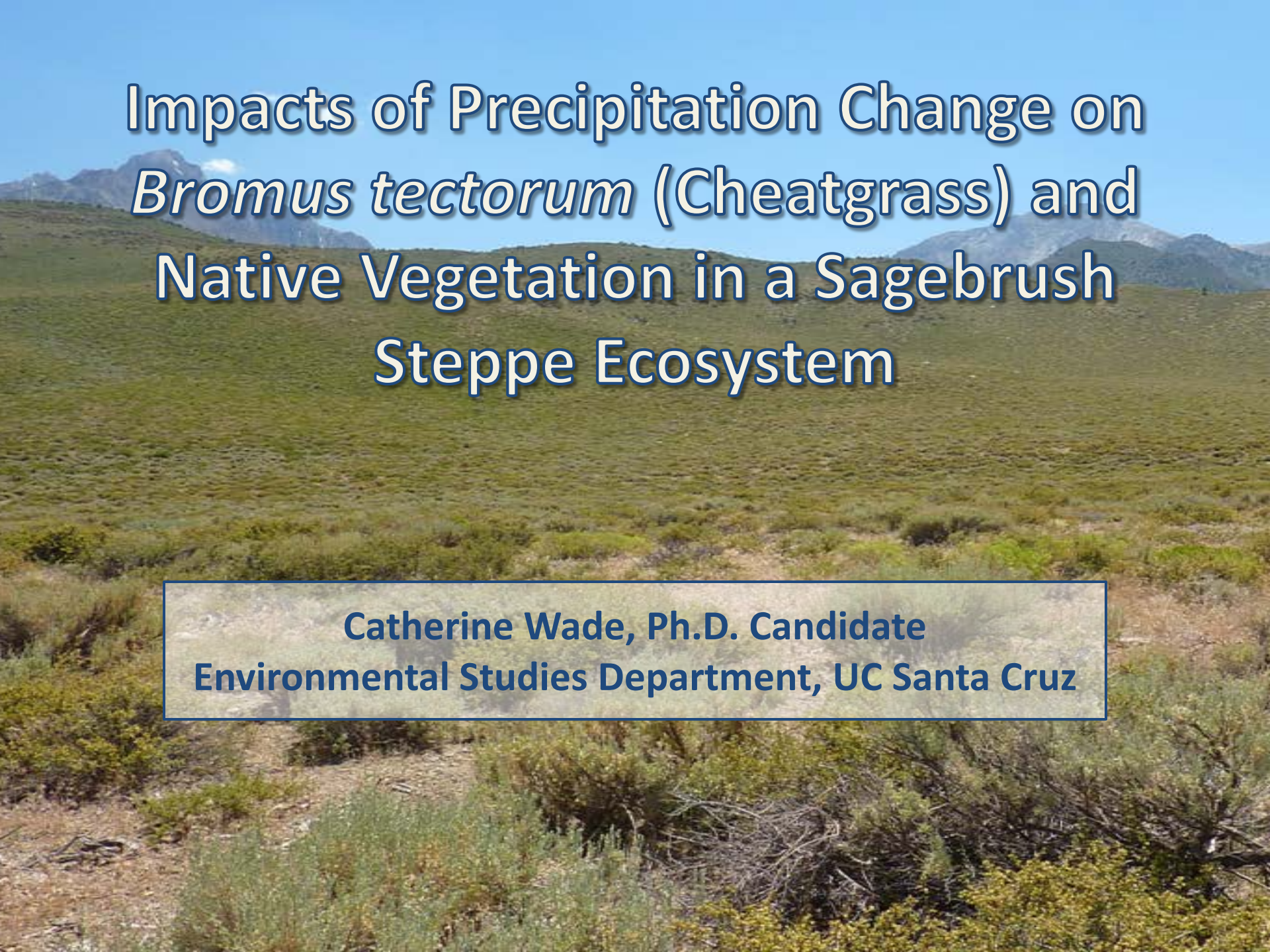
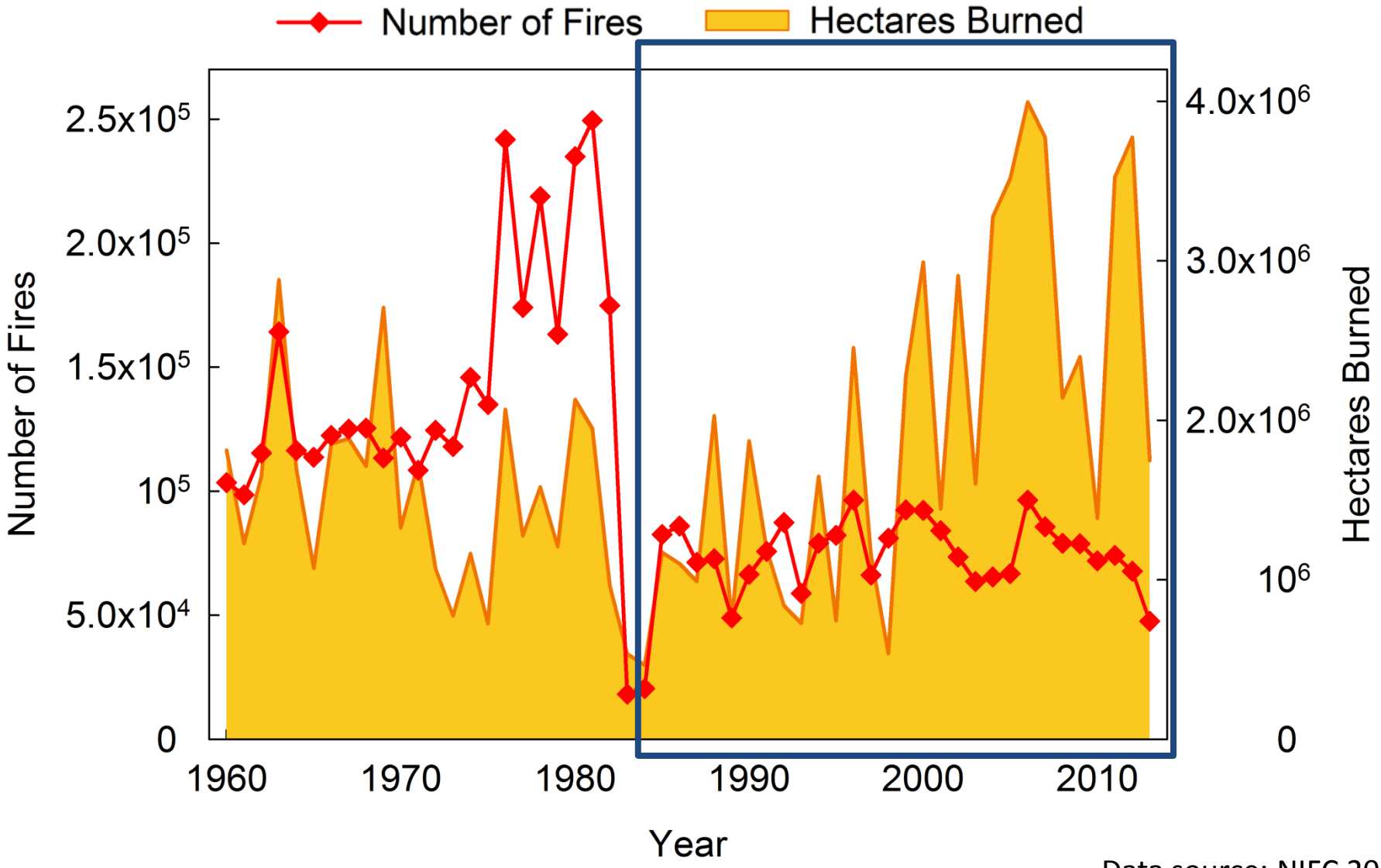


Impacts of Precipitation Change on *Bromus tectorum* (Cheatgrass) and Native Vegetation in a Sagebrush Steppe Ecosystem

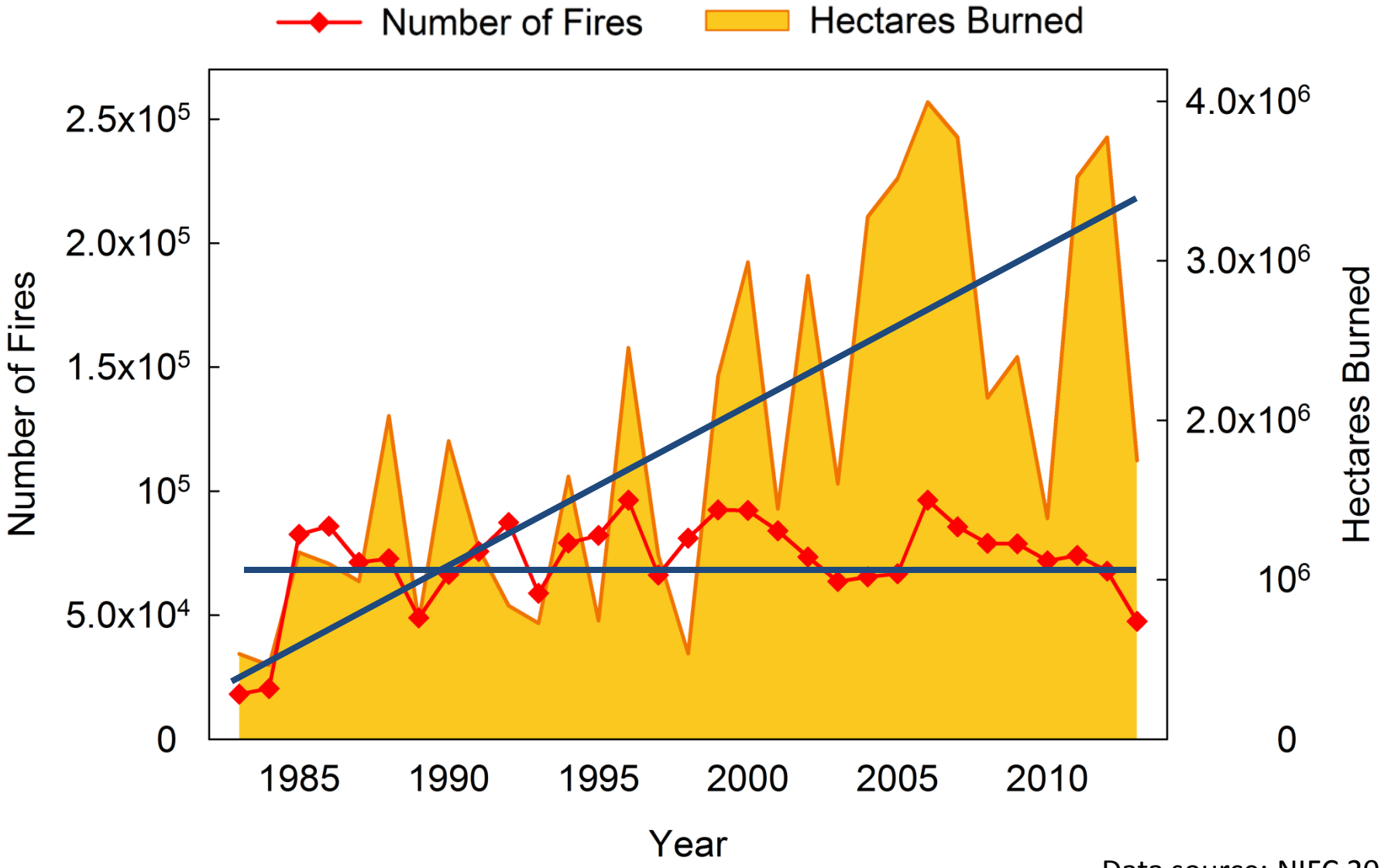
Catherine Wade, Ph.D. Candidate
Environmental Studies Department, UC Santa Cruz

