Grassland ecosystems and climate change: Insights from experiments

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Knowledge to Go Places

NRI Knowledge For Tomorrow's Solutions

NIGEC

The Nature Conservancy
Saving the Last Great Places

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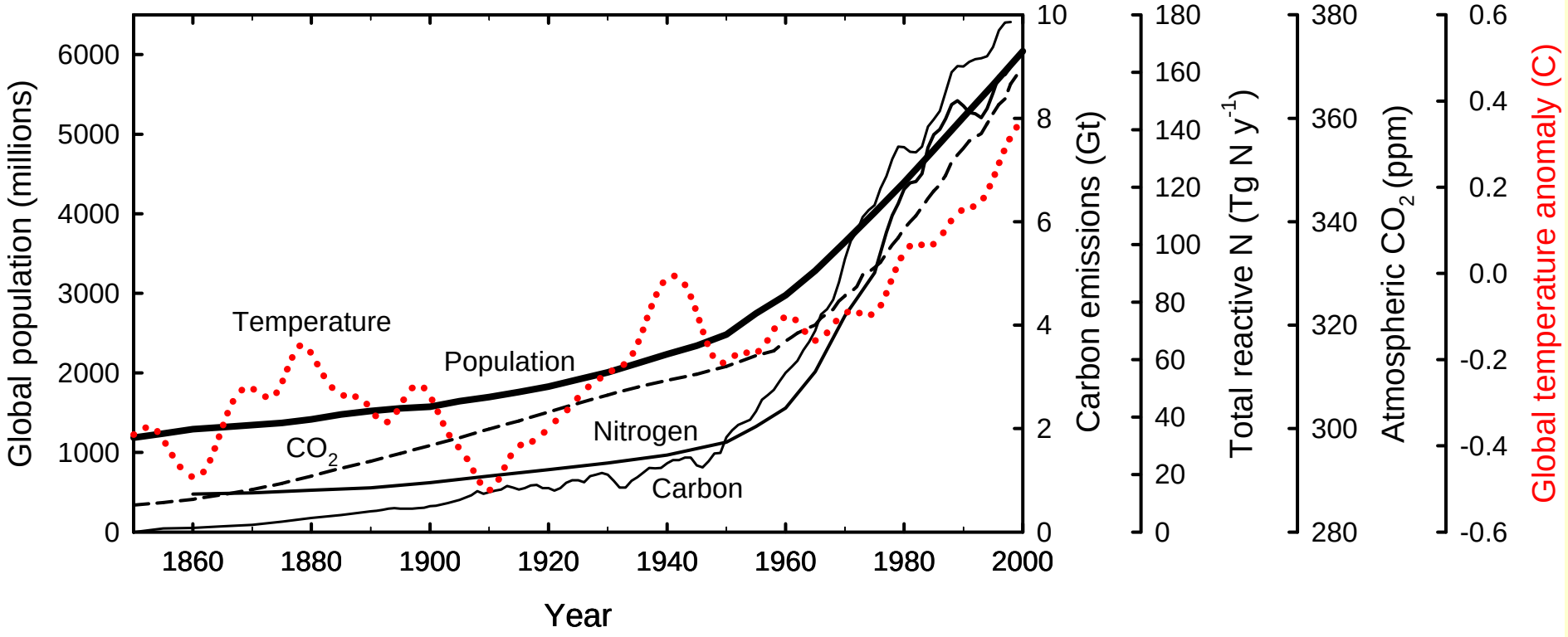
KONZA PRAIRIE BIOLOGICAL STATION

K-STATE Kansas State University

…we are changing Earth more rapidly than we are understanding it.

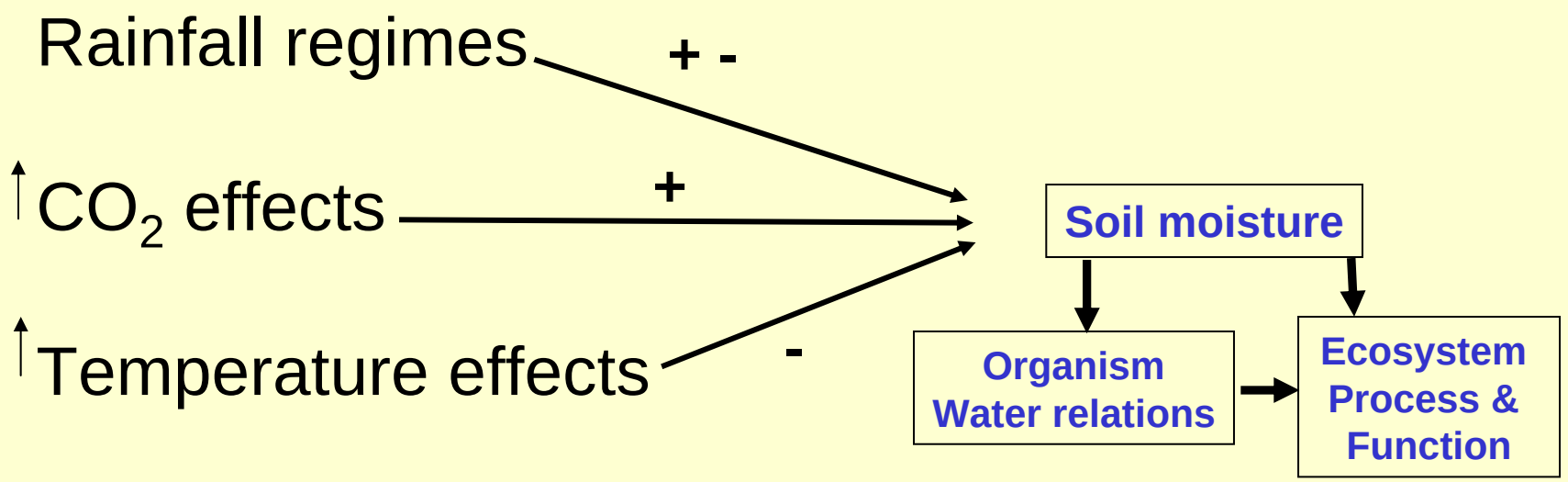
-Vitousek et al. 1997

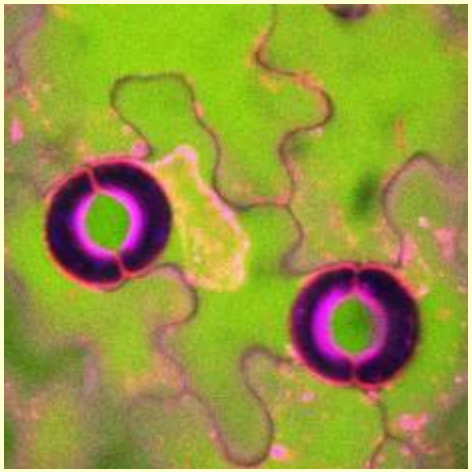


What do we know?

We know that climate change is chronic and directional, but also that variability will be increased

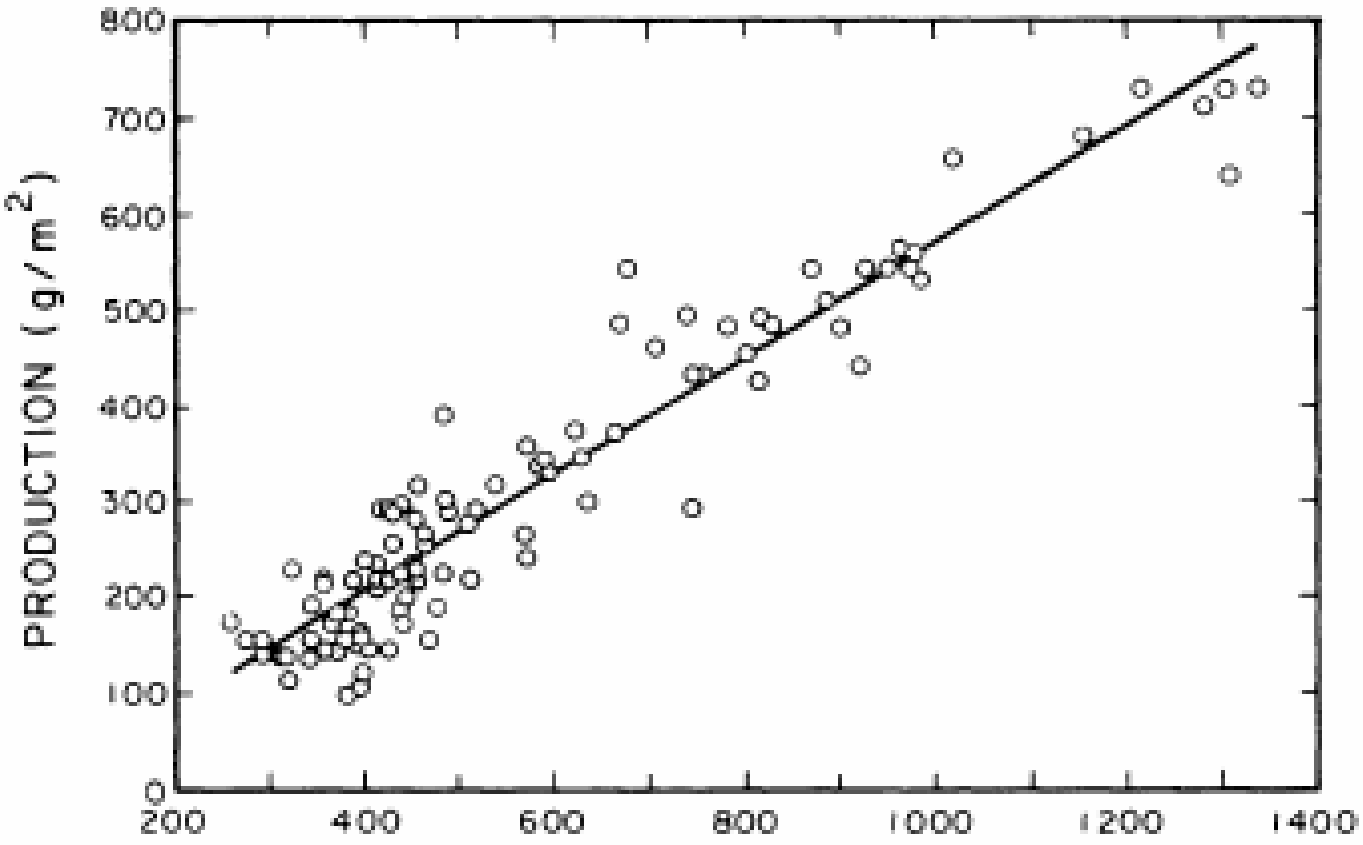
Global changes in rainfall, temperature and CO_2 can be linked in most ecosystems through their *indirect* effects…





NA Grasslands (most) are water limited systems and precipitation amount predicts spatial patterns of ANPP well…

Rainfall vs. Production across the Central US



Sala et al. 1988

What do we need to know?

