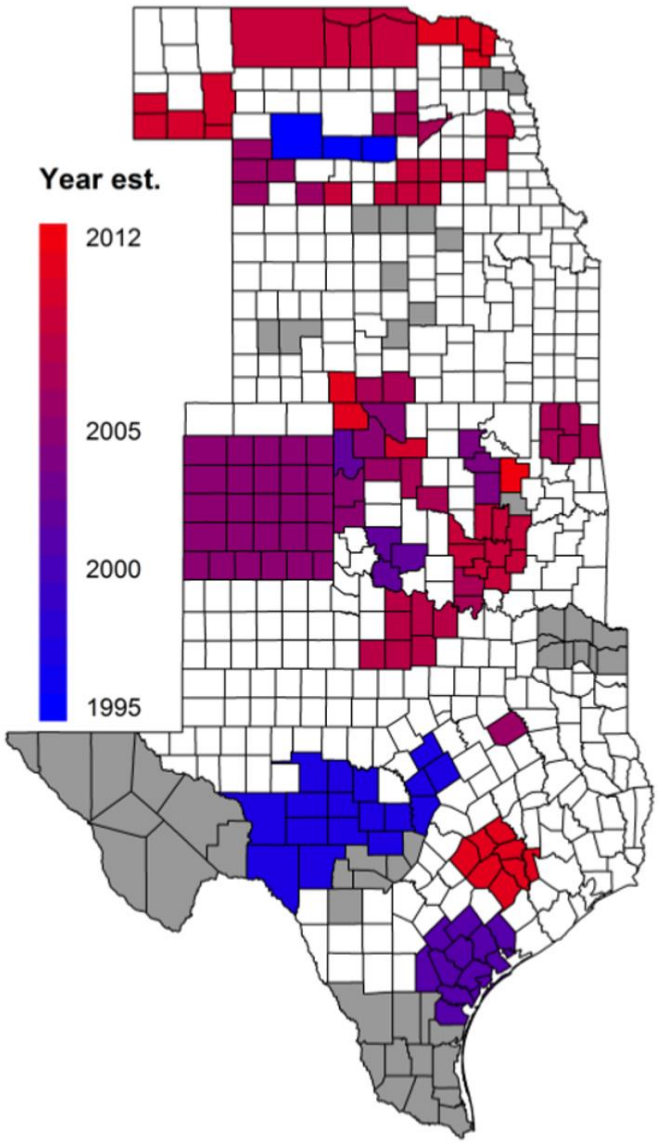
Wildfire occurred July 2012



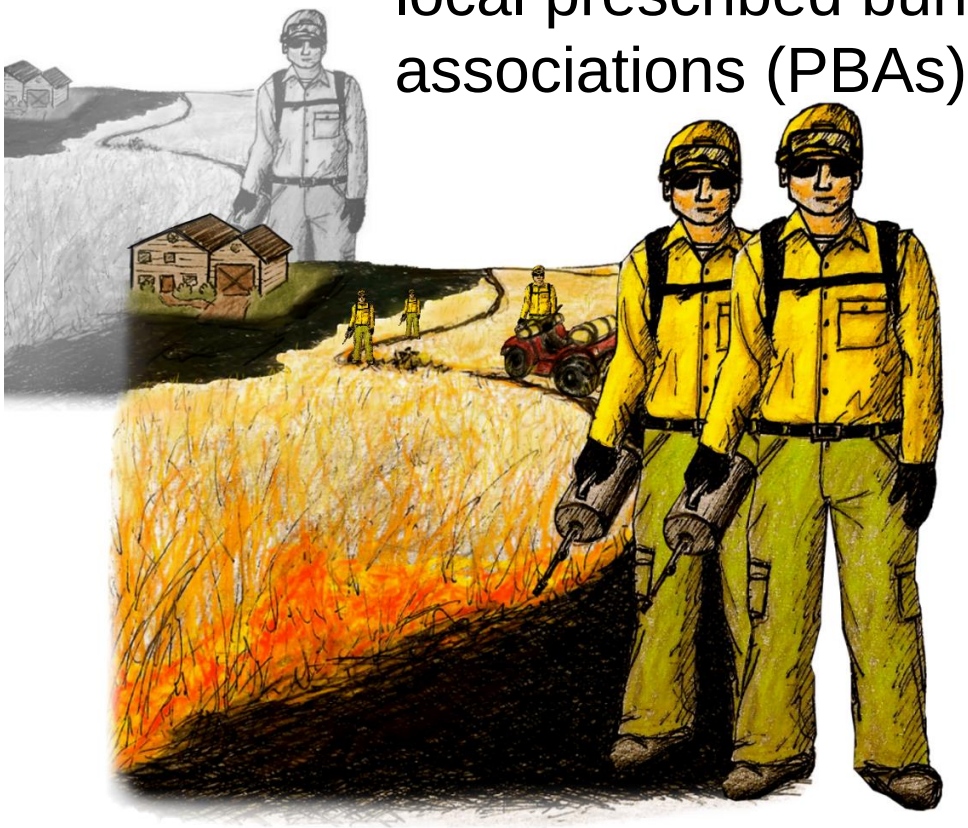
The Sandhills:
More resilient than commonly believed
Copyright Chris Helzer/The Nature Conservancy

But I lack people, equipment and experience...