Wildfire Activity in the U.S., 1960-2013



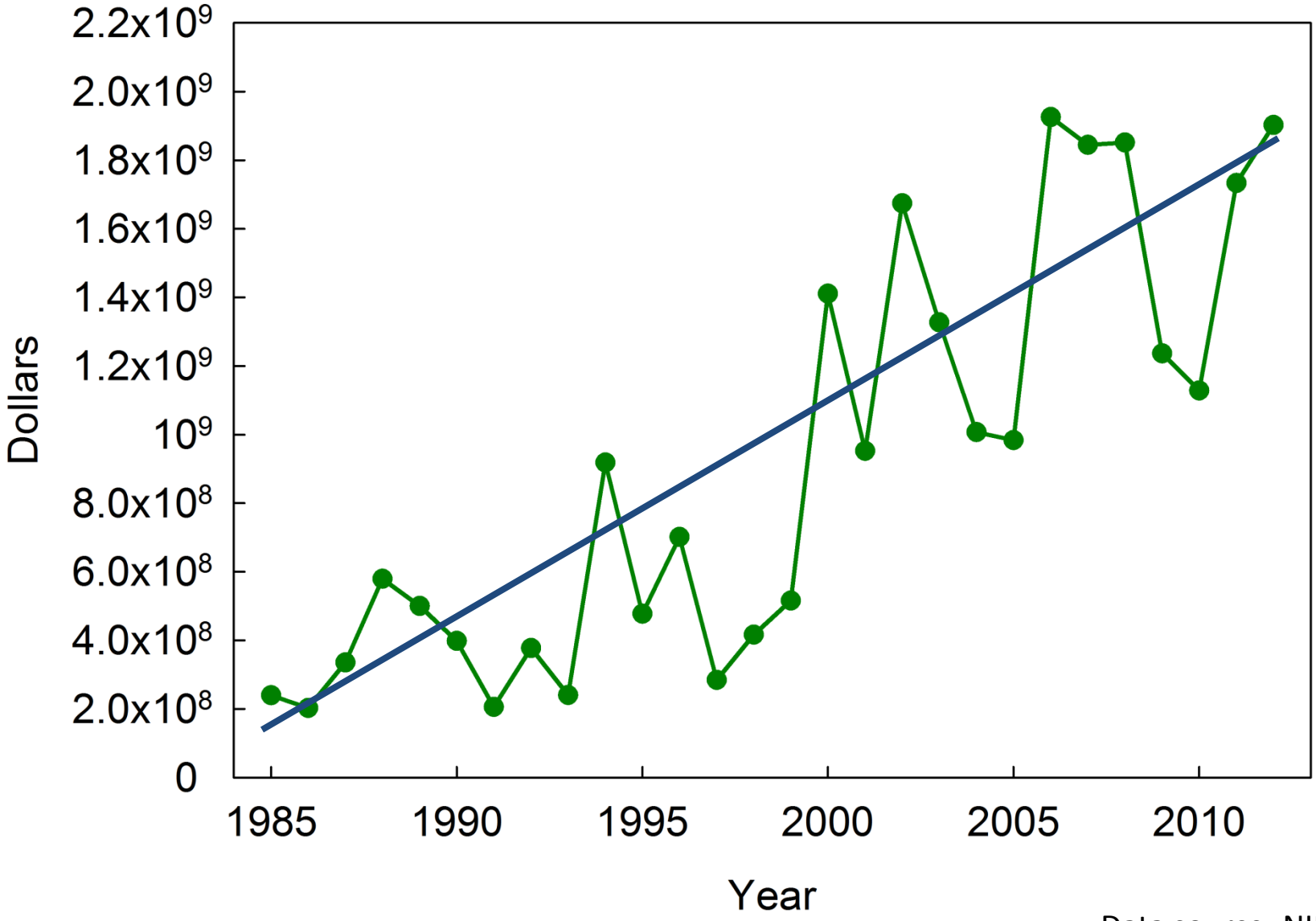
Data source: NIFC 2014

Area burned has been increasing while number of fires has been constant



Data source: NIFC 2014

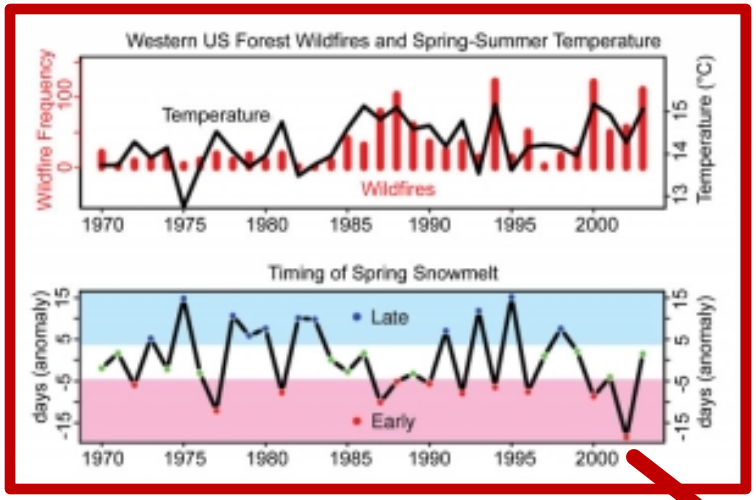
Federal Fire Suppression Costs



Data source: NIFC 2013

Why the increase in area burned?