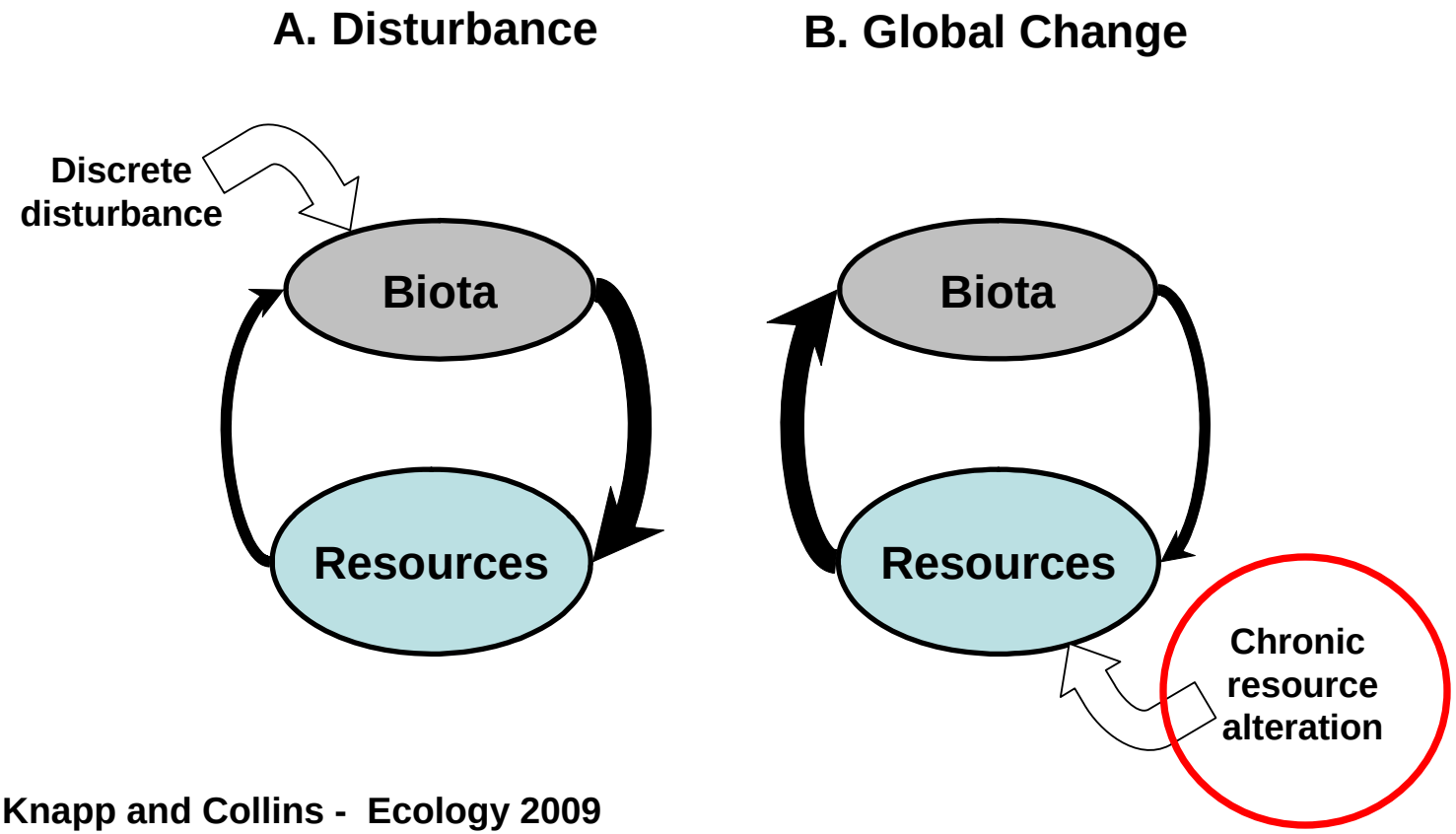
How will climate change affect earth's ecosystems?

Can we forecast the future?

"I would not say that the future is necessarily less predictable than the past. I think the past was not predictable when it started."

~Former Defense Secretary Donald Rumsfeld

How we “think” - A resource perspective…

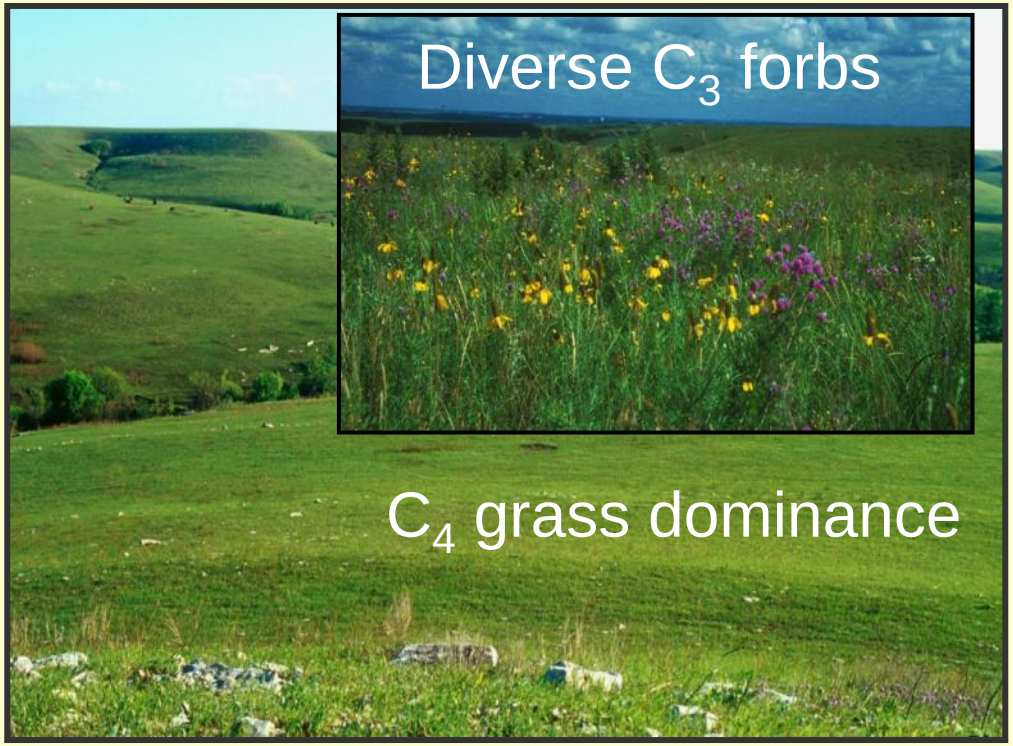


- Smith, Knapp and Collins - Ecology 2009

Moving from a “disturbance centric” world

Mesic Grasslands of North America
The Flint Hills of Kansas – The Konza Prairie

A dynamic & tractable system



- Tallgrass prairie is the most mesic of Great Plains grasslands – sufficient precipitation to support forest
- Flint Hills are located at the dry edge of the original range of tallgrass prairie – Mean annual precipitation = 835 mm

Chronic (water) resource addition

What is the degree of water limitation in this “mesic” grassland?

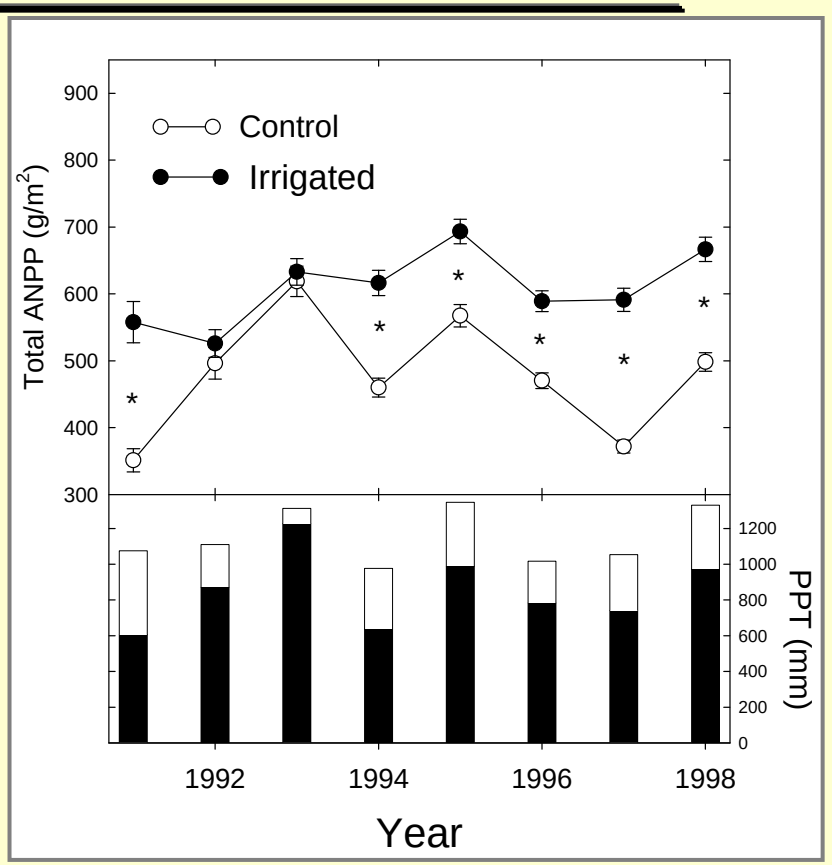
If water is limiting this system, what are the consequences of a chronic change in resource abundance (soil moisture)?

