Assessing the Sensitivity of Grassland Ecosystems to Climate Change

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Graduate Degree Program in Ecology
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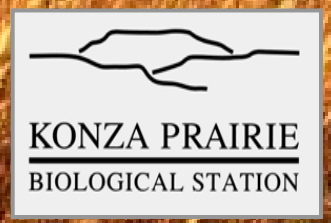
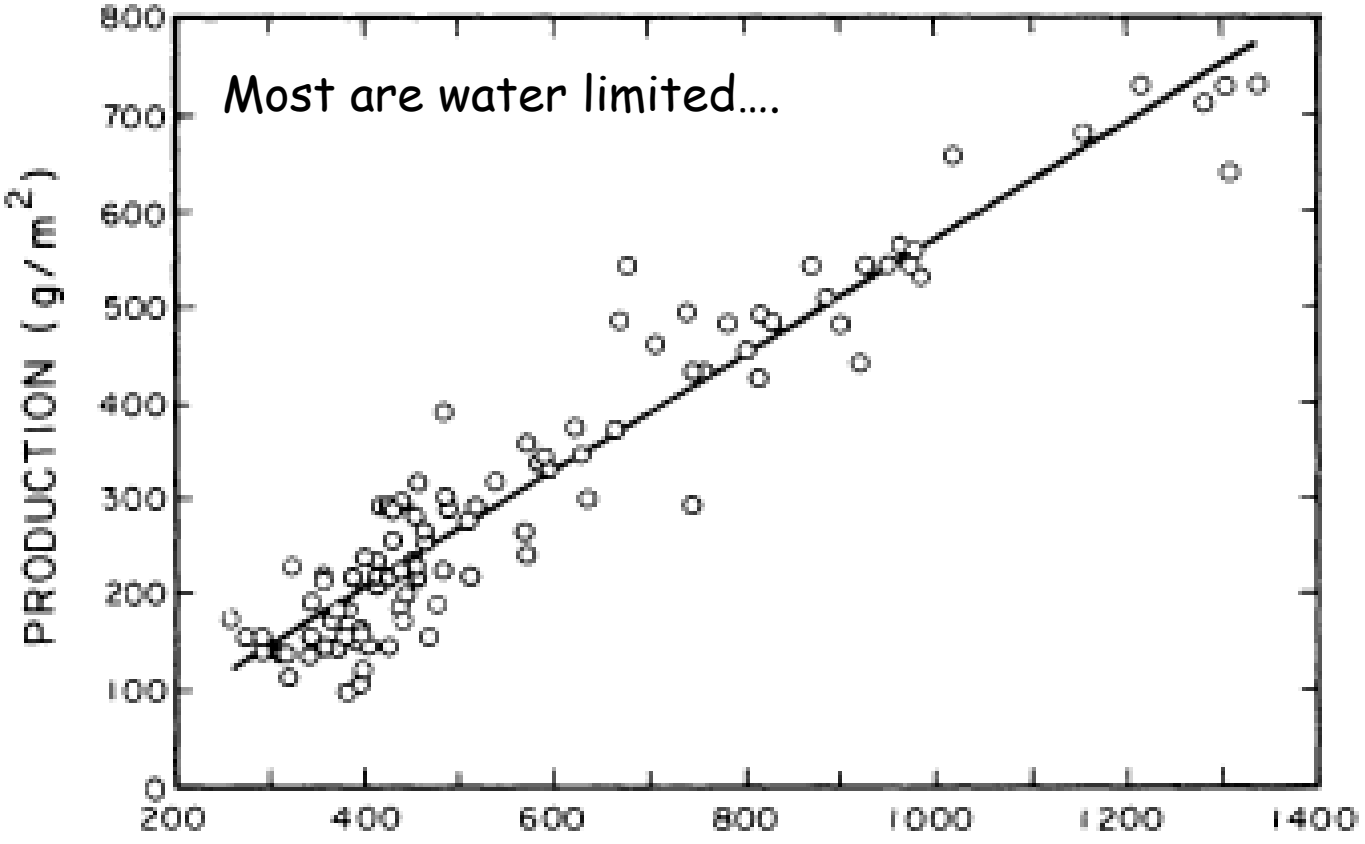