Social networks have emerged to overcome this issue

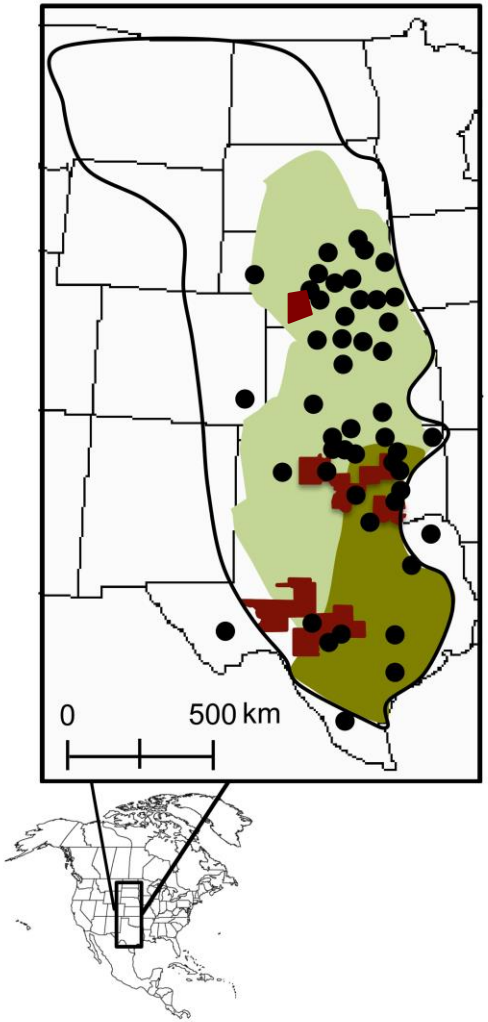


Neighbor-help-neighbor local prescribed burn associations (PBAs)



Pictures by Christine Bielski

The rising Great Plains fire campaign: citizens' response to woody plant encroachment



Legend

- Locations of known burn cooperatives
- Converted to juniper woodland†
- Transitioning to juniper woodland†
- Areas with minimal encroachment in Great Plains†
- Areas where cooperatives are known to have special exemptions to burn during periods when government mandates cease outdoor burning activities

†Adapted from Engle et al. 2008

Twidwell et al. 2013 *Frontiers in Ecology and the Environ.*

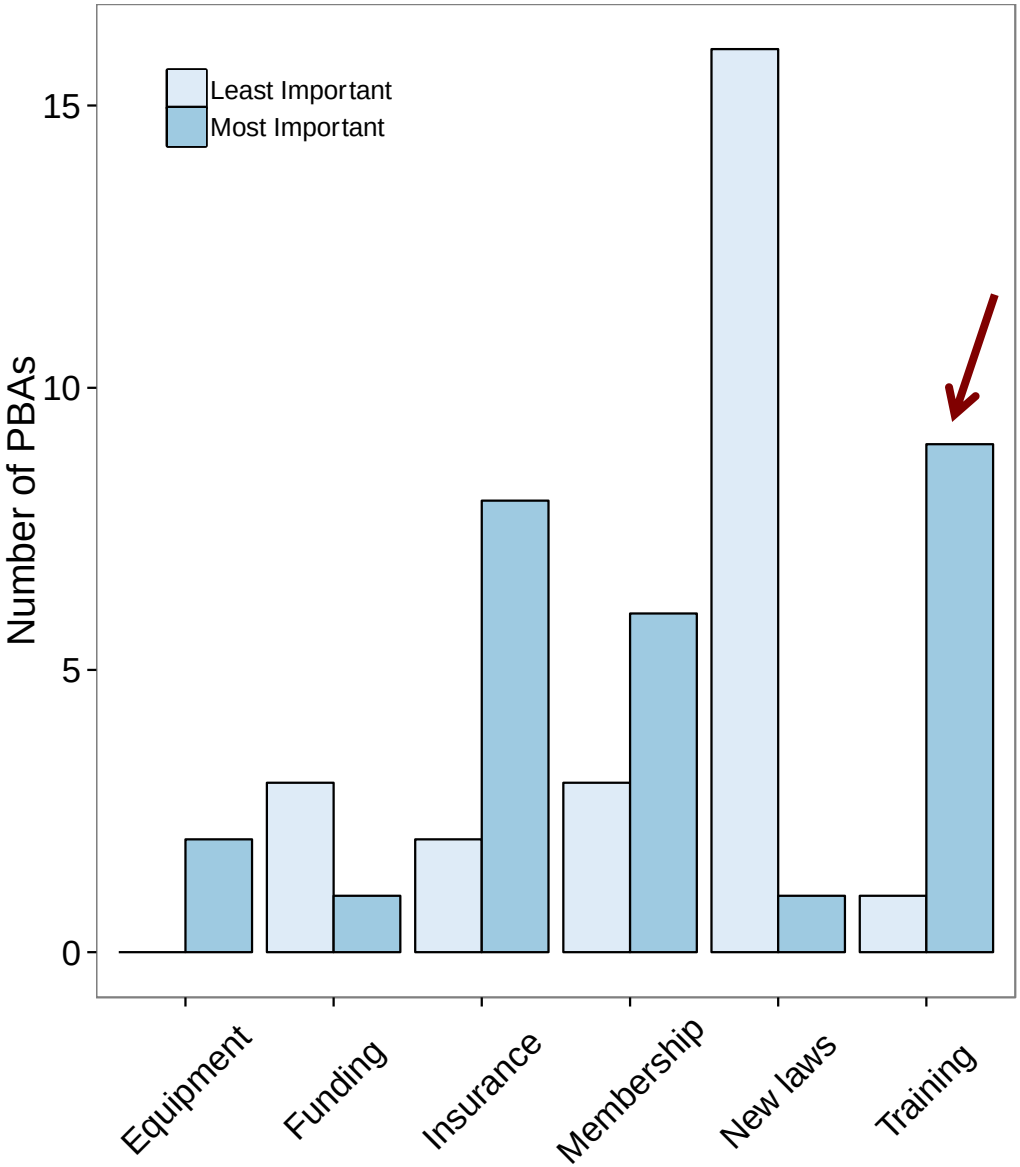
1995 – first burn cooperative formed in Great Plains (NE)