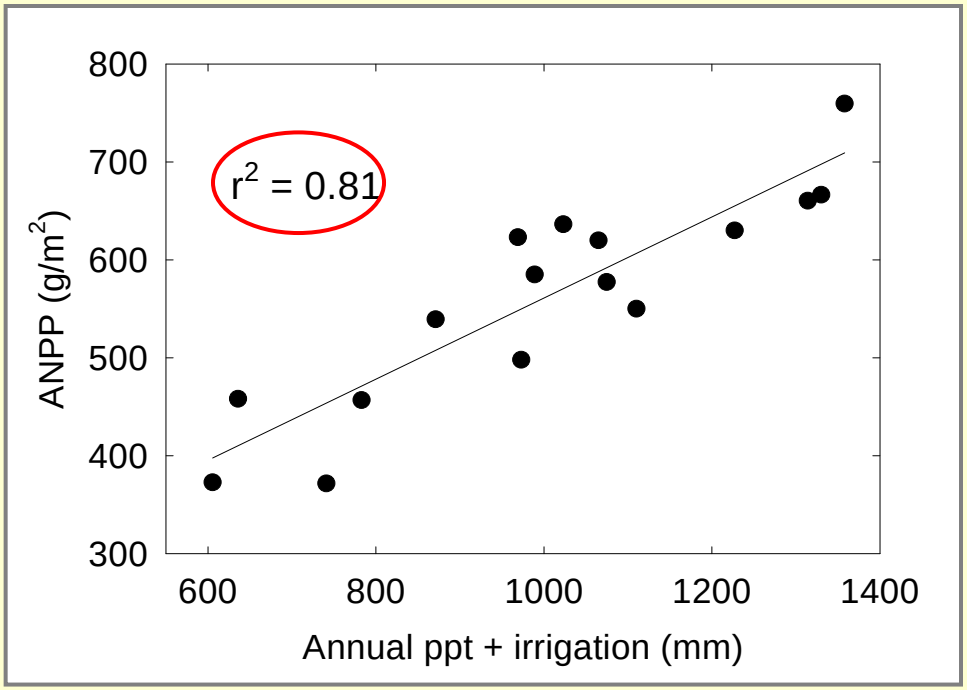
Long-term Irrigation Study

- Treatments initiated in 1991
- Supplemental water added during the growing season to replicate 140 m transects (paired with control transects)
- Designed to meet plant water demand and minimize intra-annual variability in soil water deficits

Summary of the first eight years…

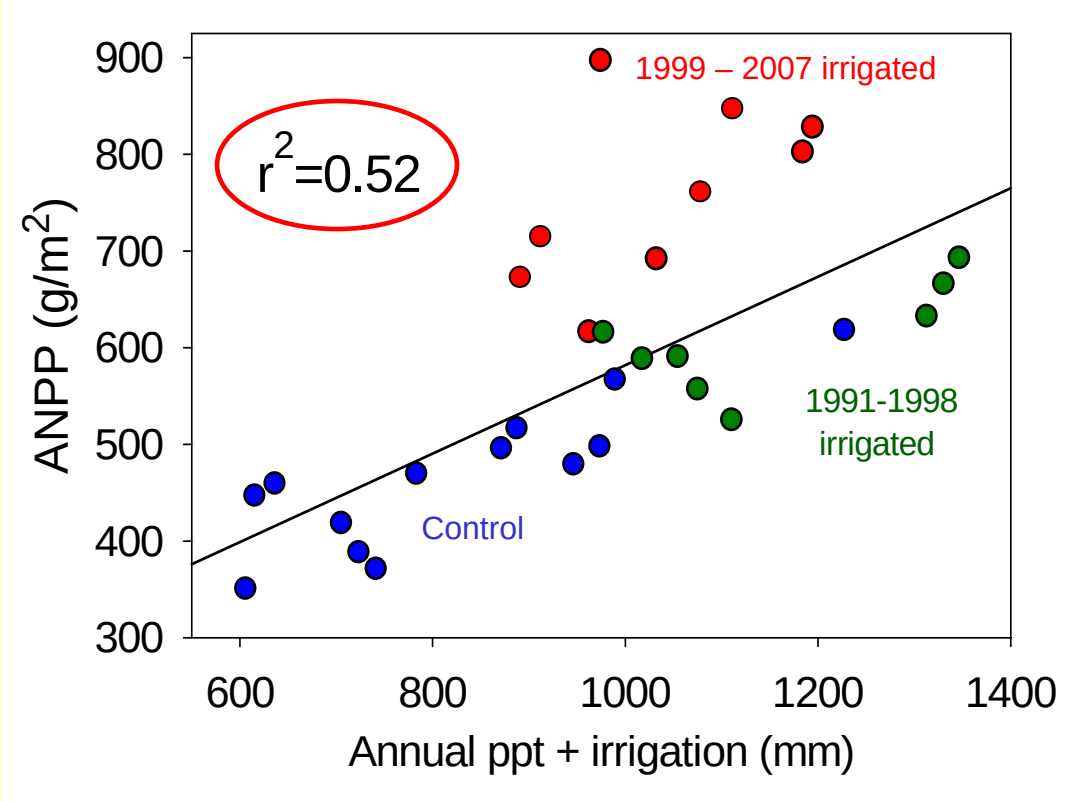
- Water availability limited ANPP 6 out of 8 years
- Irrigation increased ANPP by ~25% (physiological response)

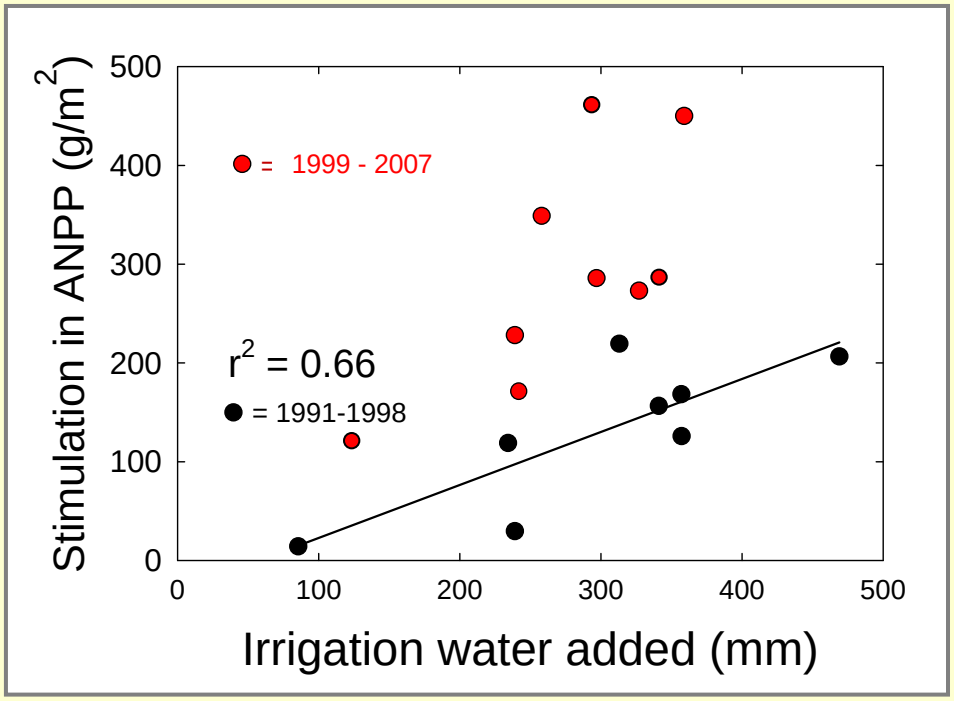




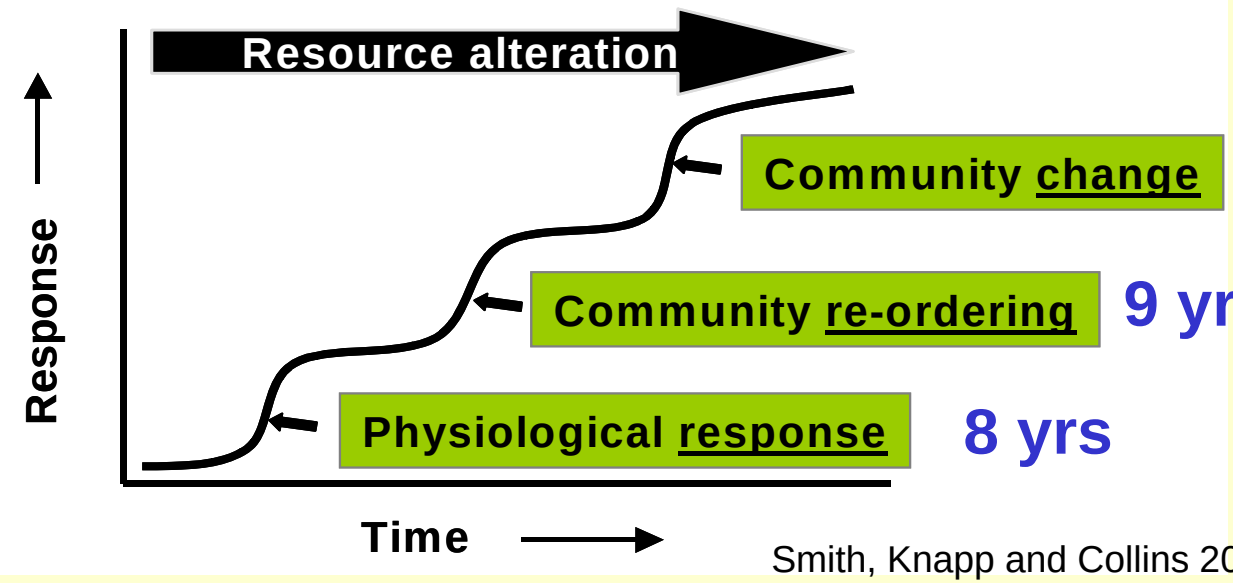
The value of long-term experiments…(+15 years)