CLIMATE CHANGE

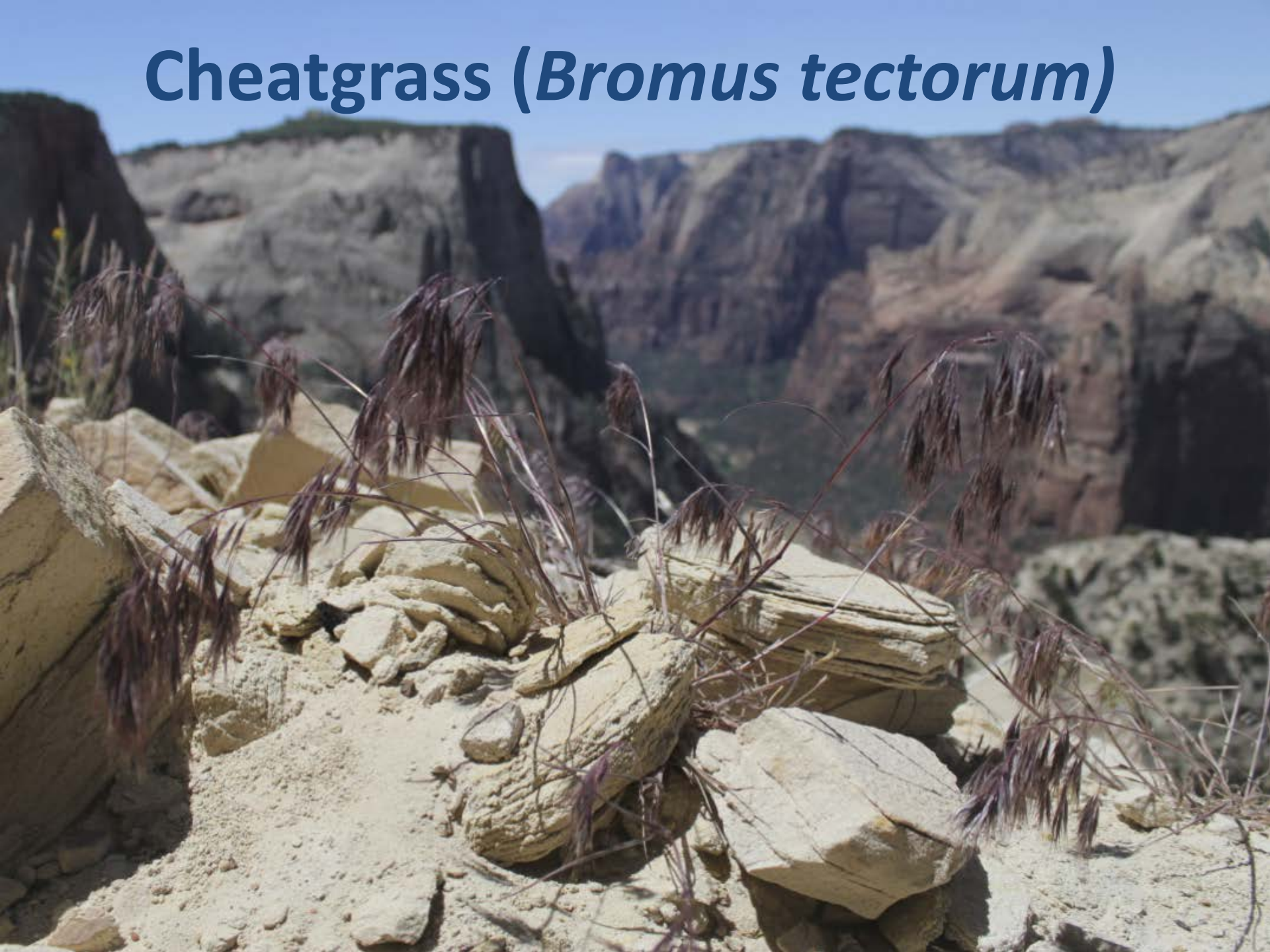


Westerling et al. 2006

MANAGEMENT

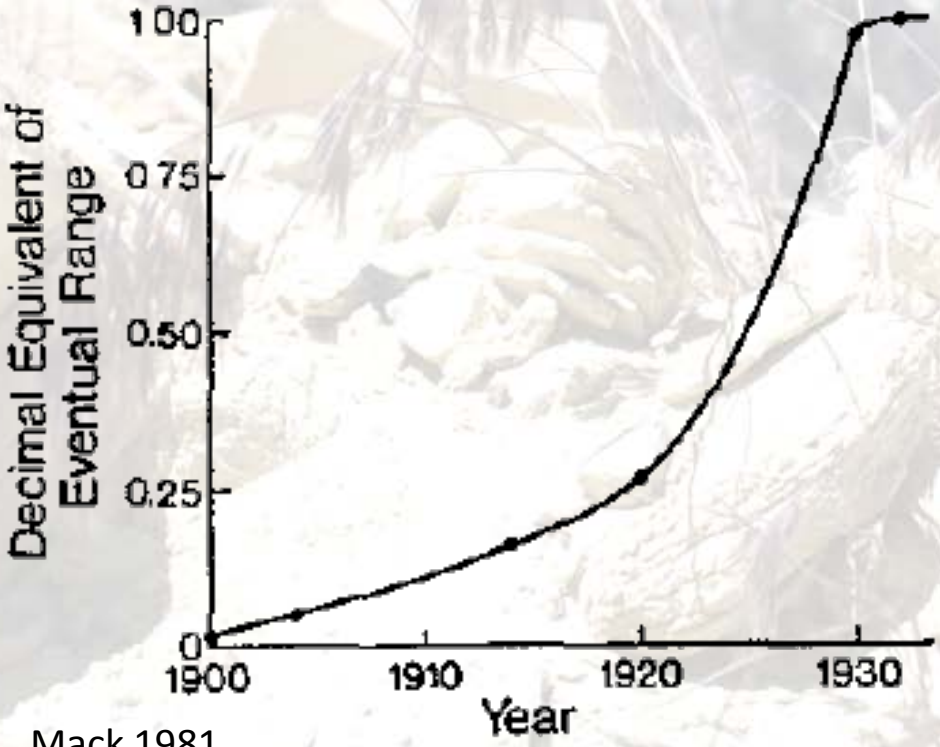
INVASIVE SPECIES

Cheatgrass (*Bromus tectorum)*



Cheatgrass (*Bromus tectorum*)

- Native range: Europe, Asia, Northern Africa
- Accidentally introduced to the U.S. in the late 1800s



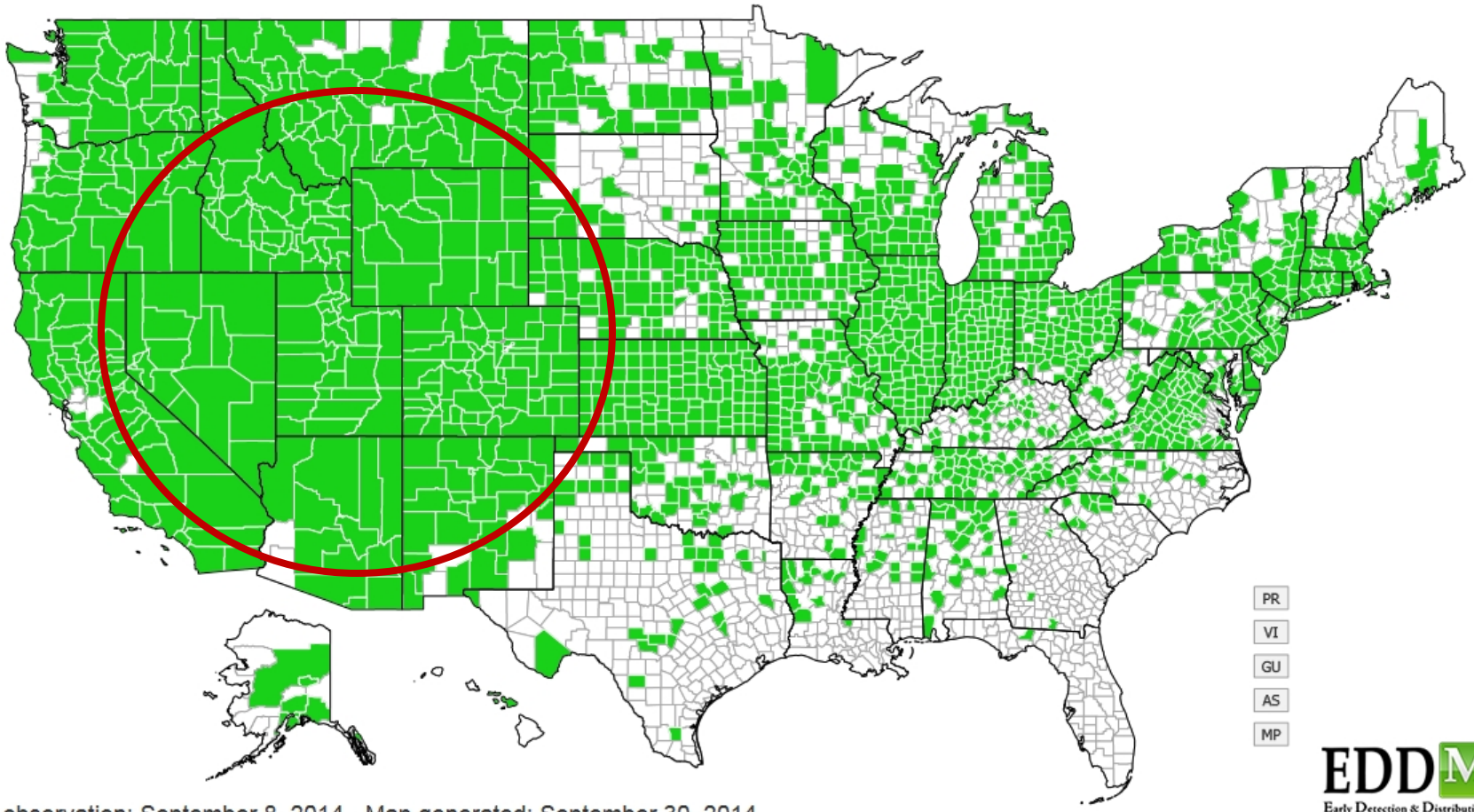
Mack 1981

"Ecological stowaways....found thousands of square miles of ready-made seedbed prepared by the trampling hoofs of range livestock. In such cases the ***spread was often so rapid as to escape recording; one simply woke up one fine spring to find the range dominated by a new weed. A notable instance was the invasion of the intermountain and northwestern foothills by....cheat grass (*** **Bromus tectorum** ***)."***

—Aldo Leopold, *A Sand County Almanac* (1949); pp. 164-165

Cheatgrass Occurrence

Bromus tectorum



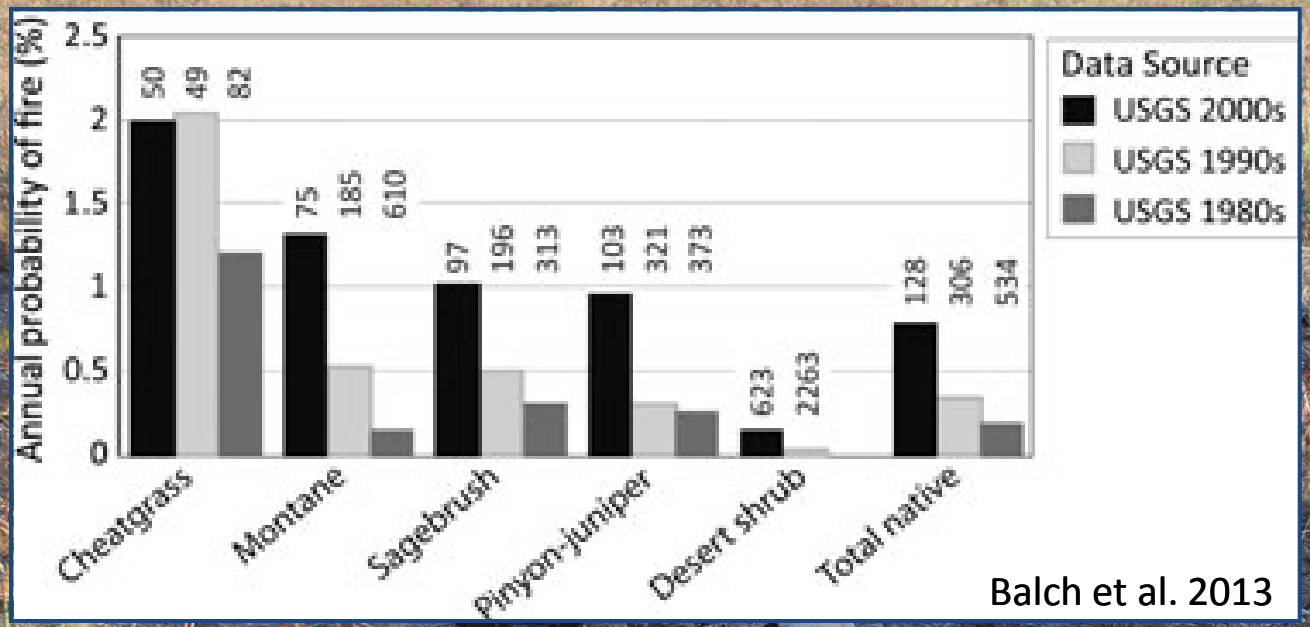
Last observation: September 8, 2014 - Map generated: September 30, 2014

Cheatgrass Dominance

- >40 million hectares in the Intermountain West (Whisenant 1990)
- ≥6% of the Great Basin (Balch 2013)
- ~20% of the sagebrush steppe vegetation zone (Knapp 1996)

Cheatgrass-Fire Cycle

Cheatgrass Fire Impacts



Balch et al. 2013

Twice as likely to burn

78% of the 50 largest fires (2000-2009)

- Increased fire activity across the arid western U.S., 1980-2009
- Disproportionately large fuel source during the largest fires in the 2000s (as well as a primary ignition point)
- Extends length of the fire season (Brooks et al. 2004)

"It is impossible fully to protect cheat country from fire."