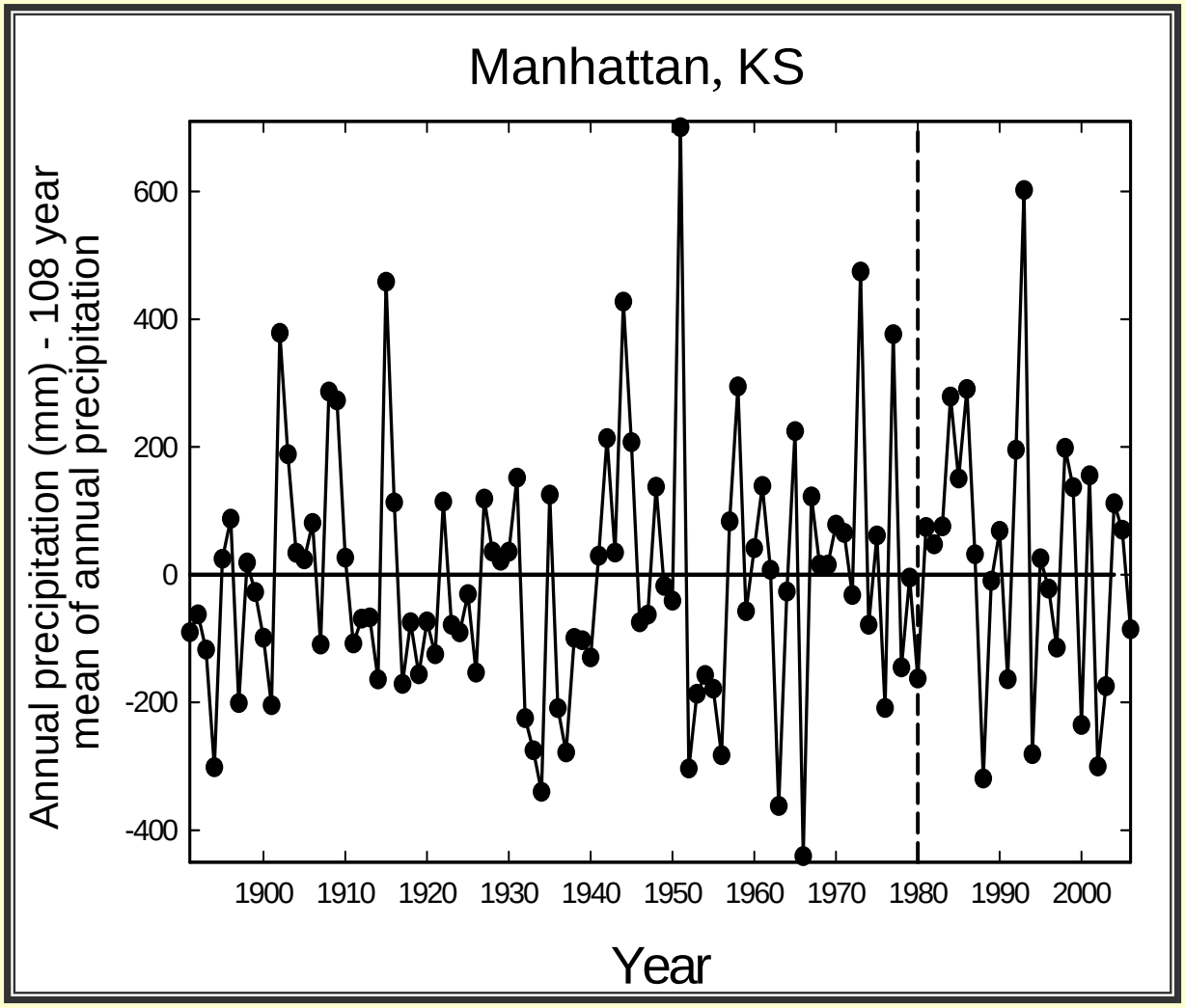
Setting the stage…



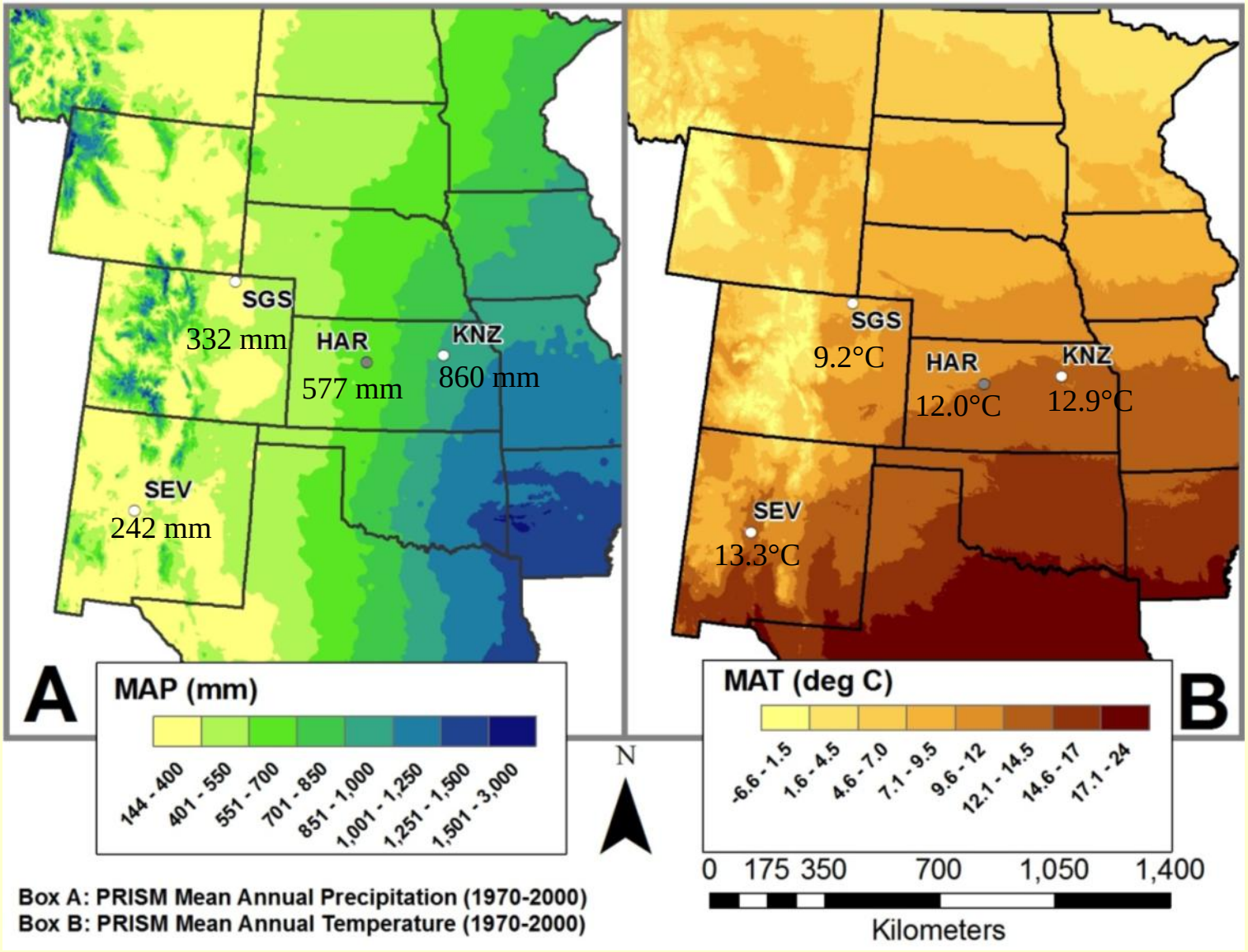
Sala et al. 1988

The climates of US grasslands are characterized by…

High interannual rainfall variability

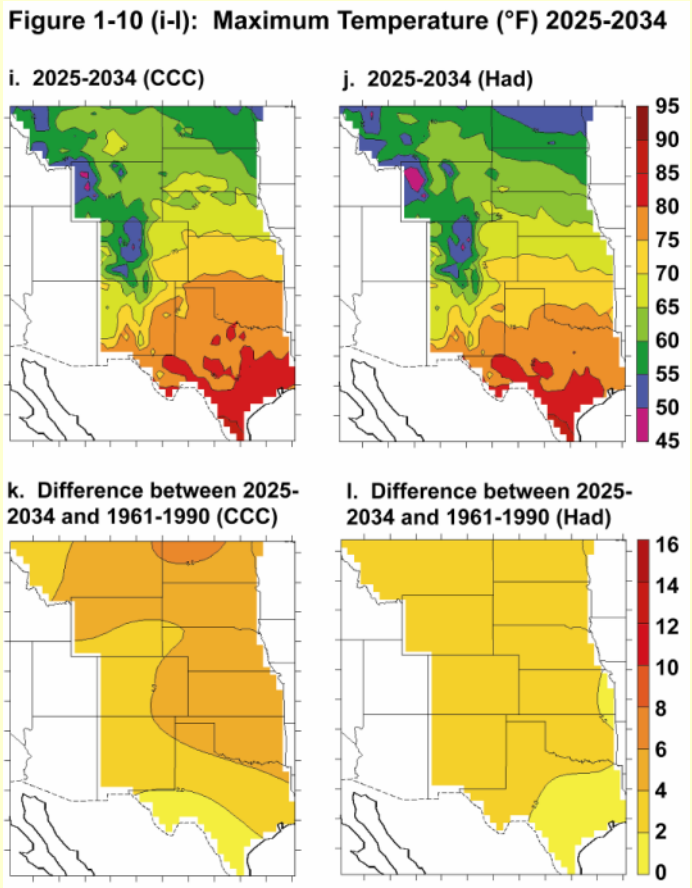


Strong regional gradients in mean annual precipitation and temperature…