- Mean increase in ANPP for the next nine years was 65% (vs. 25%)
- An 8 year lagged response…



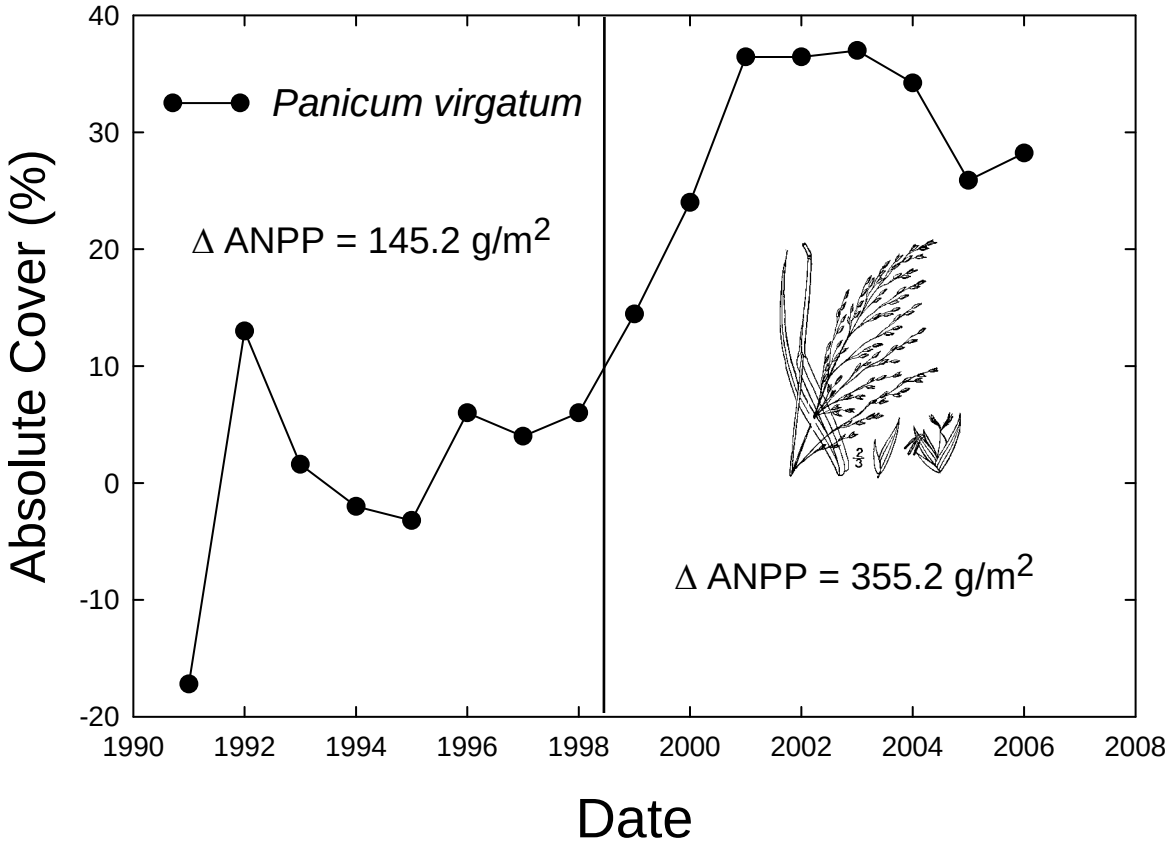


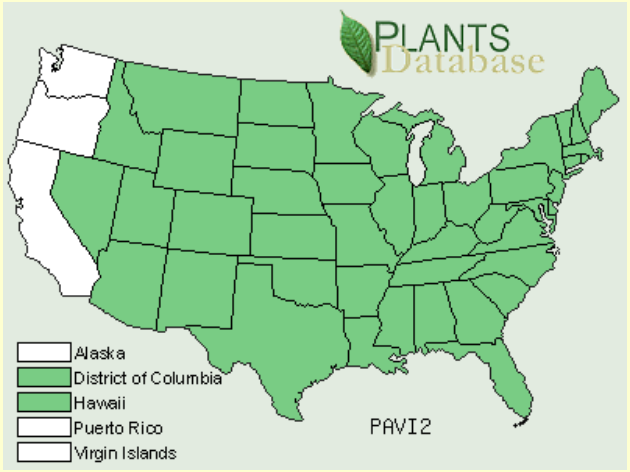
What would change the relationship between ANPP and precipitation?

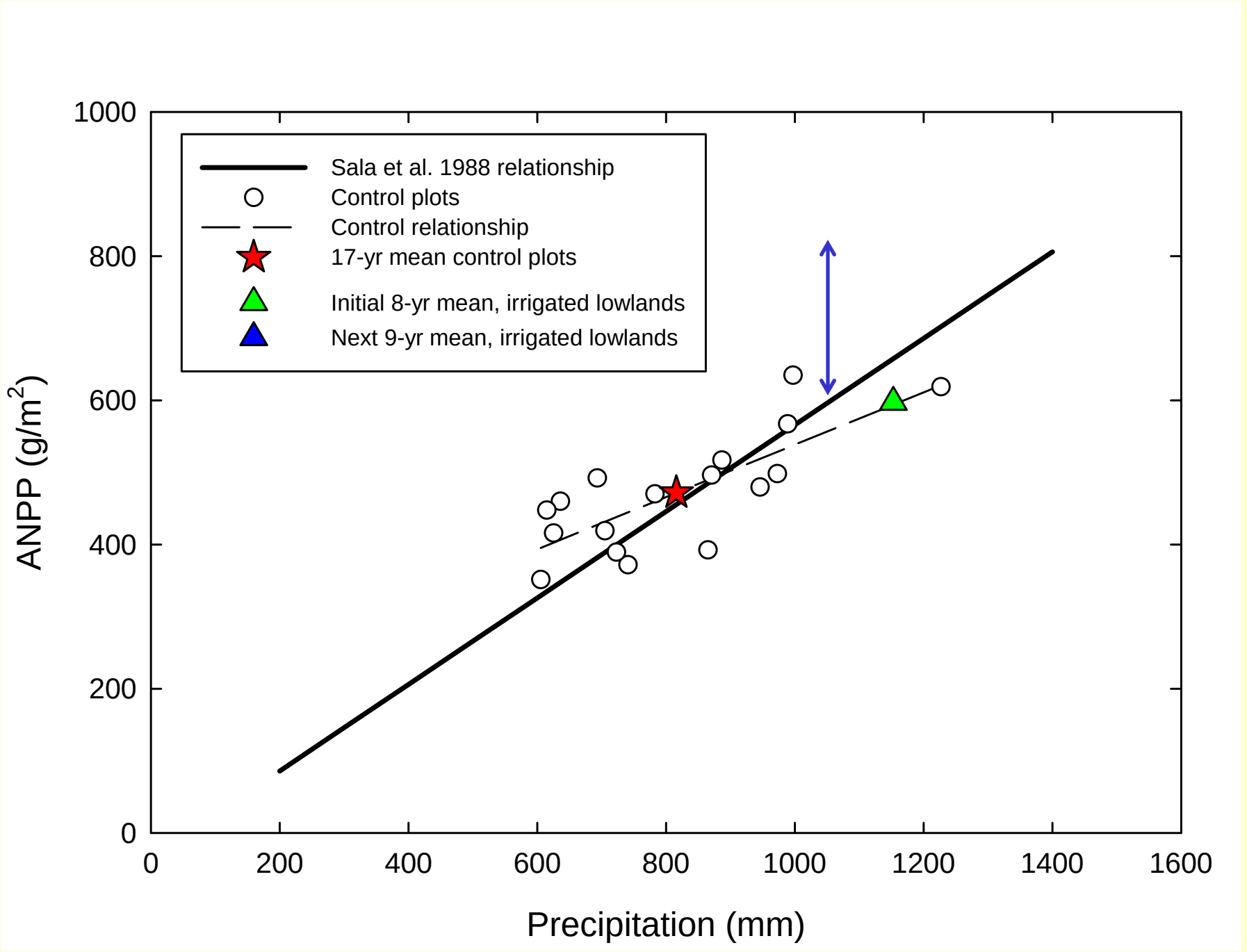


Smith, Knapp and Collins 2009

Difference in Absolute cover between Irrigation and Control transects



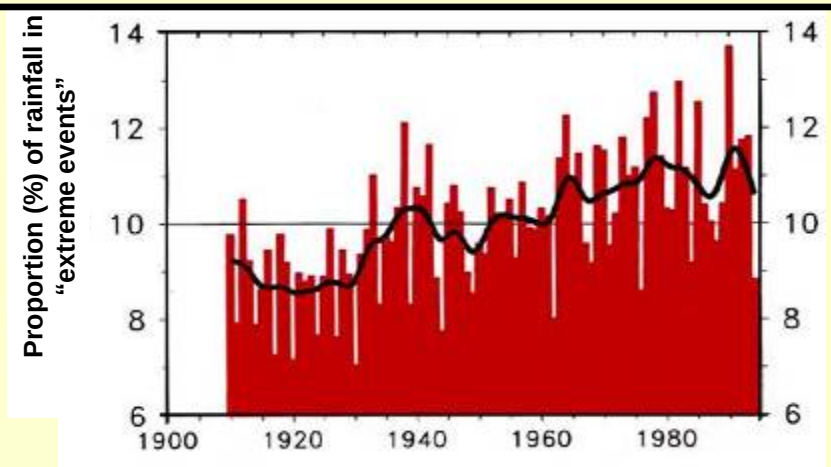



Sala et al. 1988 relationship
Control plots
Control relationship
17-yr mean control plots
Initial 8-yr mean, irrigated lowlands
Next 9-yr mean, irrigated lowlands
ANPP (g/m2)
Precipitation (mm)
0
200
400
600
800
1000
1200
1400
1600