—Aldo Leopold, *A Sand County Almanac* (1949); p. 166

Cheatgrass Range Expansion

- >40% of sagebrush steppe is estimated to be at moderate to high risk of displacement by *B. tectorum* in the next 30 years (Chambers et al. 2007)
- Over the last 10-15 years, *B. tectorum* has been expanding into higher elevations (Weltz et al. 2011)

Questions

How will climate change affect the distribution of *B. tectorum* near its high-elevation range margin?

1) How do *snow depth* and *melt timing* influence species composition, phenology, fuel loading, and fuel moisture?

2) Does different *timing of precipitation* events (i.e., spring vs. summer) elicit different responses from native and invasive species?

Hypotheses

H_1: ***Species composition*** will vary according to ***snow depth***.

H_2: ***Increased and decreased snowpack*** will delay and advance ***phenology***, respectively, due to differences in ***snowmelt timing***.

H_3: ***Decreased snow depth*** will result in ***lower soil moisture*** and ***fuel moisture***.

H_4: Spring and summer ***rainfall*** simulations will ***enhance*** plant ***photosynthetic responses***.

H_5: Plant responses to the ***timing of precipitation*** will be species-specific.

Study Site

OREGON
Boise
Idaho Falls
WYOMING
Medford
Carson City
NEVADA
Sacramento
San Francisco
San Jose
Fresno
Los
San Die
Tijuana

Legend

- Sierra Nevada
- Great Basin

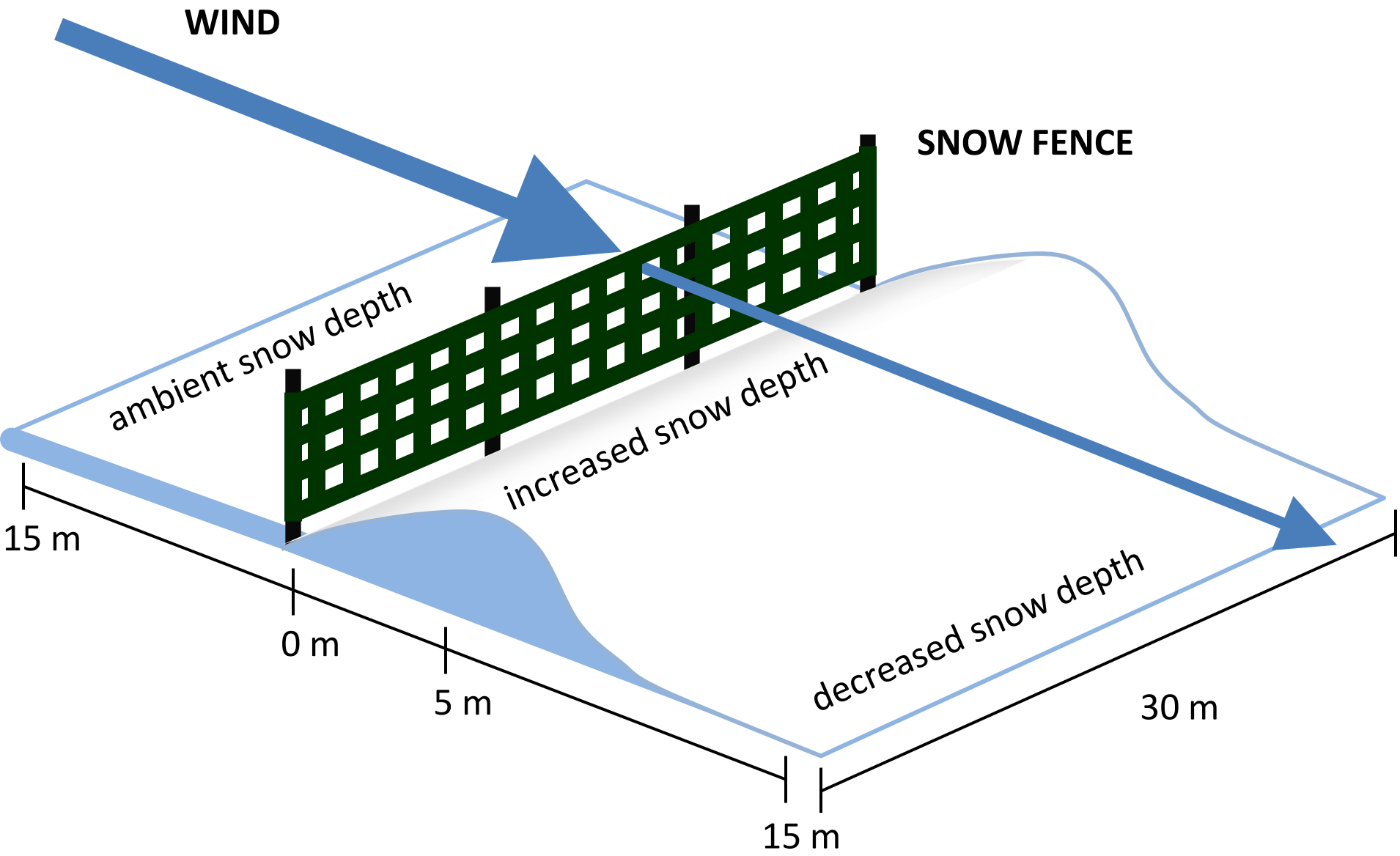
Treatments

Snowpack manipulations (winter)

Rainfall simulations (spring and summer)

Snowpack Manipulations: Snow Fences

Snow Fence Design



Rainfall Simulations: Irrigation

Bromus tectorum
(Cheatgrass)

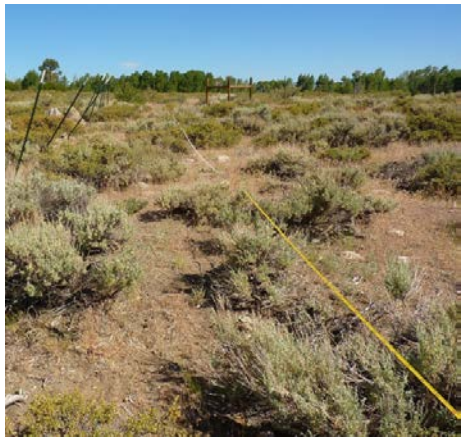
Achnatherum hymenoides
(Indian ricegrass)

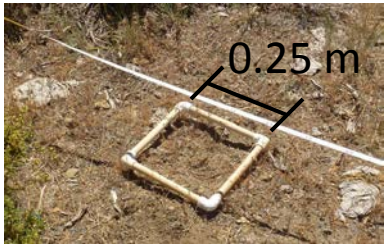
Elymus elymoides
(Squirreltail)

Lupinus argenteus
(Silvery lupine)

Measurements

- Soil moisture
- Leaf area index
- Phenology
- Physiology
- Species composition
- Cheatgrass density