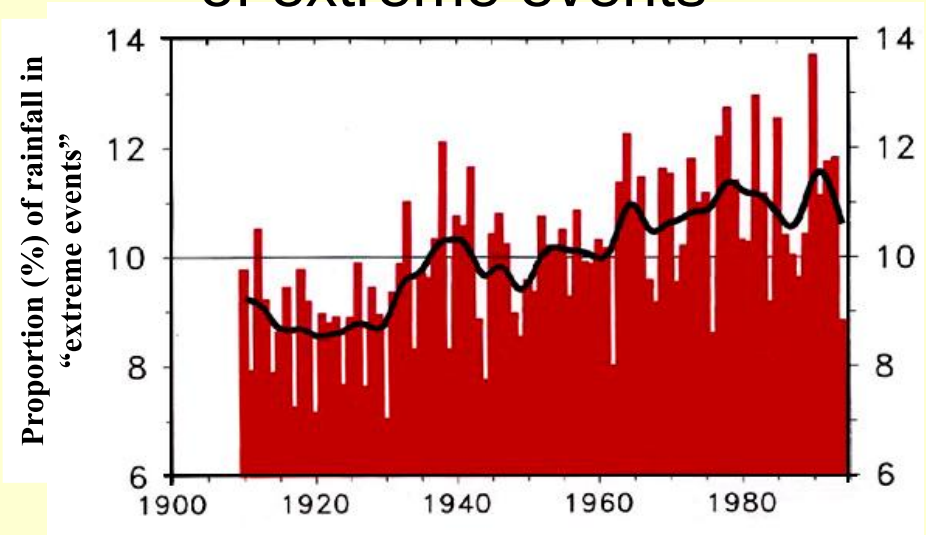


Two important climate change predictions for the US Central Plains…

1. Max and min temps are expected to increase



2. Increased rainfall variability and frequency of extreme events



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

Evidence of increasing frequency of large rainfall events in many regions

Overview:

Rainfall regimes + -

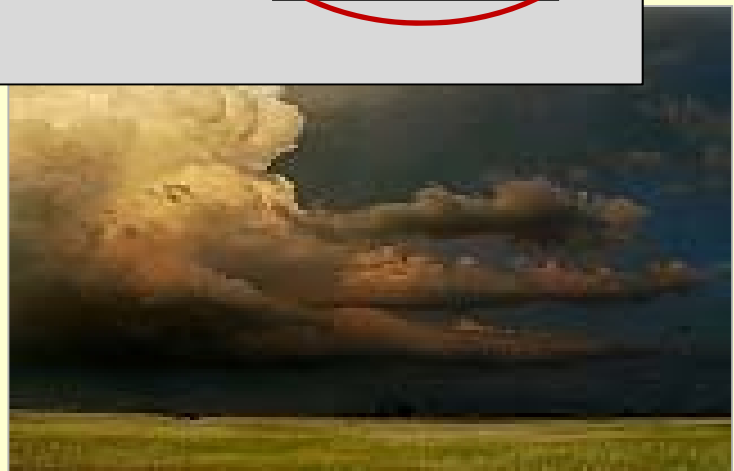
↑CO_2 effects +

↑Temperature effects -

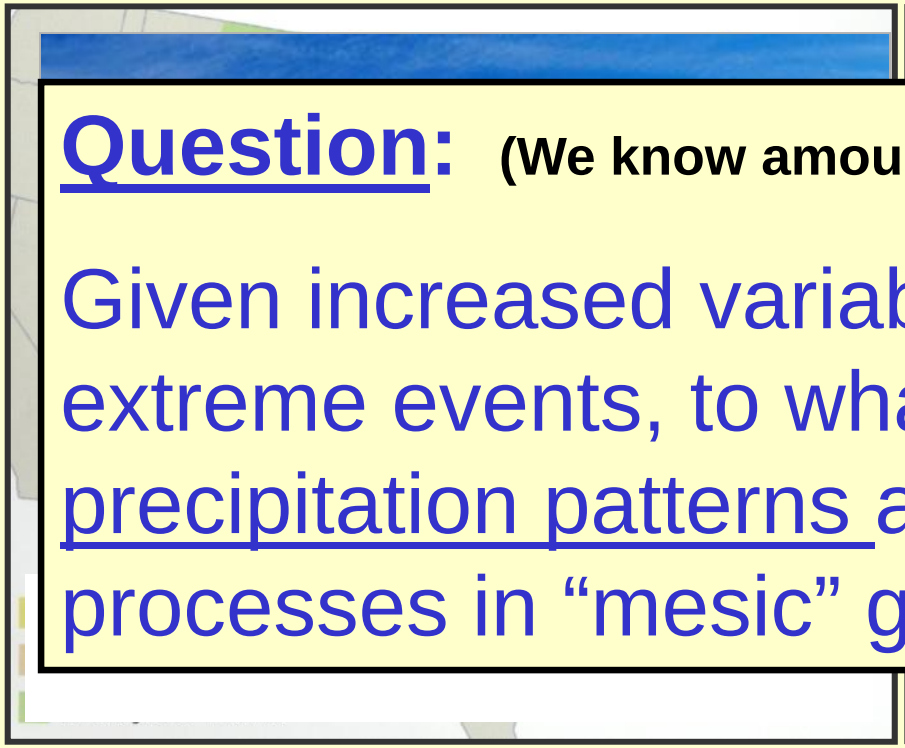
Soil moisture

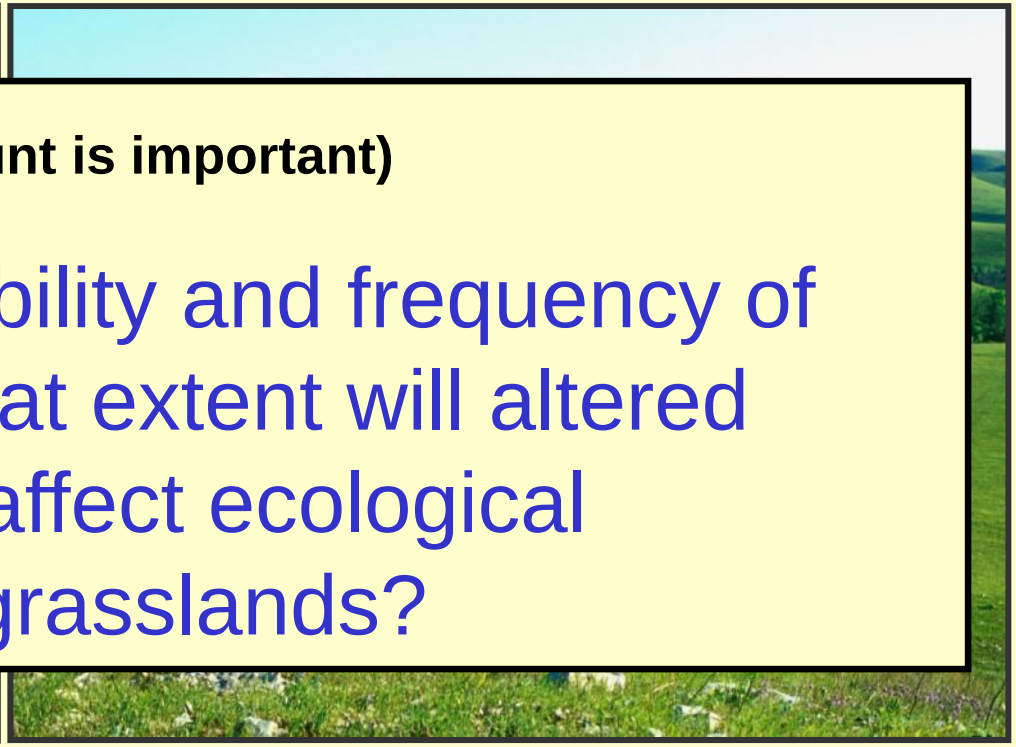
Organism Water relations

Ecosystem Process & Function



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





Question: **(We know amount is important)**

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

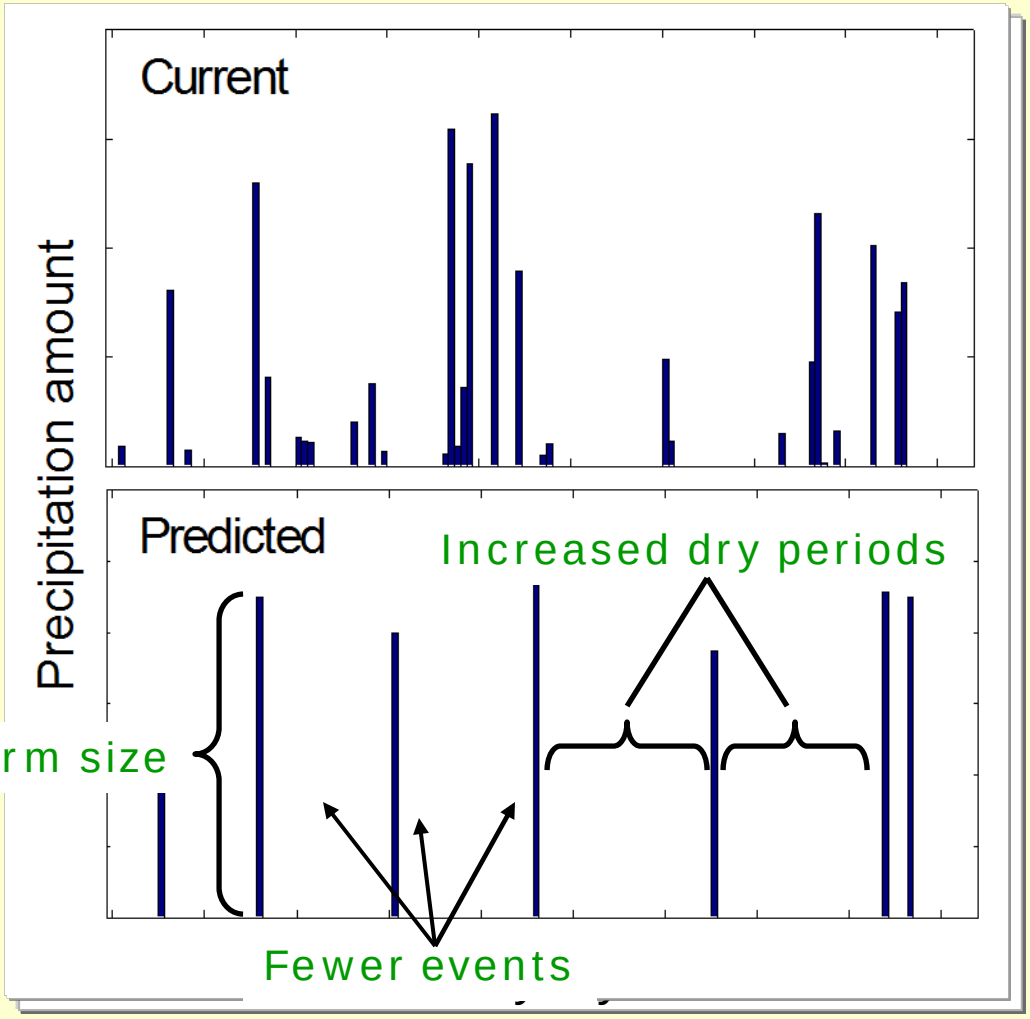
- Tallgrass prairie is the most mesic of US Great Plains grasslands – sufficient precipitation to support forest
- Flint Hills are located at the dry edge of the original range and on shallow soils