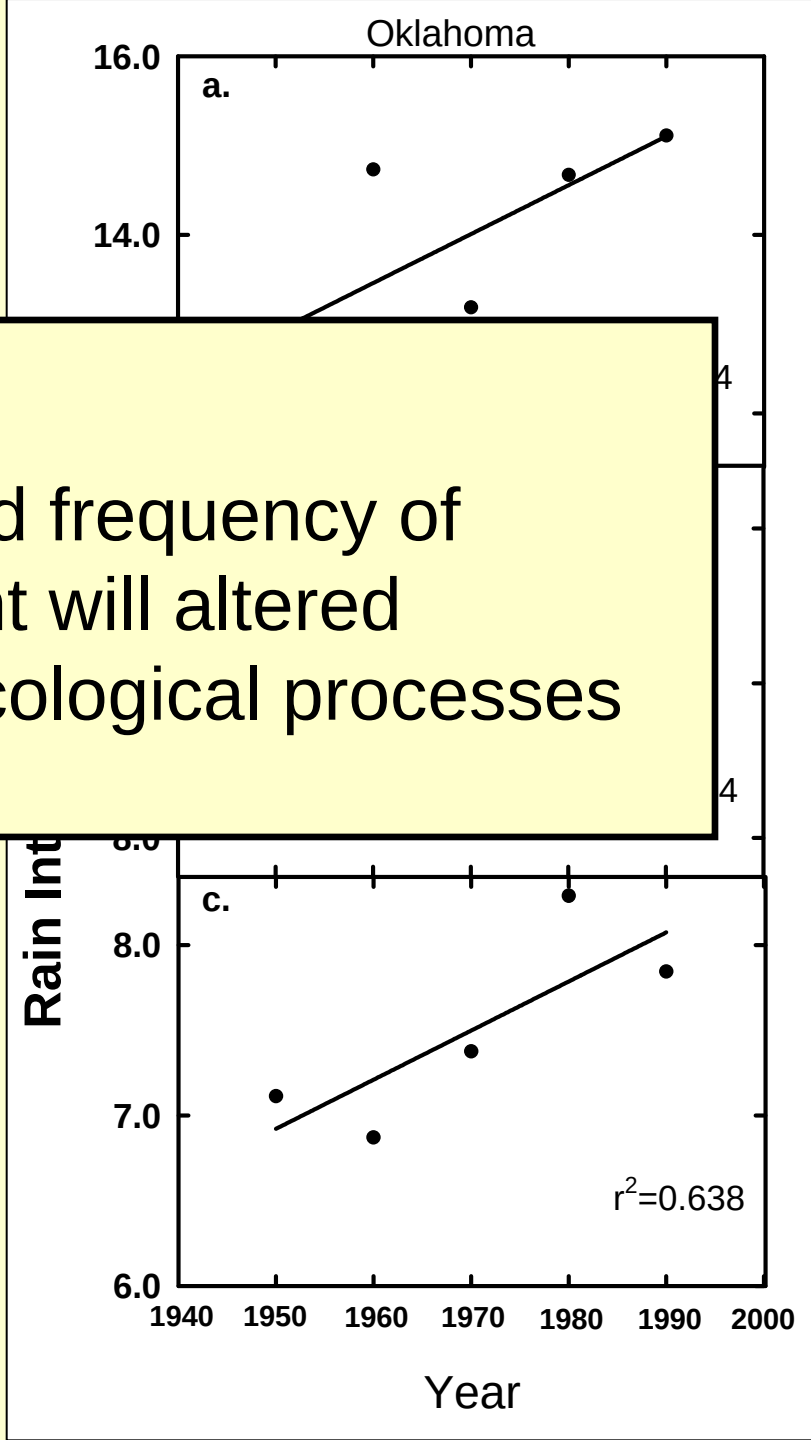
Abundant evidence that rainfall regimes are changing

Question:

Given increased variability and frequency of extreme events, to what extent will altered precipitation patterns affect ecological processes in “mesic” grasslands?



Proportion of total rainfall in the US from large (>5 cm) rainfall events

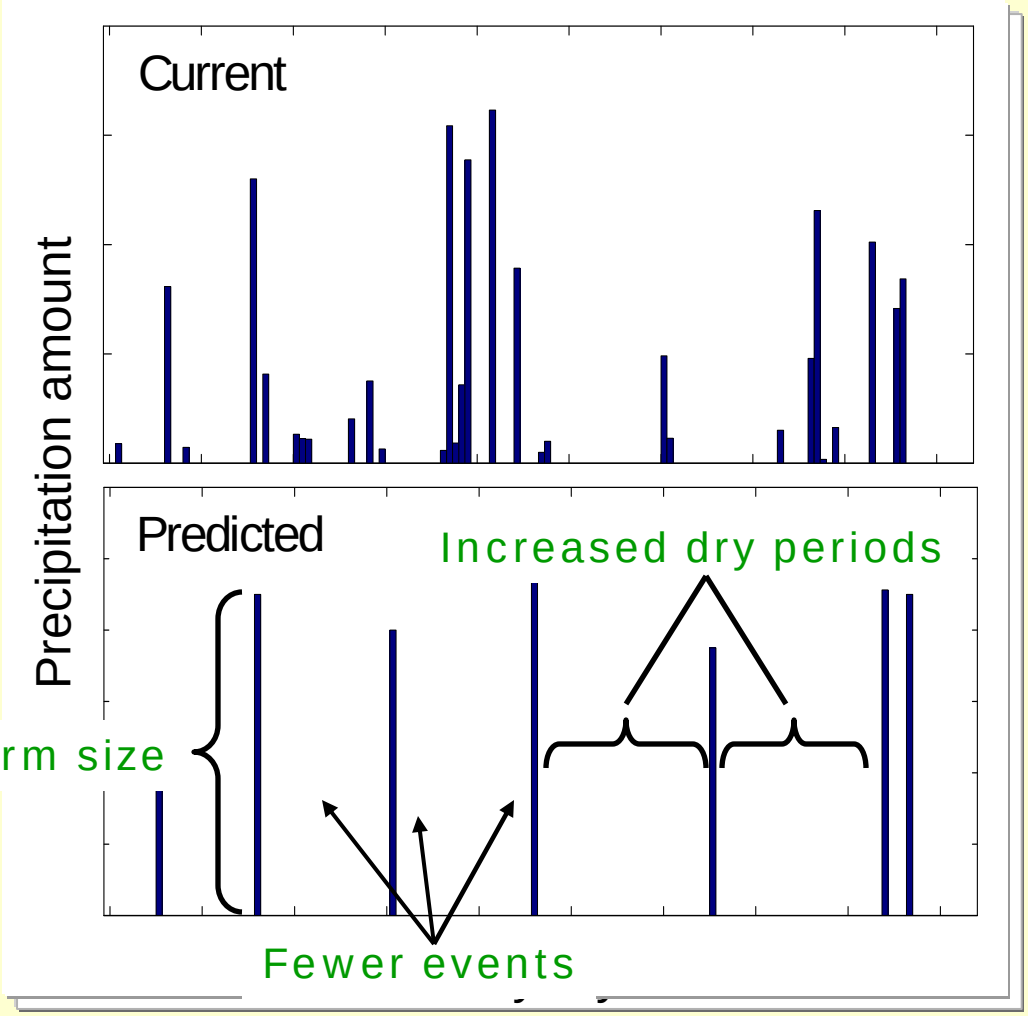


The Rainfall Manipulation Plot (RaMP) Experiment

Address the impact of changes in ***size and timing*** of growing season rainfall

- 12 rainfall manipulation plots (RaMPs) + non-sheltered controls
- Collect, store, and reapply natural rainfall on intact prairie plots
- Treatments include ambient and altered rainfall patterns

Target altered rainfall pattern: 50% longer inter-rainfall periods, larger individual rain events