2014 – 50+ fire coops

Approx. 150 fires and 80,000 acres in burn bans

6 coops have now received burn ban exemptions

Needs of Prescribed Burn Associations in the Great Plains



Weir, Twidwell, Wonkka 2015 *GPFSE*

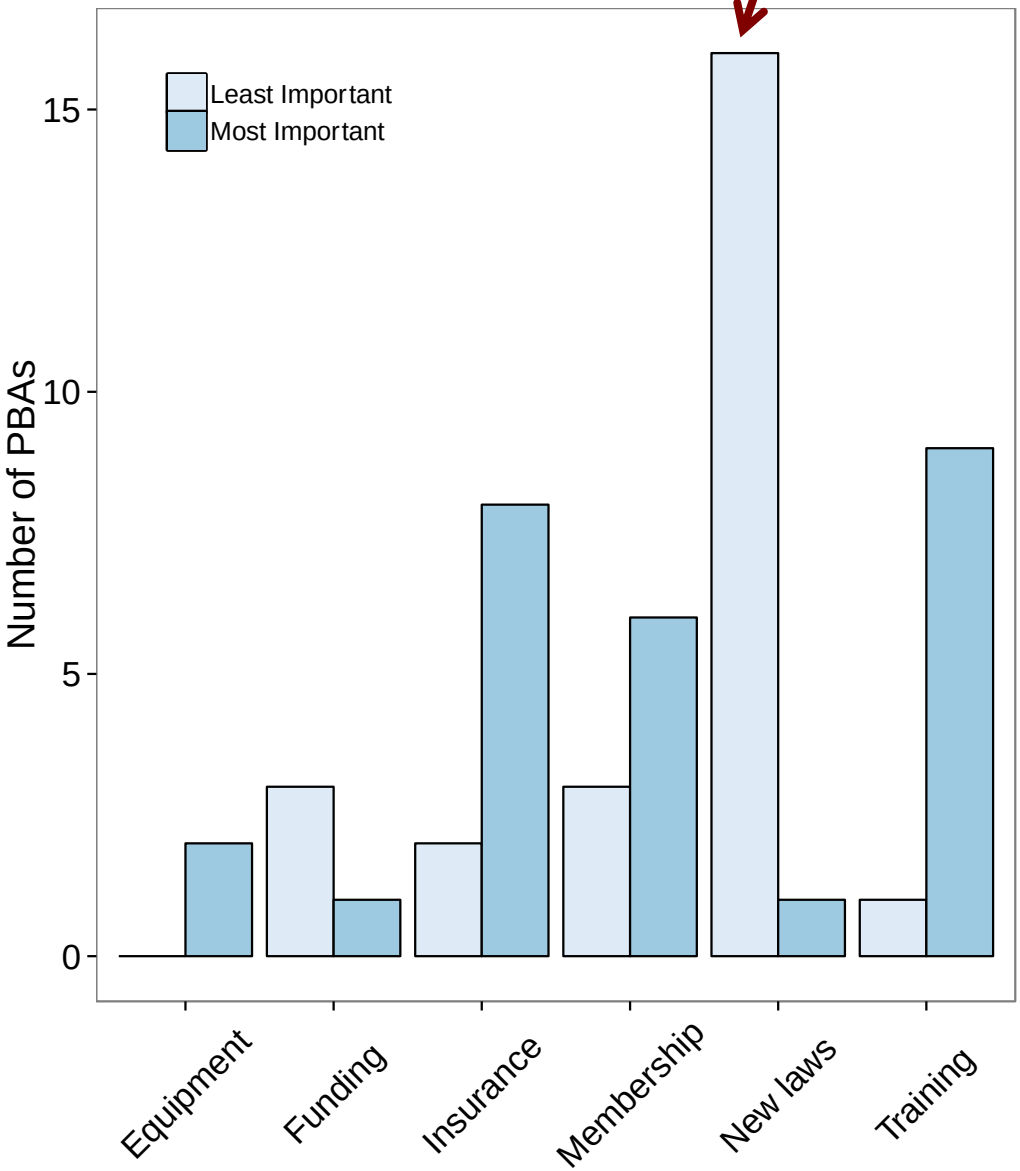
Two interesting results:

1. Training was given as the most important need
   - NE PBAs (*n*=10) also listed training #1
   - But lots of training is available...