The Rainfall Manipulation Plot (RaMP) Experiment

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

- 12 **Ra**infall **M**anipulation **P**lot**s** (RaMPs) + non-sheltered controls
- Collect, store, and reapply natural rainfall on intact prairie plots
- Treatments include ambient and altered rainfall patterns since 1998
- Elevated temperature treatment added in 2003

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



No change in total precipitation quantity

Soil moisture dynamics

Ambient ppt timing:

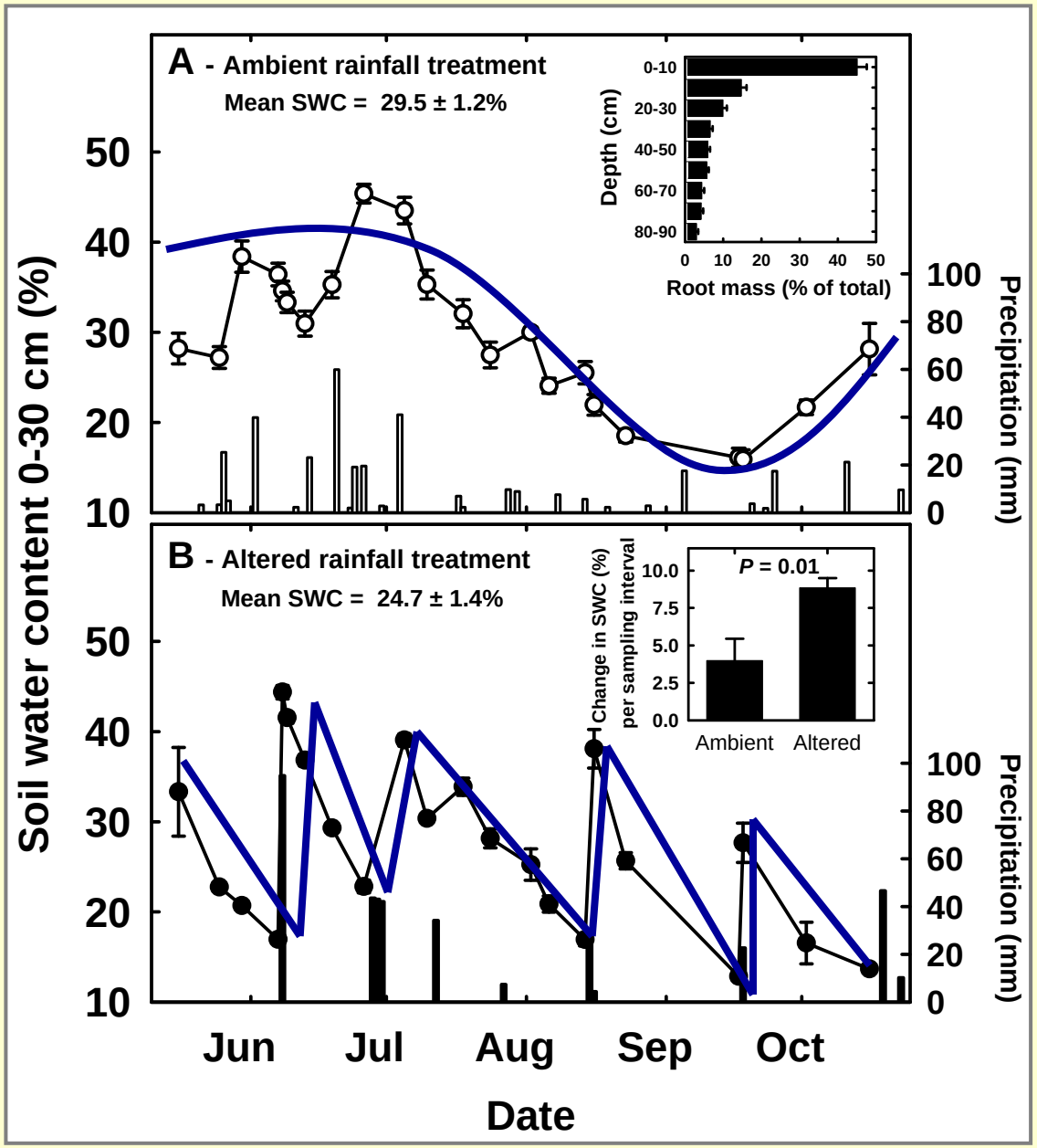
- "typical" seasonal pattern

Altered ppt timing:

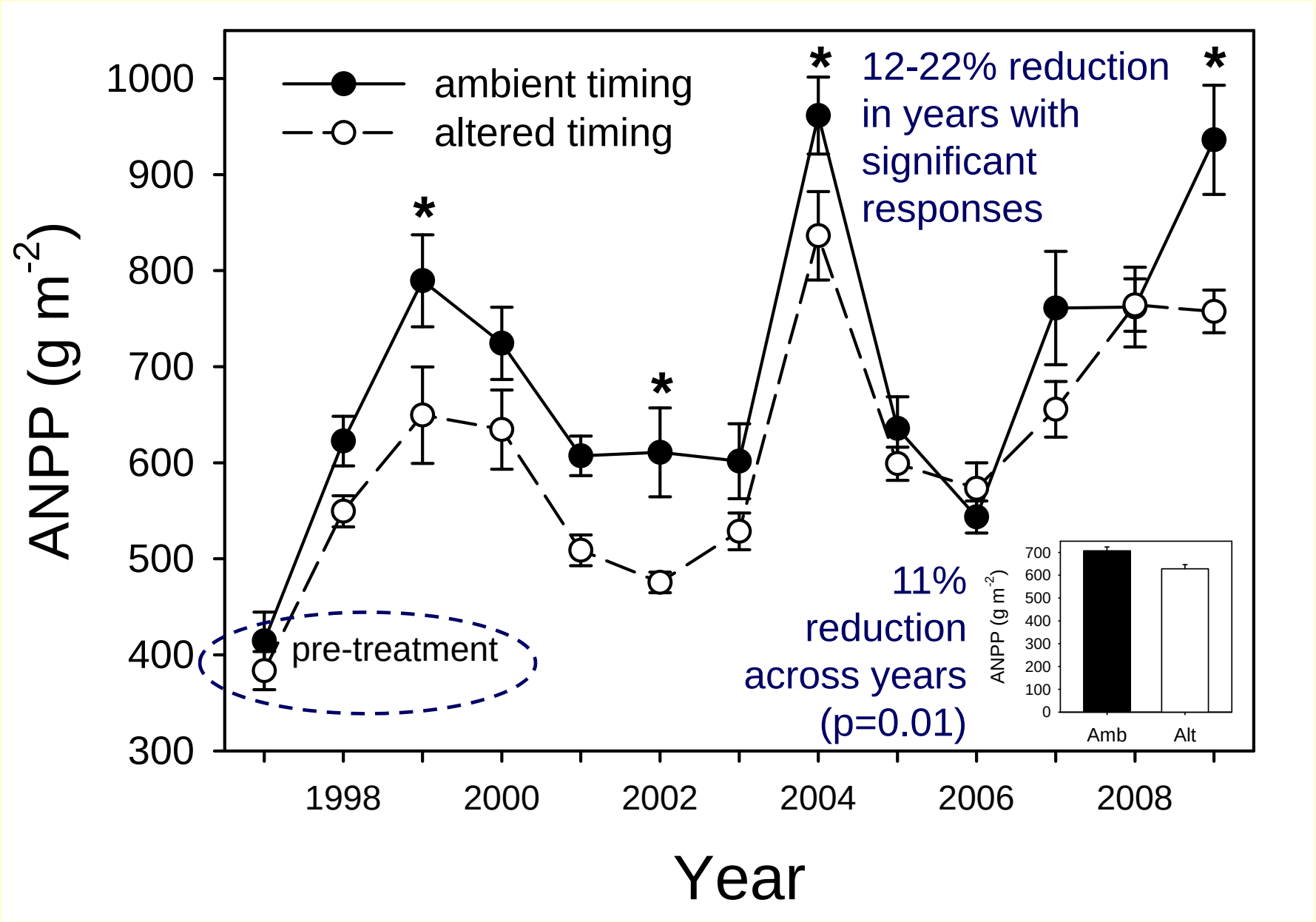
- repeated deficits
- more extreme wetting and drying cycles