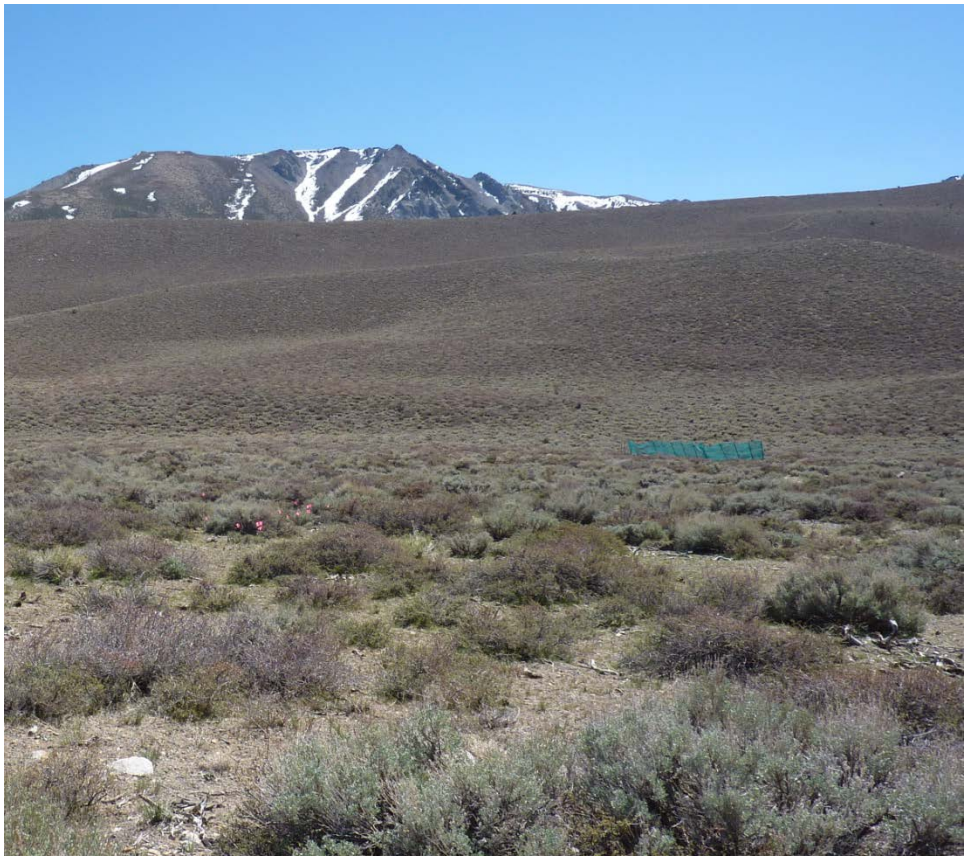


Measurements

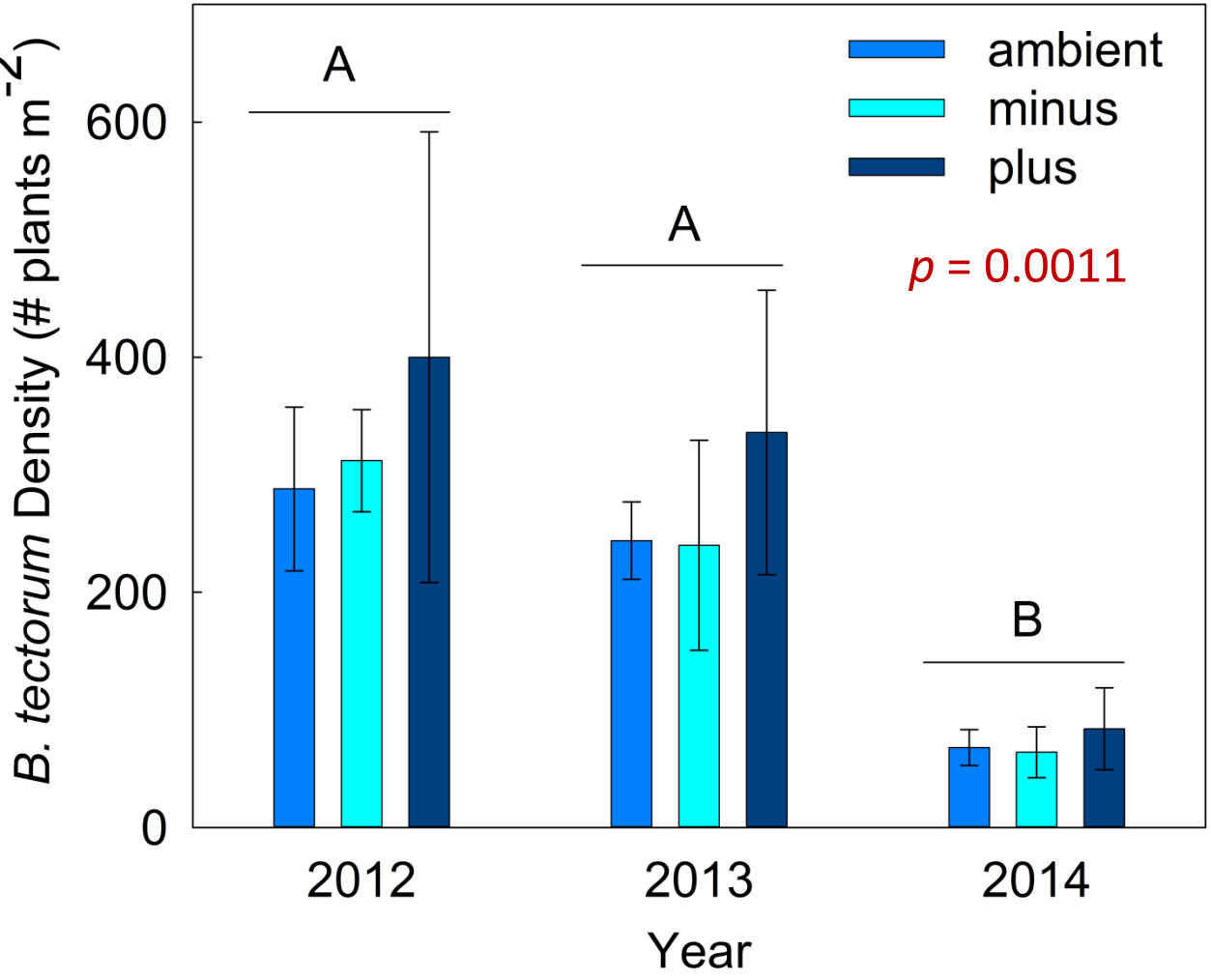
- Soil moisture
- Plant height and number of inflorescences
- Physiological measurements
  - Photosynthetic rate
  - Stomatal conductance to water vapor
  - Quantum yield of Photosystem II
  - Electron transport rate

Within each year, no effect of snow depth on…

- Soil moisture
- Leaf area index
- Species richness
- Percent cover
- *B. tectorum* density