     <u>Suggests disconnect exists</u>

This conference provides the platform for addressing this divide

Needs of Prescribed Burn Associations in the Great Plains



Weir, Twidwell, Wonkka 2015 *GPFSE*

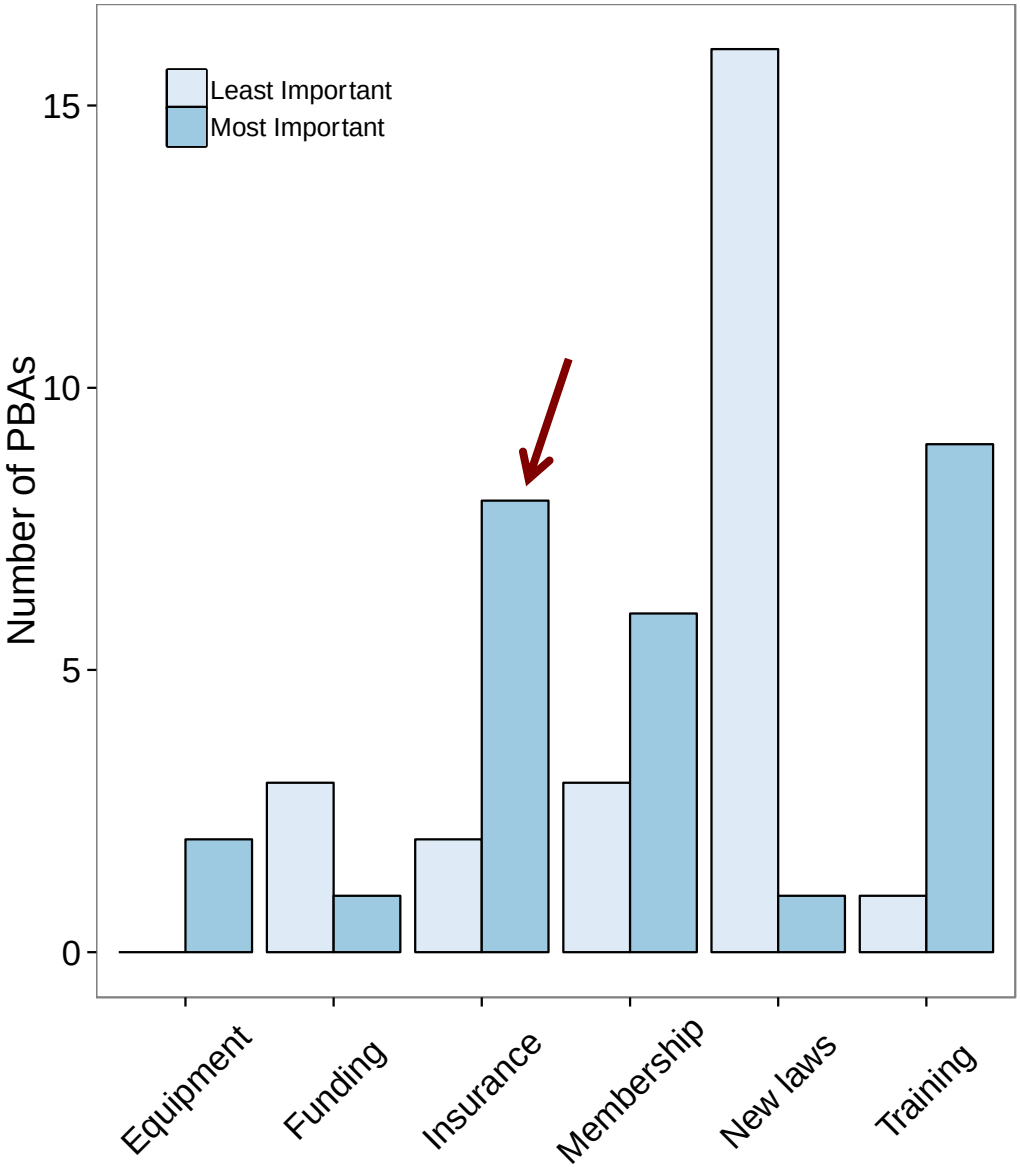
Two interesting results:

1. Training was given as the most important need
   - NE PBAs (*n*=10) also listed training #1
   - But lots of training is available...