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

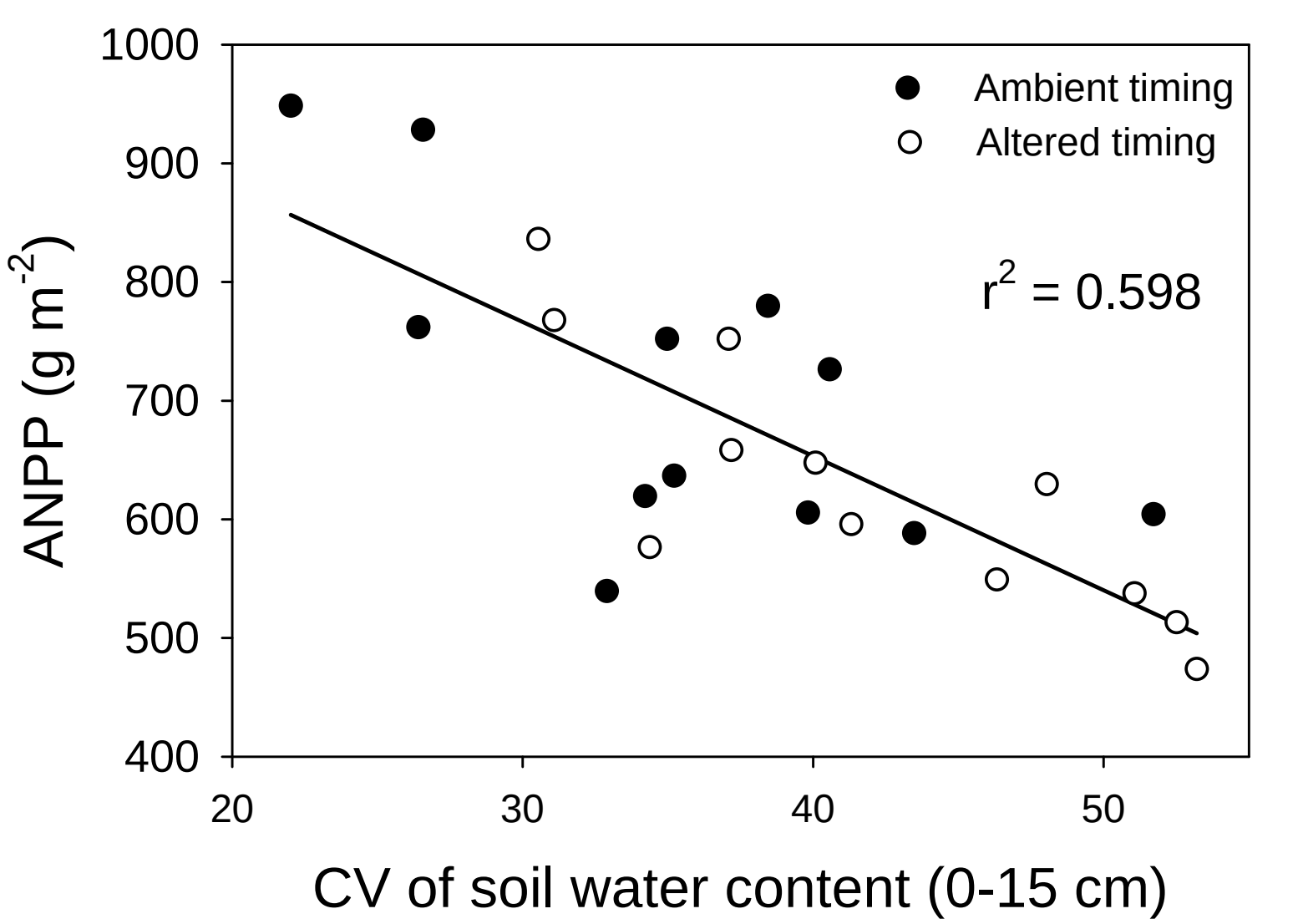
Variability in soil moisture:
- increased by 27%



ANPP responses to altered rainfall timing



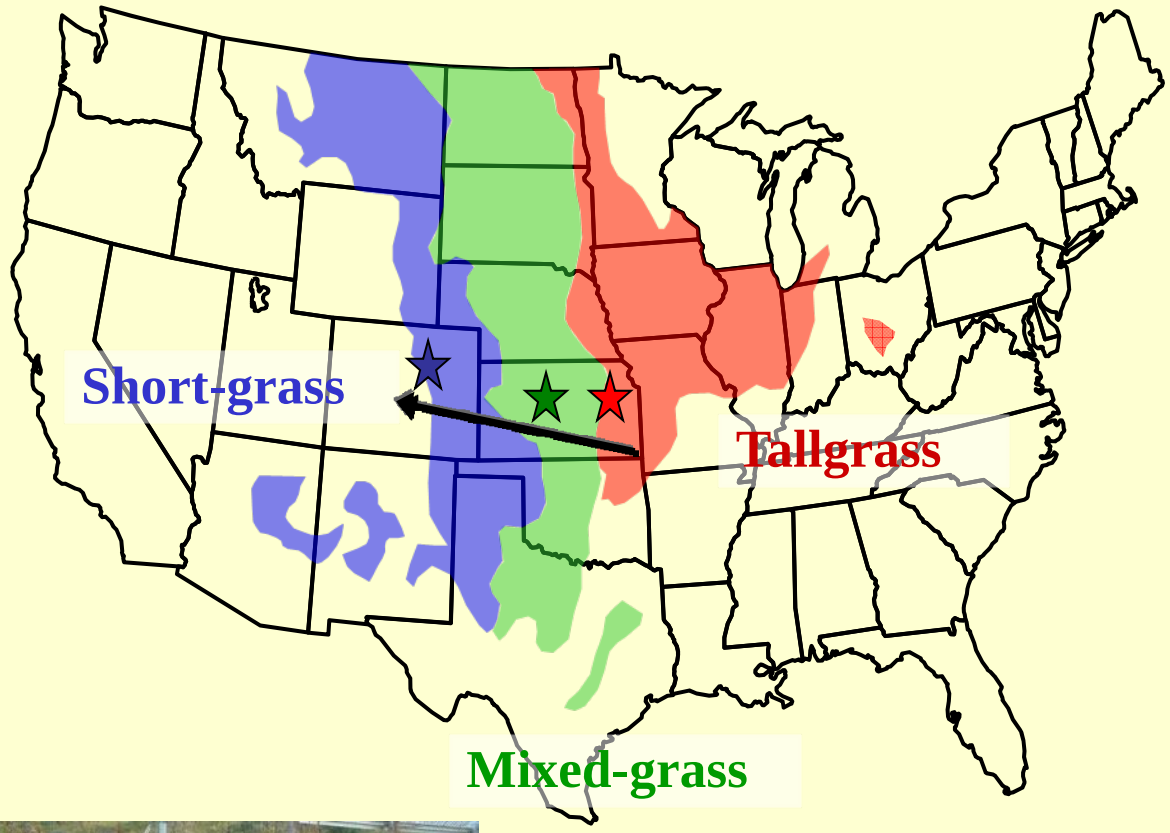
Greater variability in soil water content reduces productivity across all years and treatments

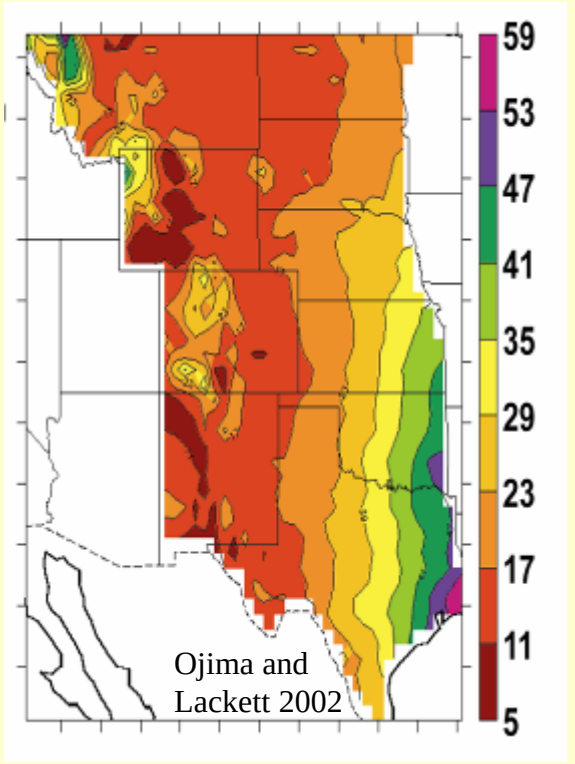


If only the entire world worked like Konza….