Reduced *B. tectorum* density following the driest winter



Phenology by Species

Achnatherum hymenoides

Elymus elymoides

Bromus tectorum

Percent Producing Spikelets/Seeds

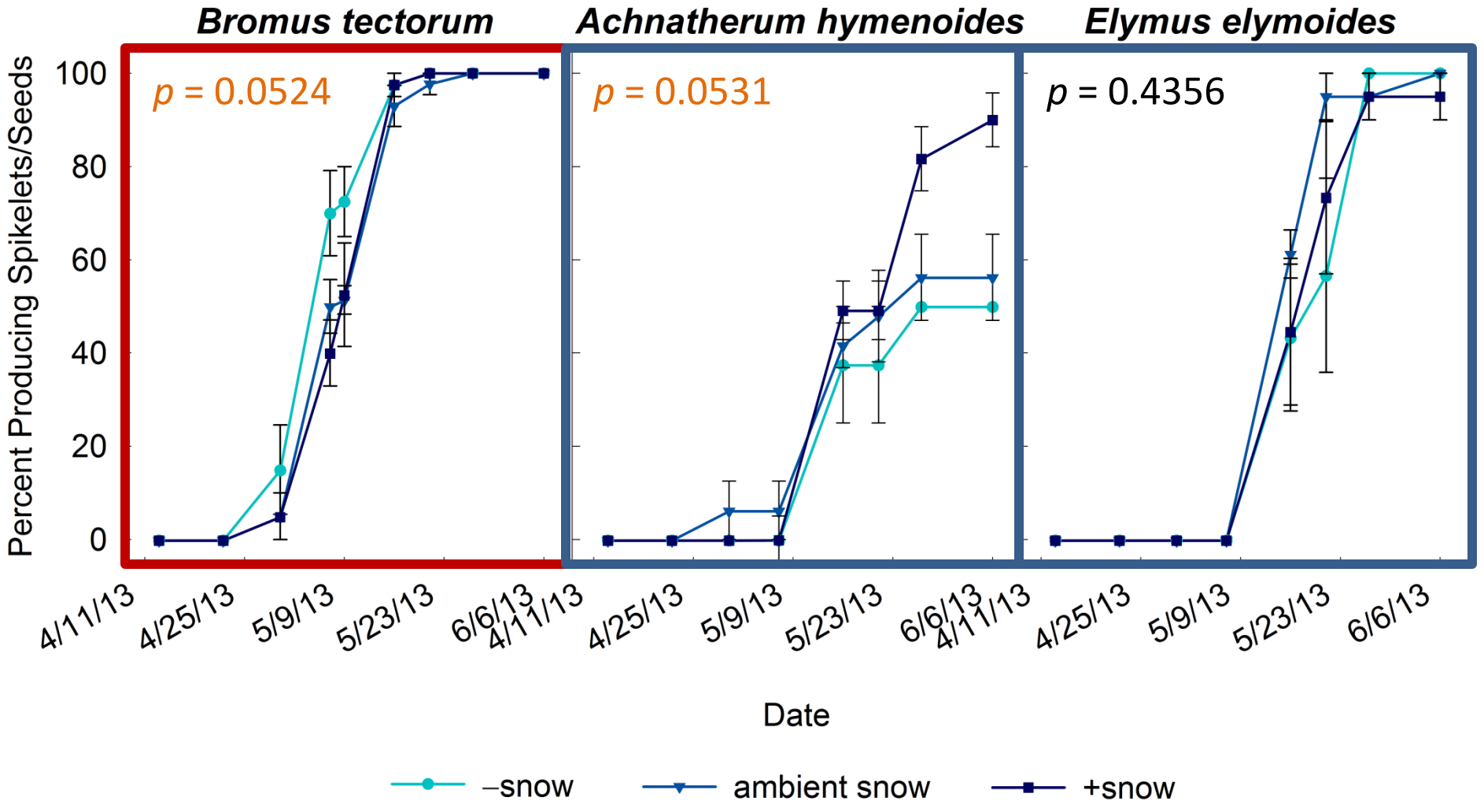
100
80
60
40
20
0

4/8/13
4/22/13
5/6/13
5/20/13
6/3/13

Date

$p < 0.0001$

Phenology by Snow Zone



Rainfall Timing: Spring

- No effect on plant height or number of inflorescences

Physiological Responses

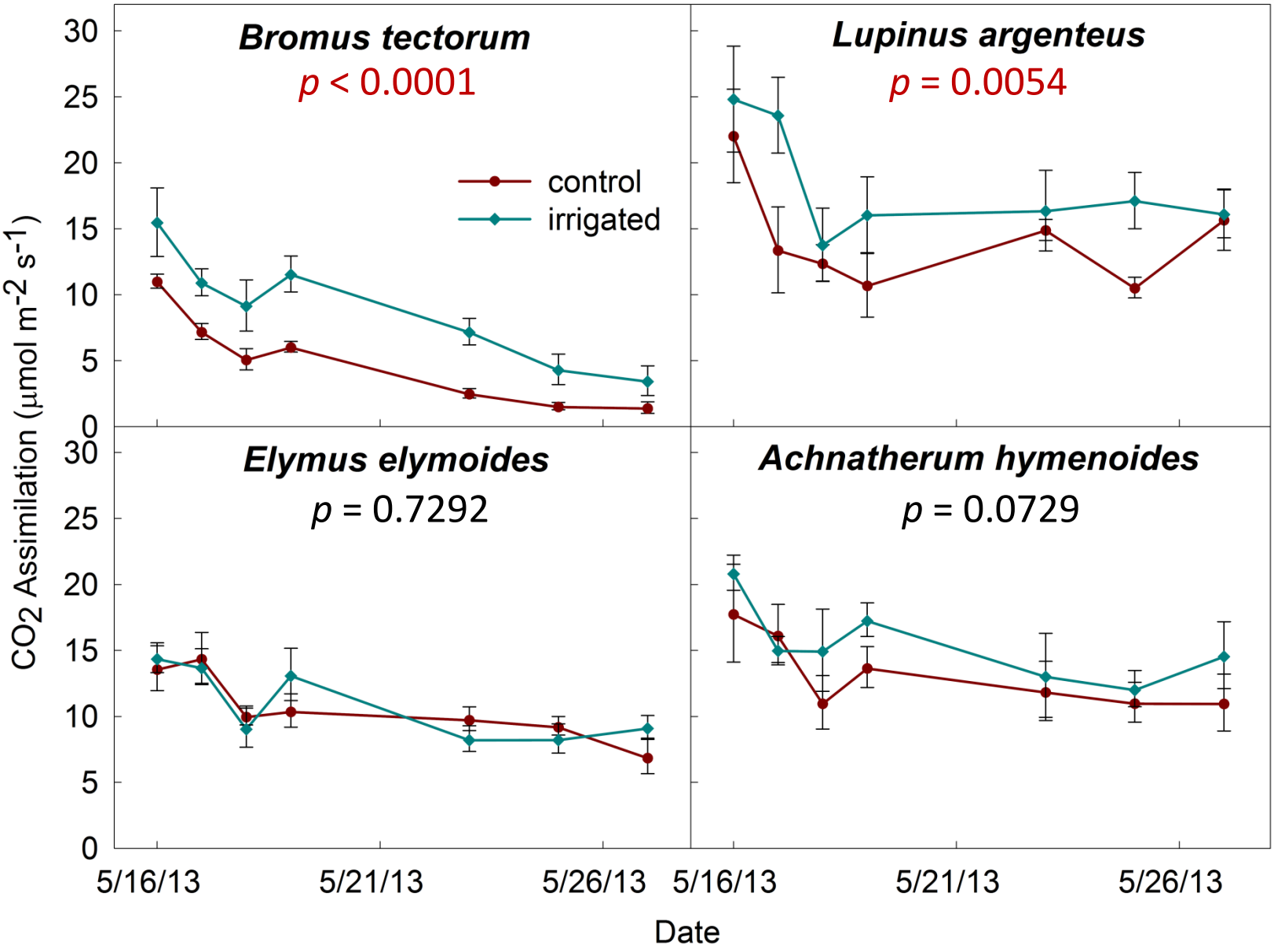
Bromus tectorum

Lupinus argenteus

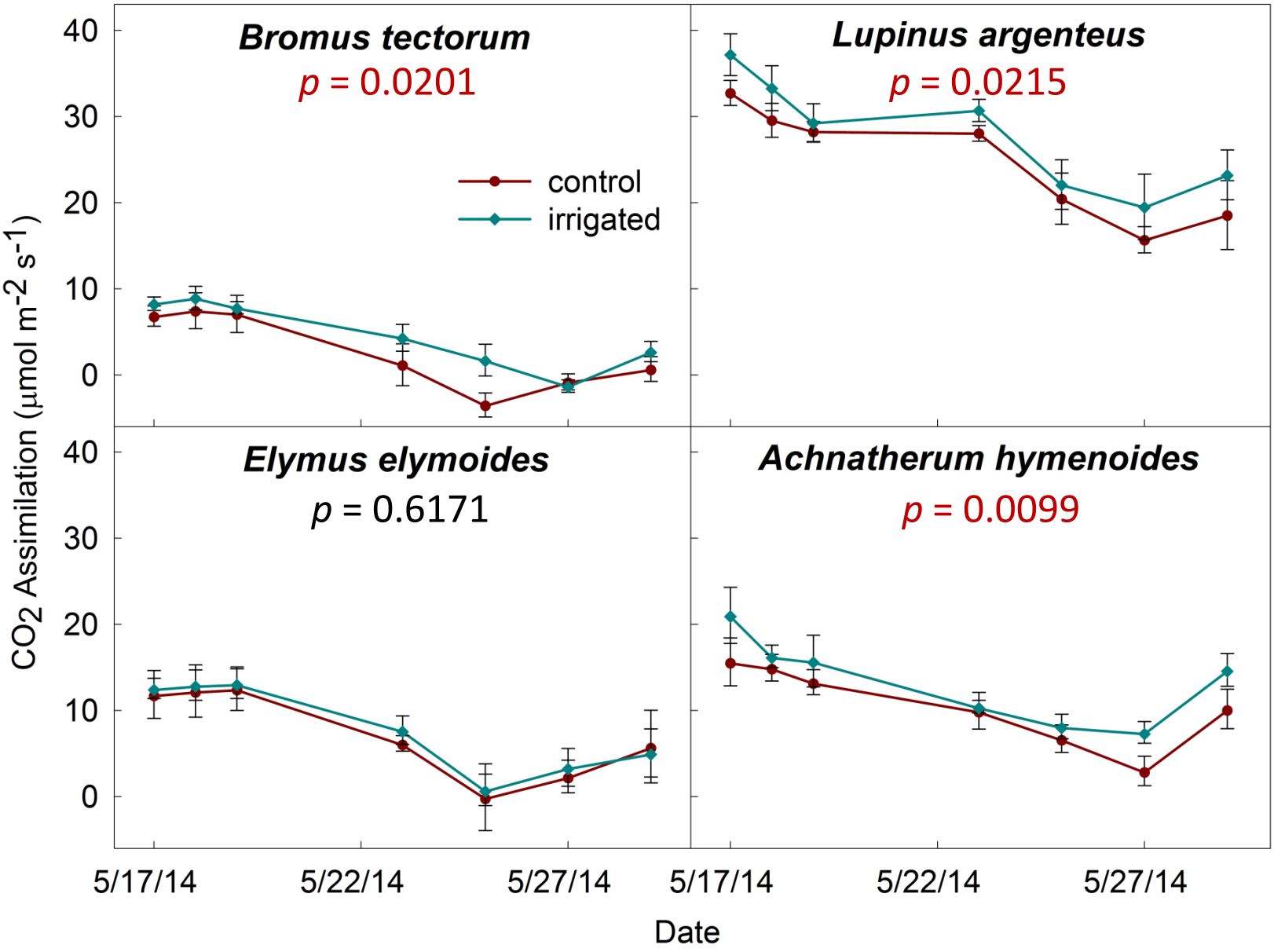
Elymus elymoides

Achnatherum hymenoides

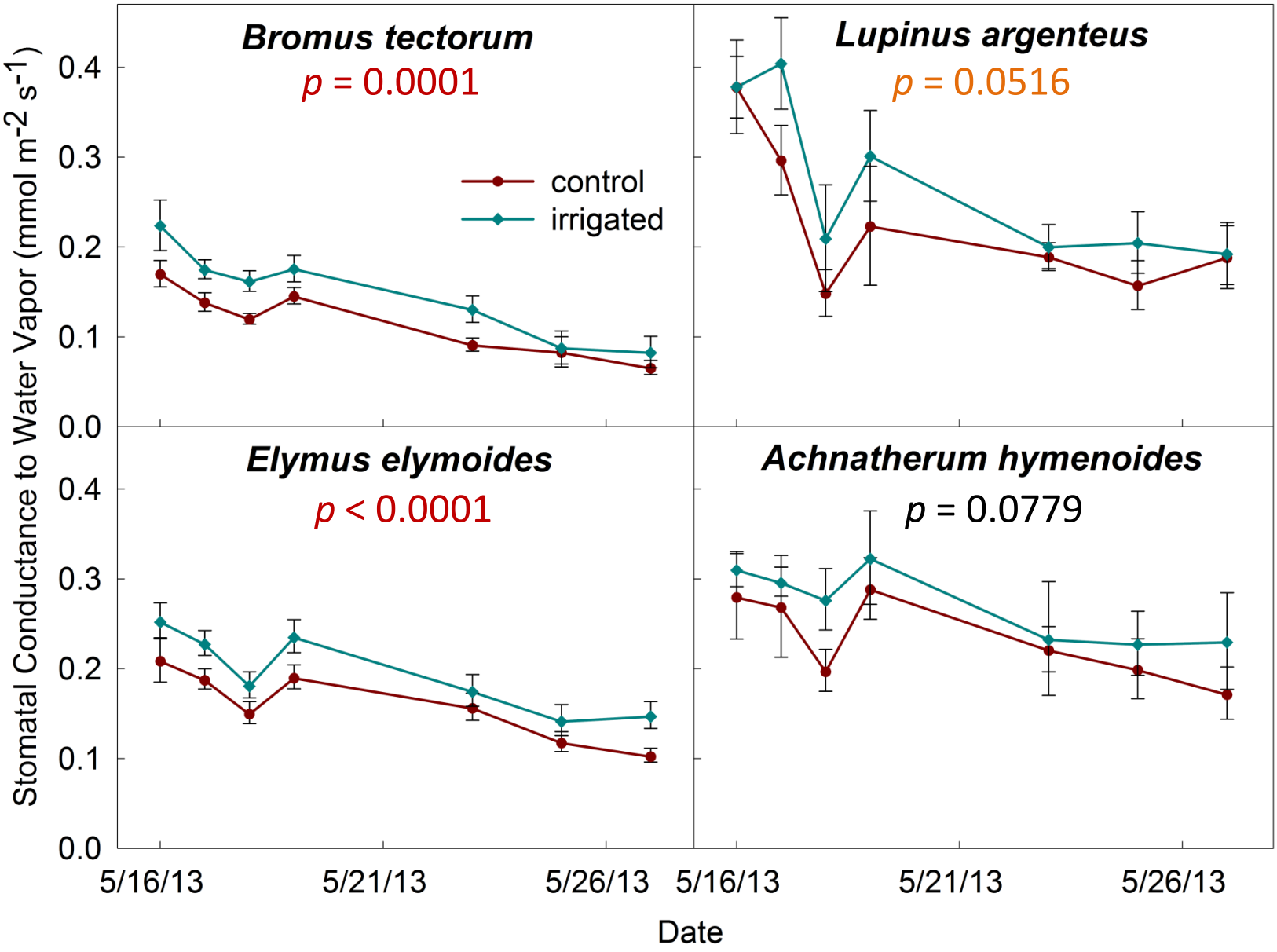
Photosynthesis (2013)