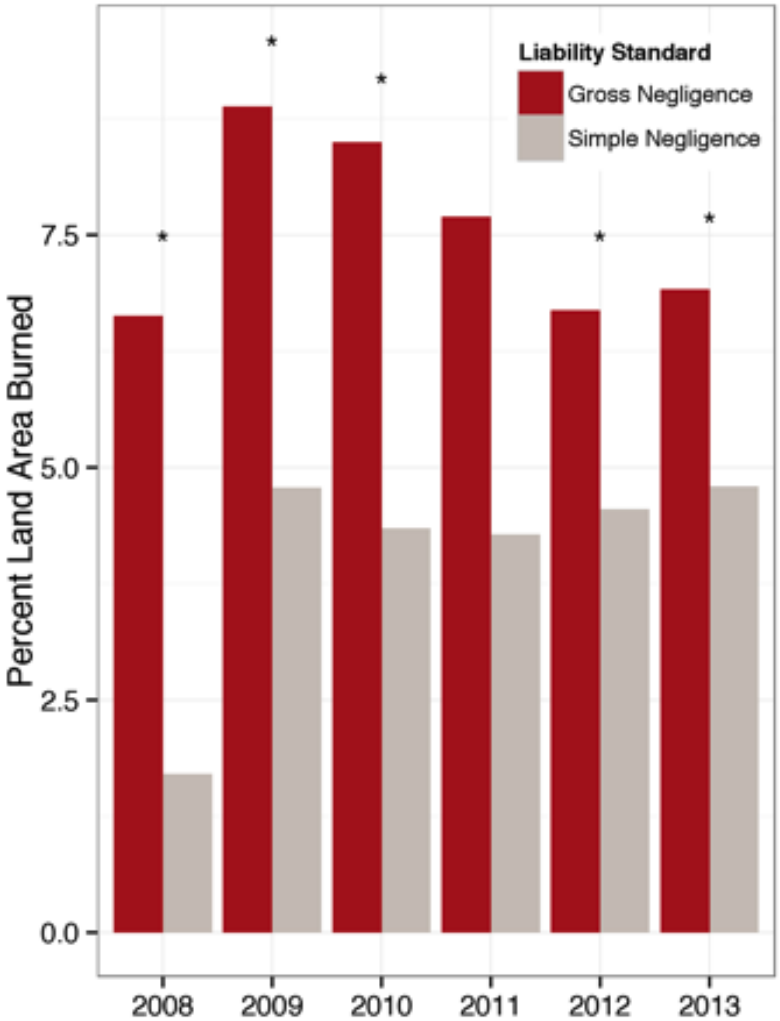
     <u>Suggests disconnect exists</u>

2. New laws were given as the least important need
   - But liability is consistently given as a major reason why people do not use prescribed fire

More likely to promote prescribed fire if statutes specify lower liability for prescribed burners