No change in total precipitation quantity

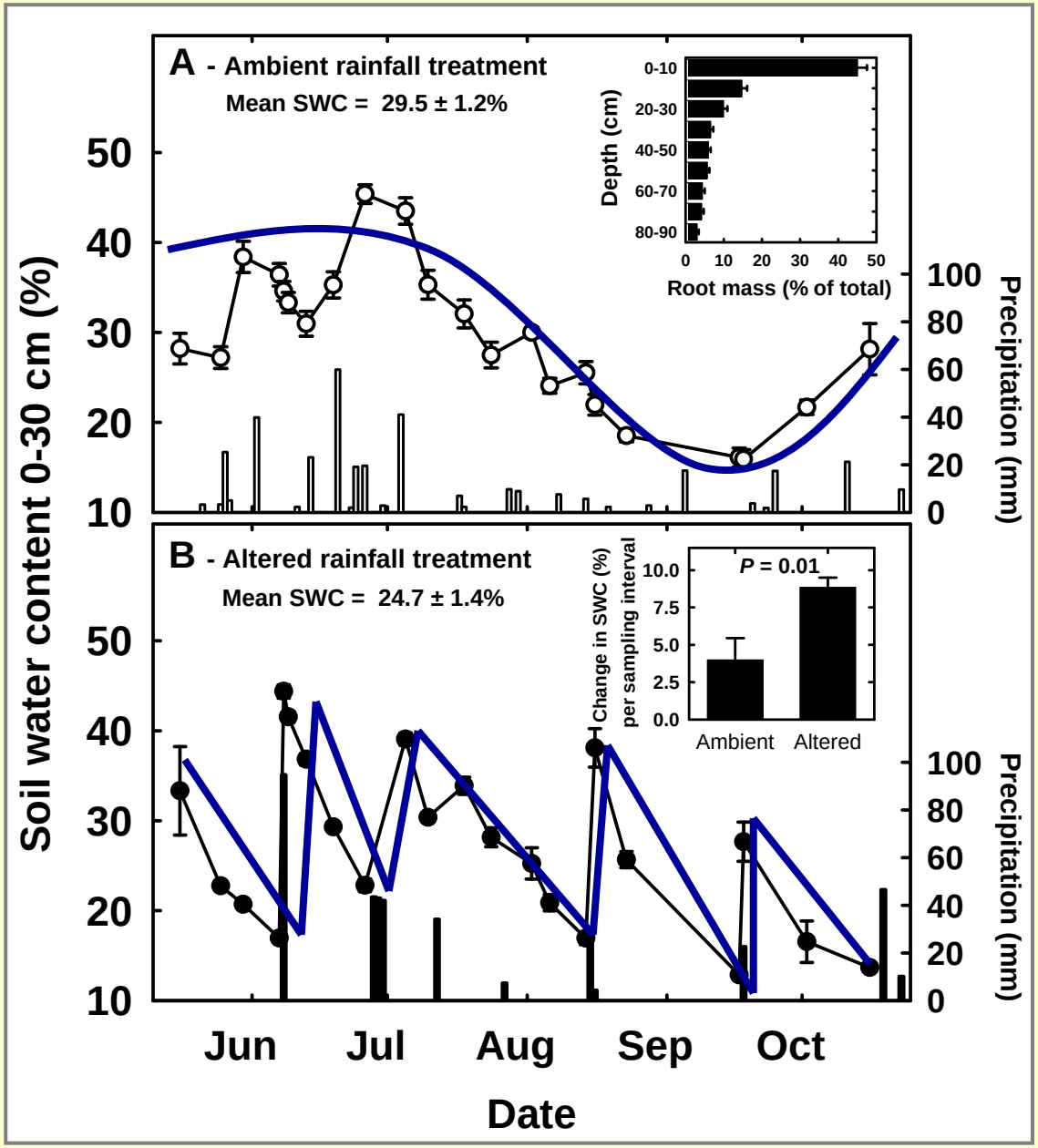
Key driver of responses: Soil moisture dynamics

Ambient ppt timing:
- "typical" seasonal pattern

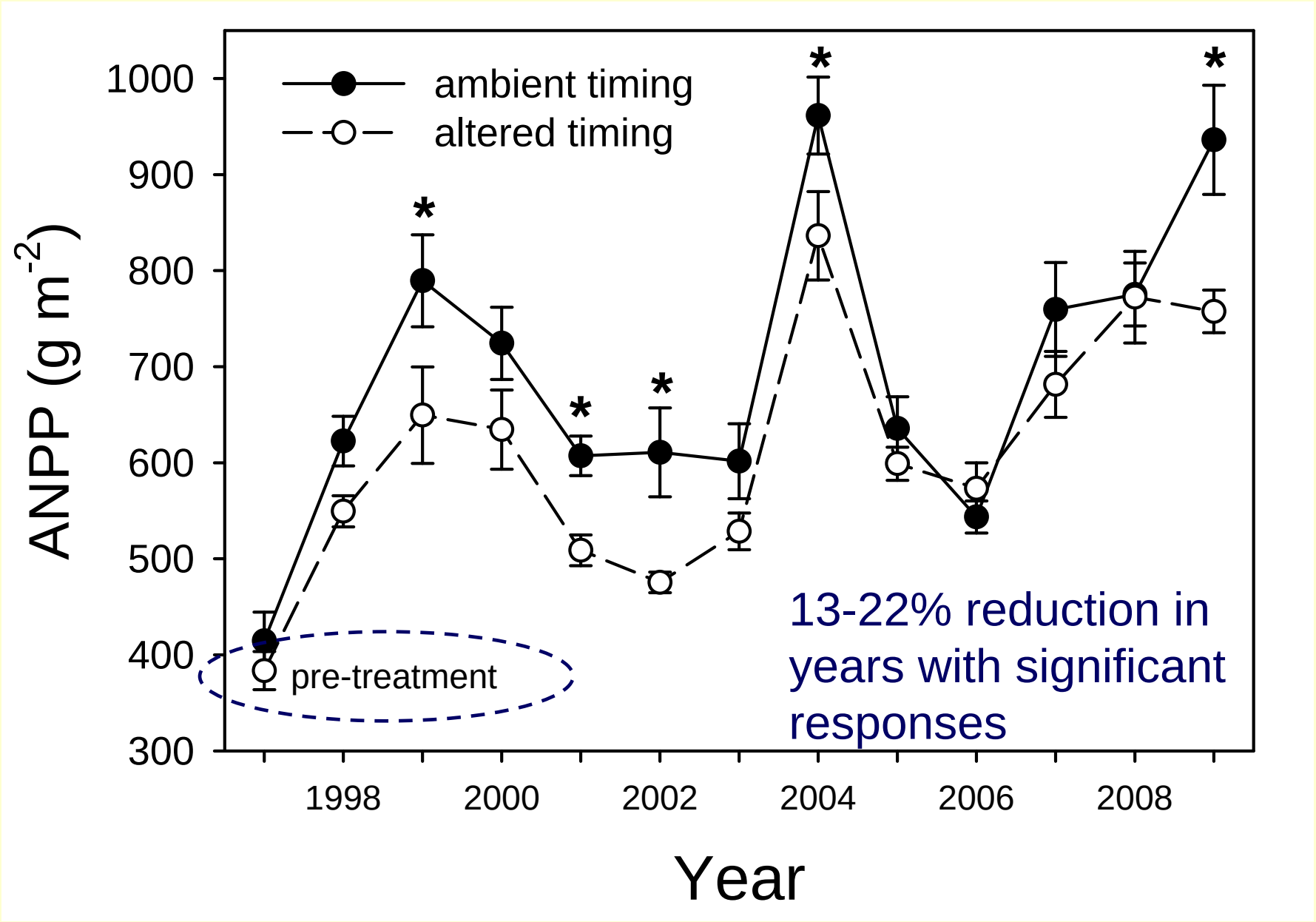
Altered ppt timing:
- repeated deficits
- more extreme wetting and drying cycles

Average soil water content in top 30 cm:
- reduced by 12%

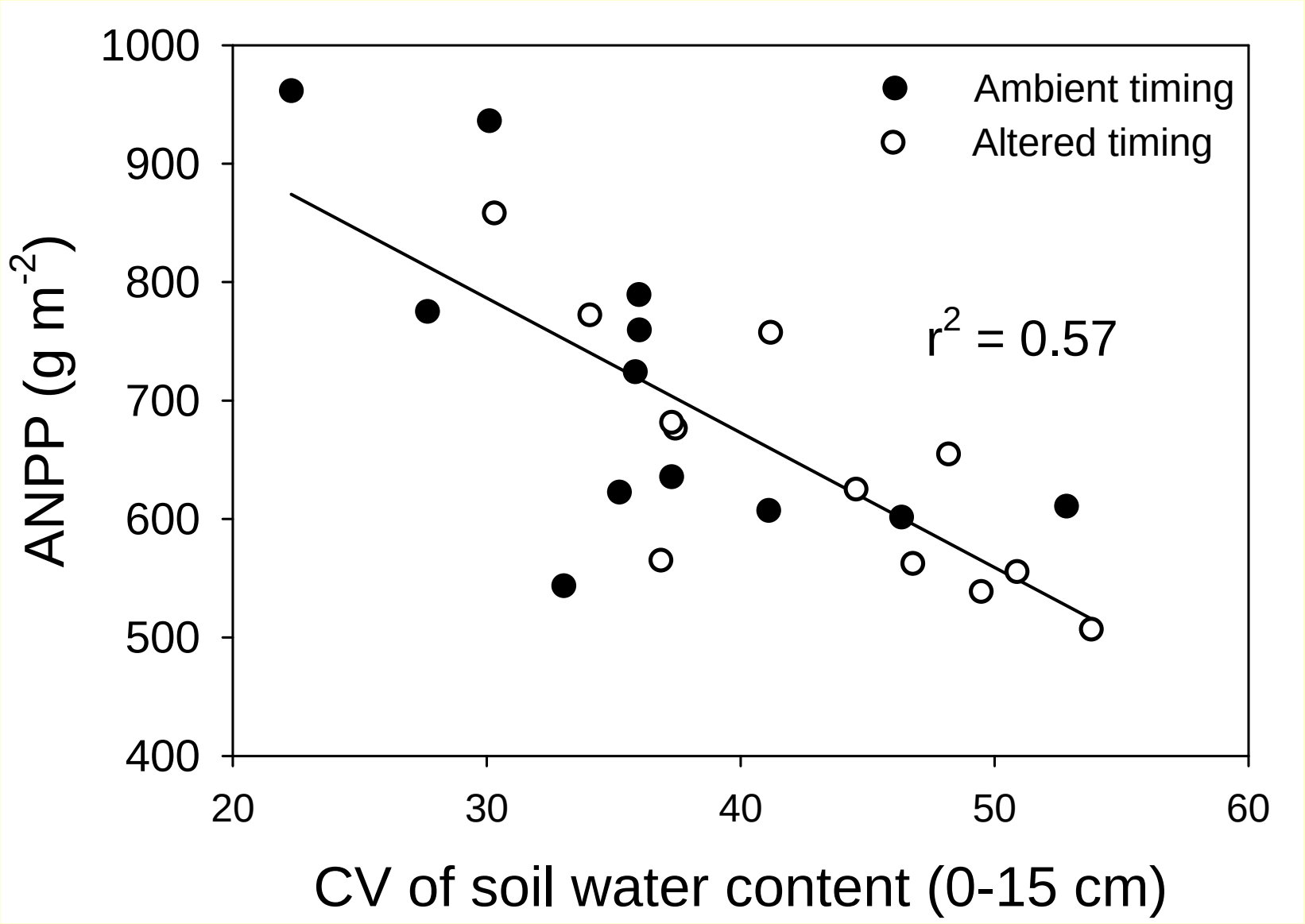
Variability in soil moisture:
- increased by 27%