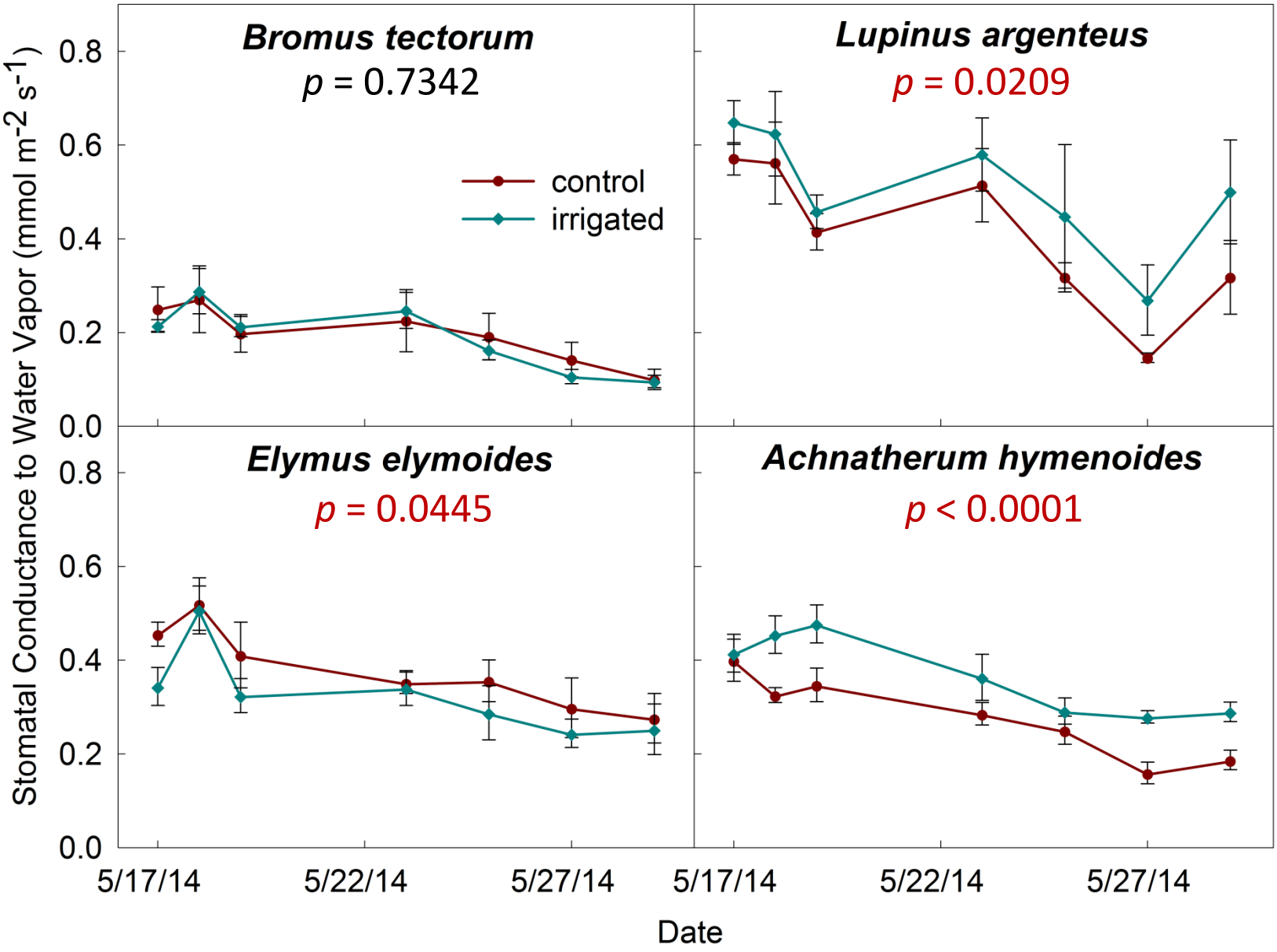
Photosynthesis (2014)



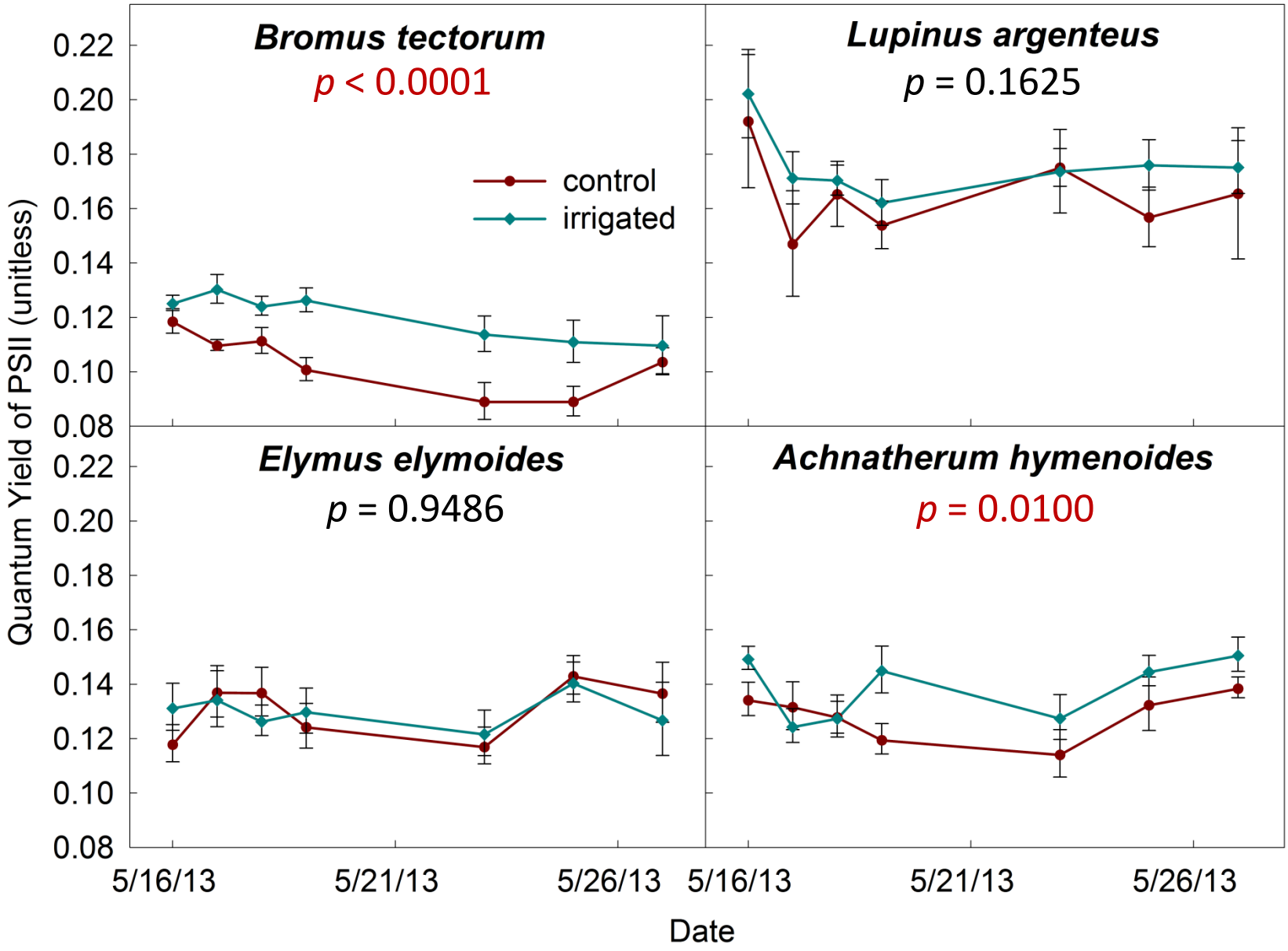
Stomatal Conductance (2013)