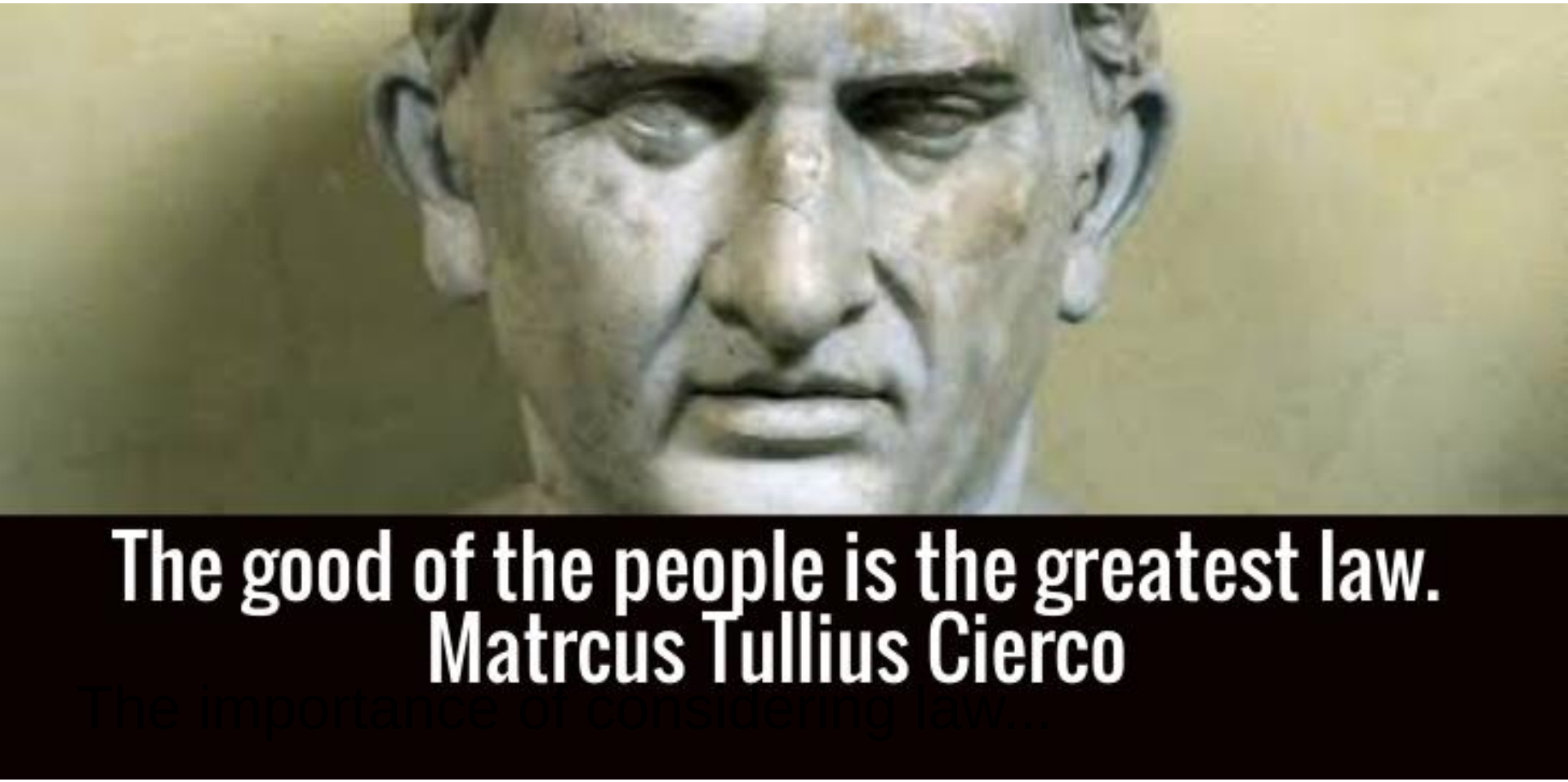


Weir, Twidwell, Wonkka 2015 *GPFSE*



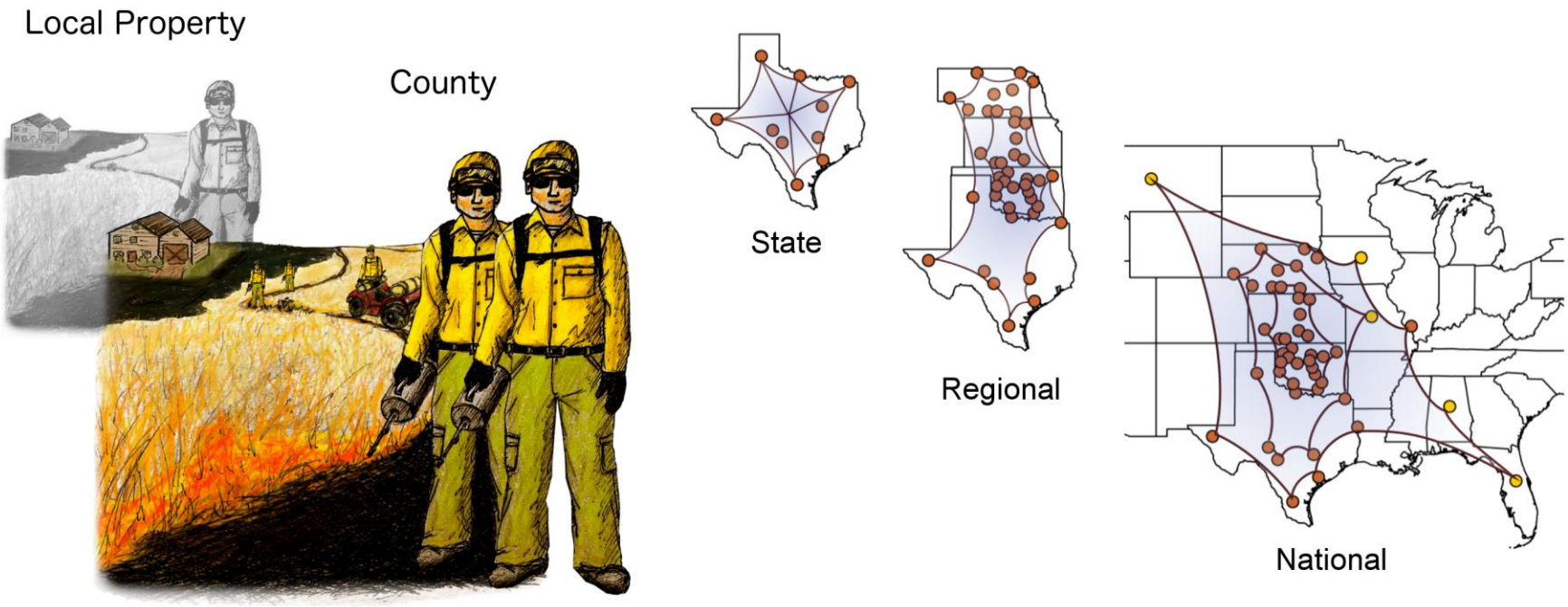
Wonkka et al. 2015 *Ecol Applications*

The importance of considering law...



The importance of considering law...