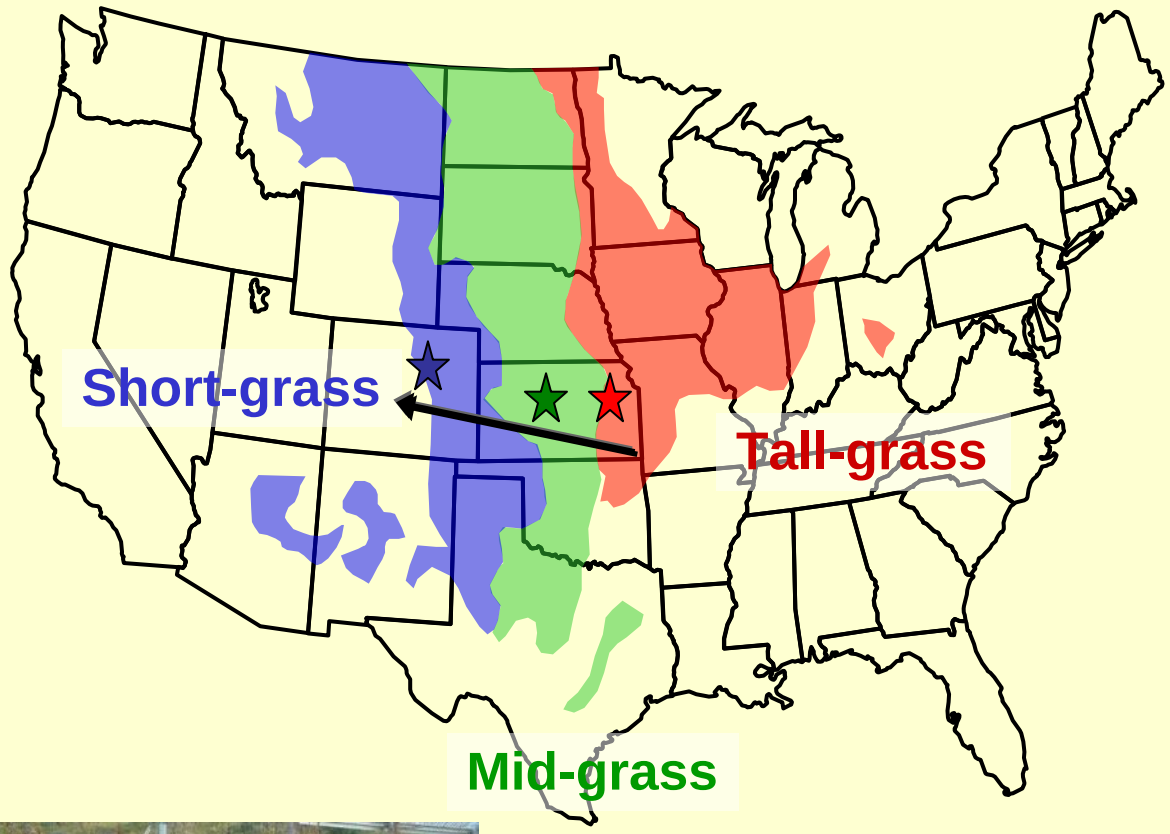
ANPP responses to altered rainfall timing

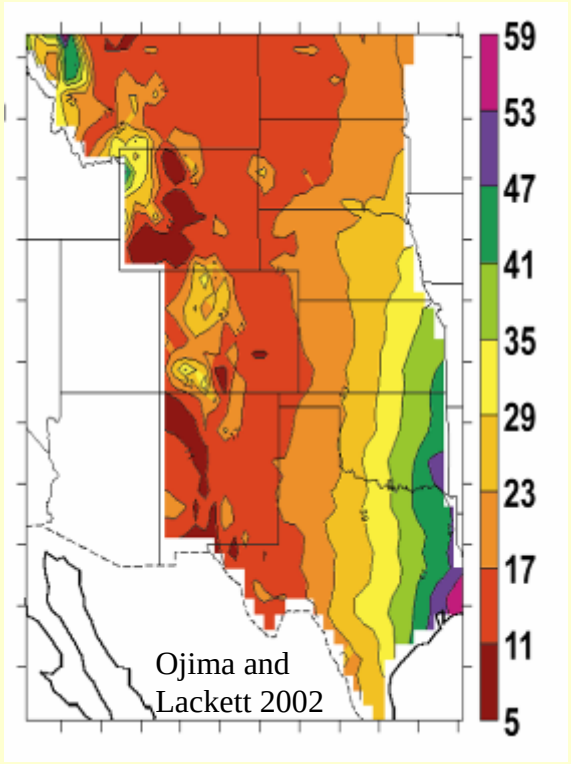


Across all years and all rainfall treatments



A regional assessment





Precipitation gradient

Jana Heisler-White et al. 2009. Contingent productivity responses to more extreme rainfall regimes across a grassland biome. *Global Change Biology* 15:2894-2904.

Experimental alteration of rainfall patterns across the Great Plains of North America

Frequent, small events

vs.