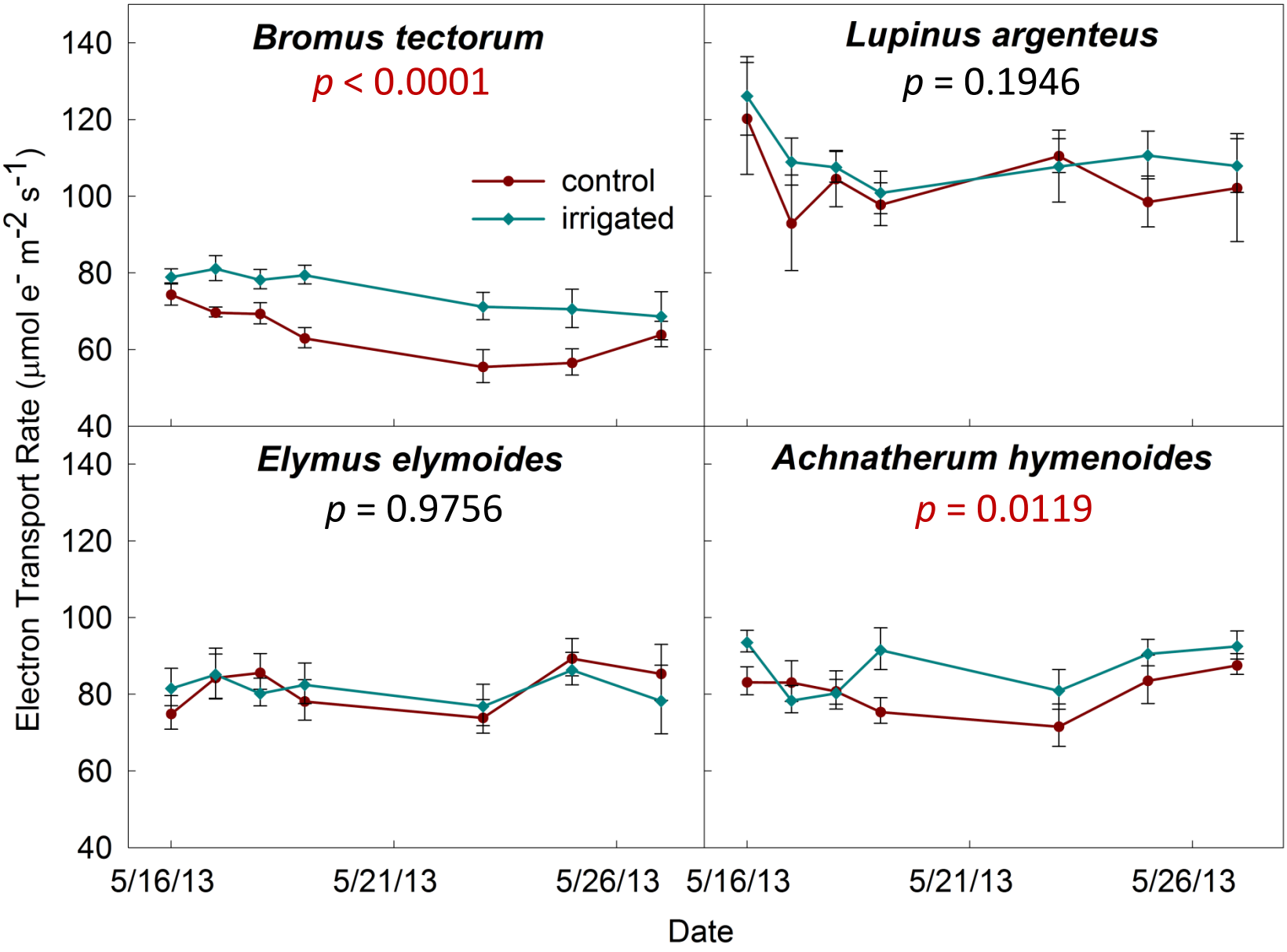
Stomatal Conductance (2014)



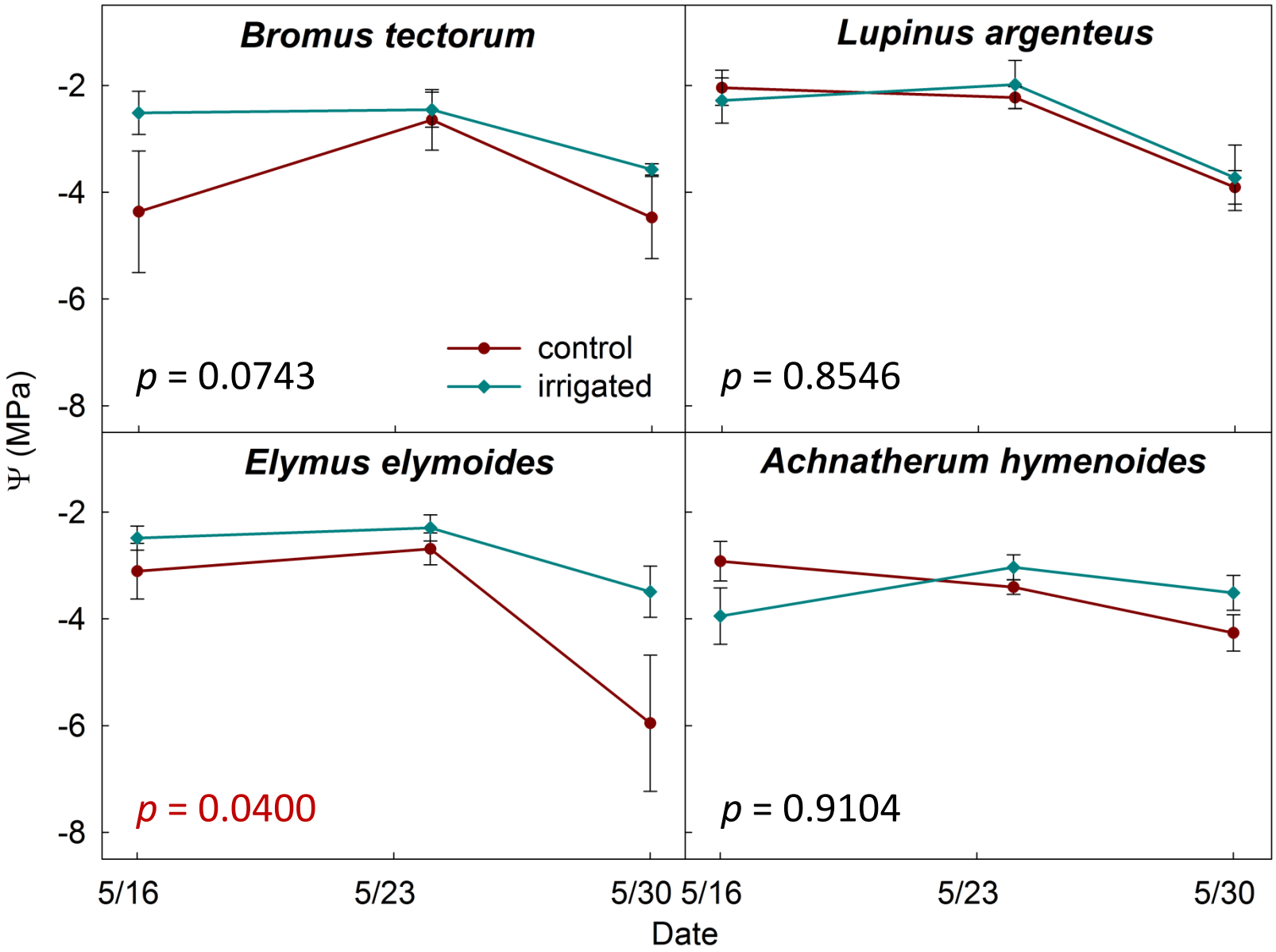
Quantum Yield of Photosystem II (2013)



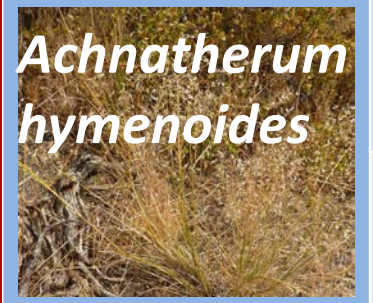
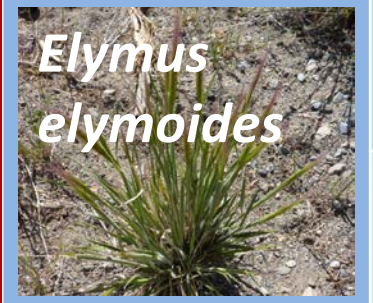
Electron Transport Rate (2013)



Water Potential (2014)



Rainfall Timing: Summer

Species	Variable	June (2013)	July (2012)	August (2012)
 *Achnatherum hymenoides*	Photo	NS	$p < 0.0001$	$p = 0.0002$
	Cond	NS	$p < 0.0001$	$p = 0.0048$
 *Elymus elymoides*	Photo	NS	$p < 0.0107$	NS
	Cond	$p = 0.0526$	NS	NS
 *Lupinus argenteus*	Photo	NS	$p = 0.0549$	Too much mortality
	Cond	NS	$p = 0.0569$	Too much mortality

Conclusions

- Relative strength of responses to precipitation change varied seasonally, annually, by species, and by precipitation type

- Predicted shifts from snow to rain could facilitate *B. tectorum* expansion at high elevation depending on the timing of rainfall events and antecedent precipitation

I listened carefully for clues whether the West has accepted cheat as a necessary evil, to be lived with until kingdom come, or whether it regards cheat as a challenge to rectify its past errors in land-use. ***I found the hopeless attitude almost universal.***

—Aldo Leopold, *A Sand County Almanac* (1949); p. 165

Informing Management Decisions: Uncertain precipitation projections with climate change highlight the importance of continued research regarding how *B. tectorum* may respond to climate change

Management Responses: Small window of opportunity to manage invasions necessitates close monitoring of high-elevation spread and areas at risk of *B. tectorum* encroachment

Valentine Camp (~2,500 m elevation), Valentine Eastern Sierra Reserve, Mammoth Lakes, CA

Acknowledgements

Committee: Dr. Michael E. Loik, Dr. Weixin Cheng, Dr. Brent Haddad, Dr. Constance Millar

Loik lab, past & present

Thank you!

Funding sources

Mildred E. Mathias Graduate Student Research Grant

Northern California Botanists Graduate Research Scholarship

Benjamin and Ruth Hammett Award

Valentine Eastern Sierra Reserve Graduate Student Research Grant

UCSC Environmental Studies Department

Other assistance: Amy Concilio, Sharifa Crandall, Melissa Cruz, Dustin Mulvaney, Devyn Orr, Lewis Reed, Kayla Spawton