...but top-down controls can completely eliminate or reverse local momentum

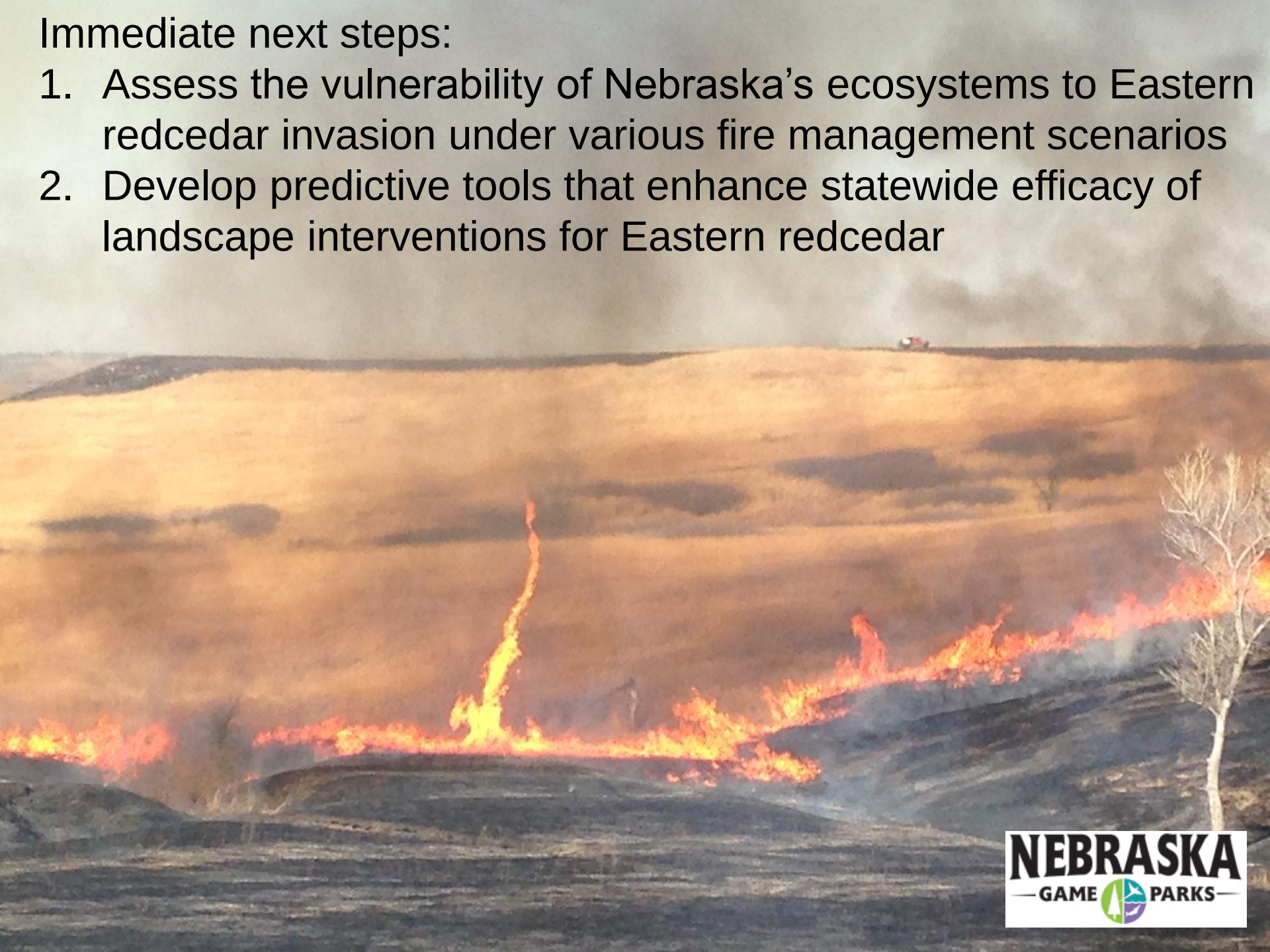


Potential Scale of Impact

Local Impact	Management of Fire Dependent Social-Ecological Values	National Impact
Local Problem	External Perception of the Scale of the Problem	National Problem
Local/Internal Dependence	Adaptive Capacity of PBAs	National/External Support
Local Change	Cultural Change	National Change
Local Influence	Legislative Influence	National Influence