Fewer, infrequent large events

SGS

A = 12 events
B = 6 events
C = 4 events
Total = 191 mm

Jana Heisler

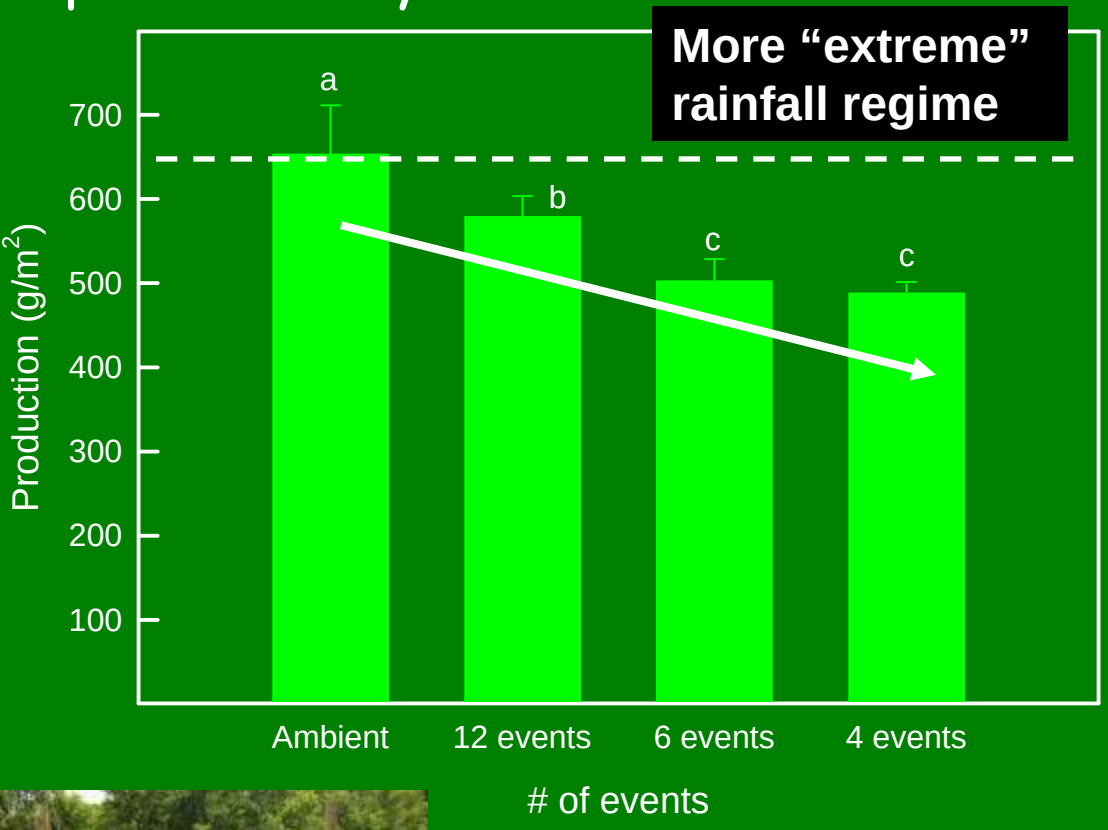
KNZ

A = 12 events
B = 6 events
C = 4 events
Total = 450 mm

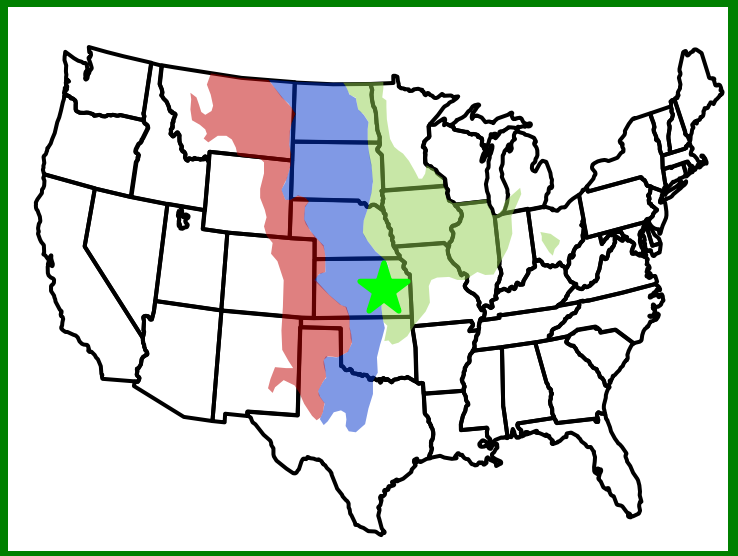
Semi-arid → Mesic

Mesic Grassland

Shift to more extreme (large) rainfall events → reduced productivity

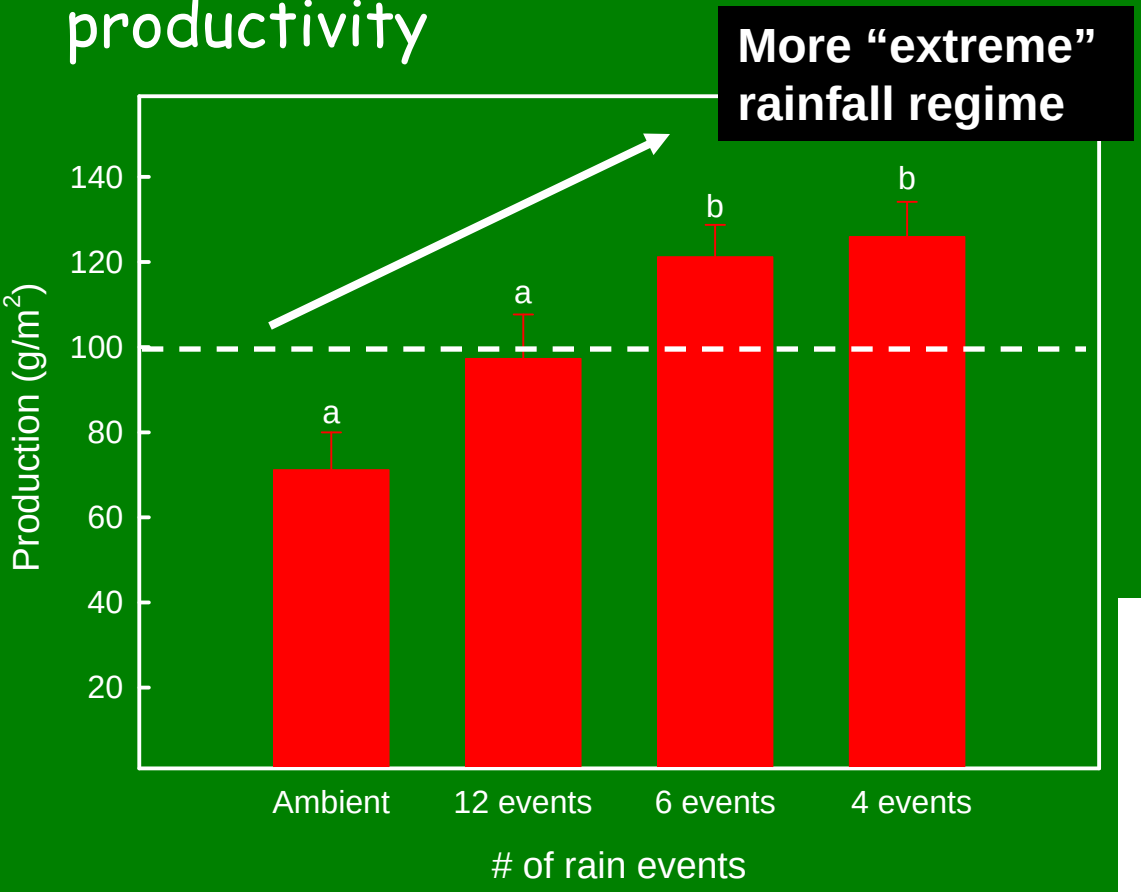


A shift from 12 to 4 events results in a 15% decrease in productivity.

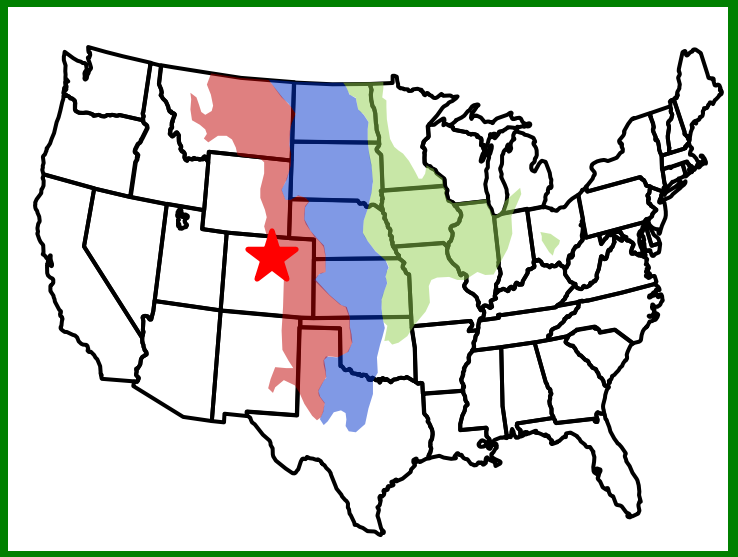


Semi-arid Grassland

Shift to more extreme (large) rainfall events → increased productivity

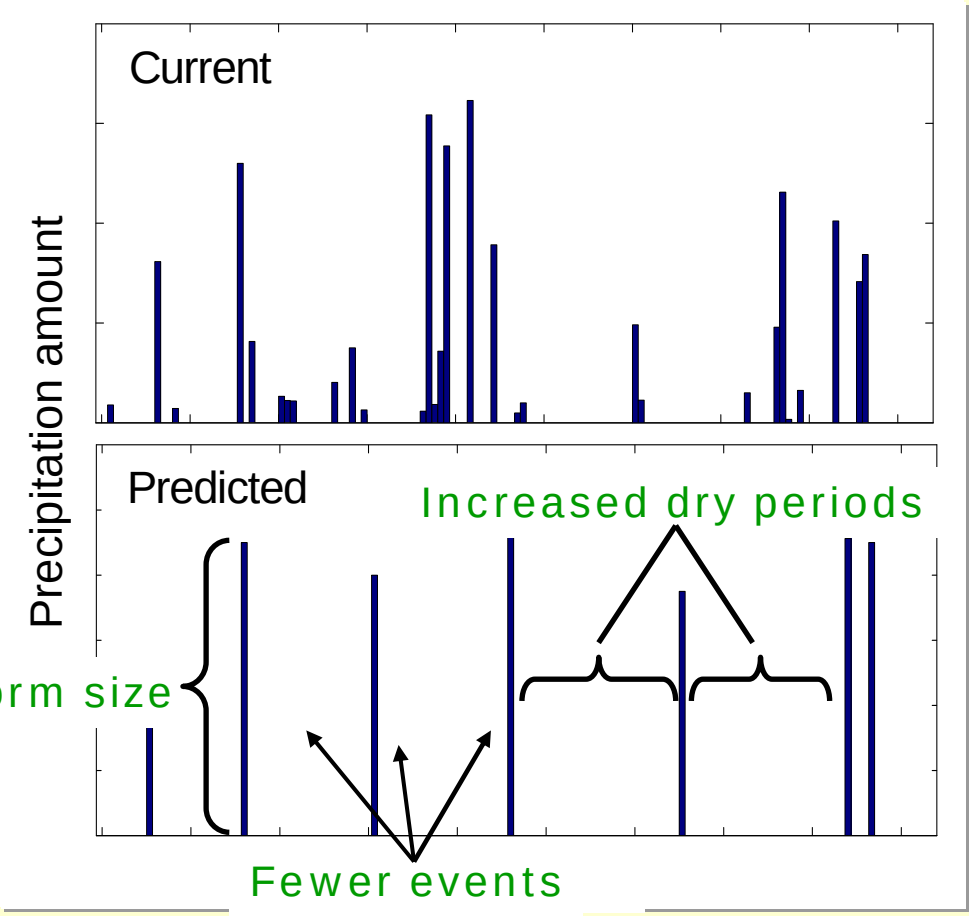


A shift from 12 to 4 events resulted in a 30% increase in productivity.



Why do arid vs. mesic grasslands respond differently?

Two aspects of more extreme rainfall regimes:



1. Larger rain events
2. Longer dry periods between events

When soils are usually moist, longer dry periods are most important…

When soil are already dry, larger rain events cause the greater response…

Where do we need to go with future field experiments?

We need more *long-term* experiments where we “push” ecosystems…

We need comparative analyses of ecosystem responses to climate change at large *spatial* scales…

Acknowledgements:

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