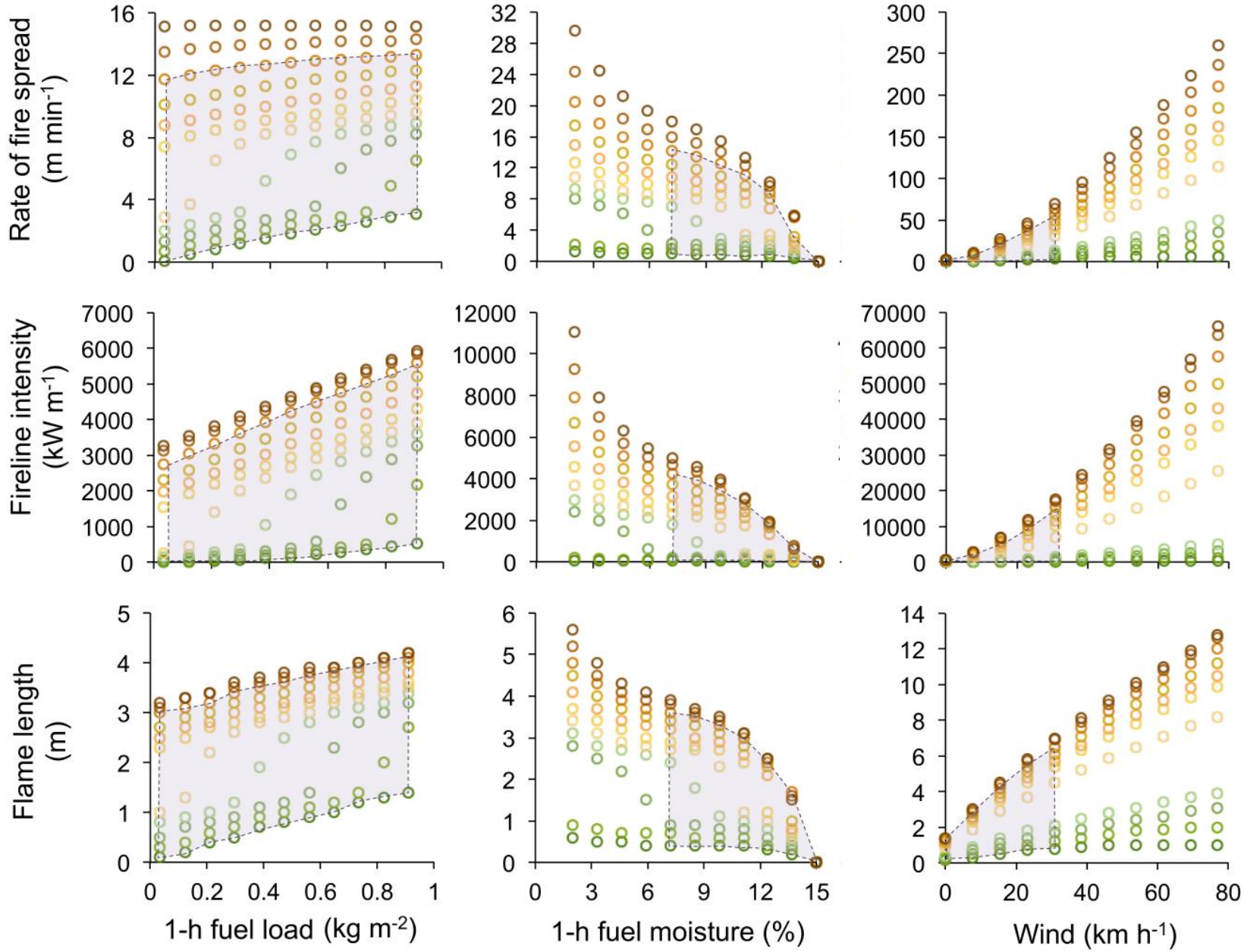
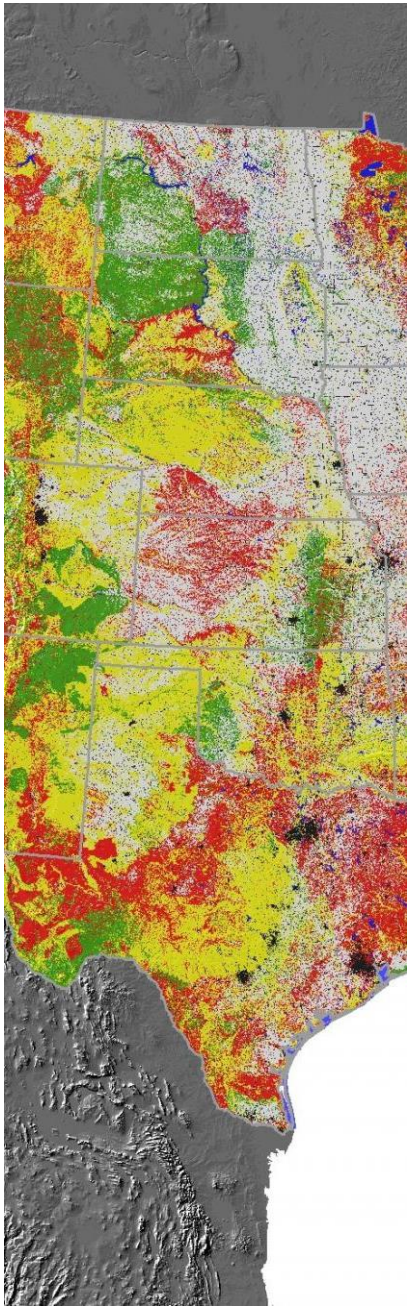
Immediate next steps:

1. Assess the vulnerability of Nebraska's ecosystems to Eastern redcedar invasion under various fire management scenarios
2. Develop predictive tools that enhance statewide efficacy of landscape interventions for Eastern redcedar



Immediate next steps:

3. Characterize sociopolitical barriers facilitating juniper invasions and limiting adoption of fire in NE
4. Develop new approaches to landscape-scale fire management that reduces risk and increases safety to personnel


Rate of fire spread (m min-1)
Fireline intensity (kW m-1)
Flame length (m)
1-h fuel load (kg m-2)
1-h fuel moisture (%)
Wind (km h-1)