Can we apply results from mesic grasslands to other climates and grasslands?

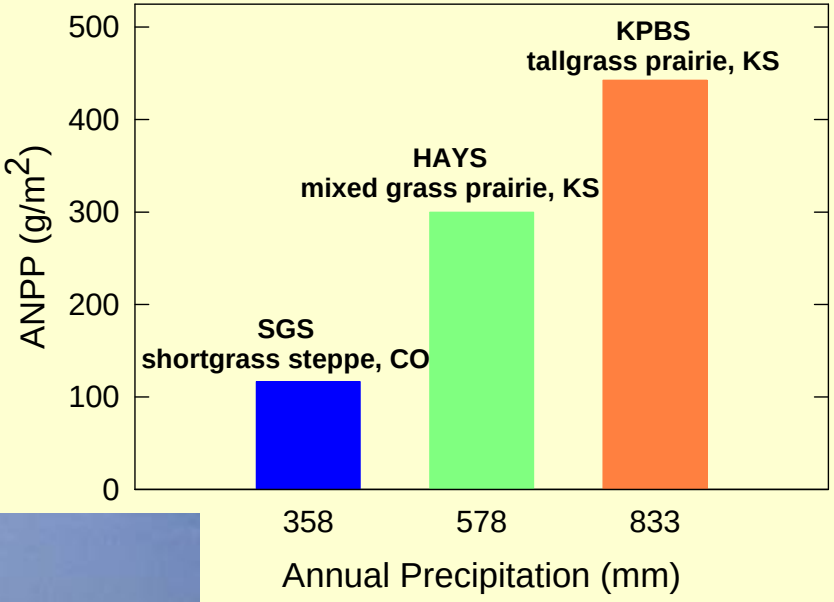
A multi-system assessment of climate change responses





Precipitation gradient

Heisler-White et al. 2009. *Global Change Biology*.



Semi-arid grassland
Extreme rainfall events, long dry intervals = reduced ANPP?

Mesic grassland
Extreme rainfall events, long dry intervals = reduces ANPP

How will these different grasslands respond to the same experimental design and treatments?

Experimental manipulation of growing season rainfall regimes

Frequent, small events vs. infrequent large events

Equal rainfall amounts within each site

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

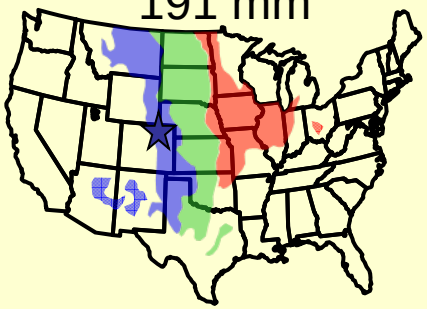
A = 12 events
B = 6 events
C = 4 events
Total = 450 mm

Semi-arid

Mesic

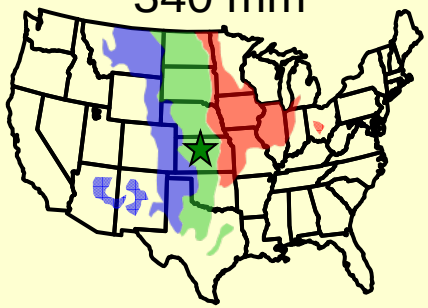
Semi-arid steppe

191 mm



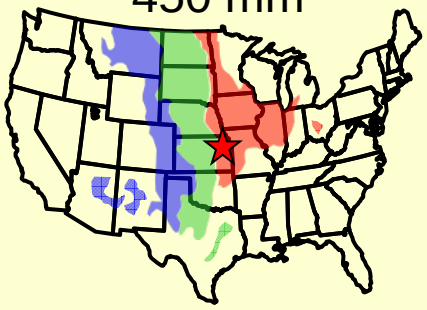
Mixed grass prairie

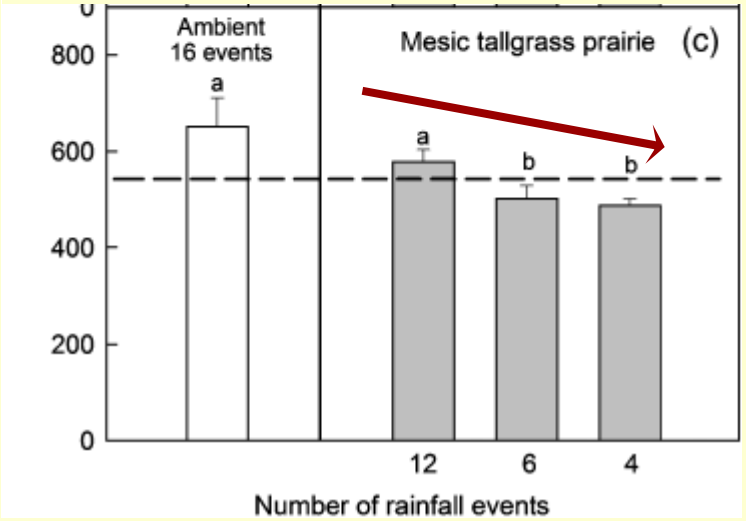
340 mm



Tallgrass prairie

450 mm



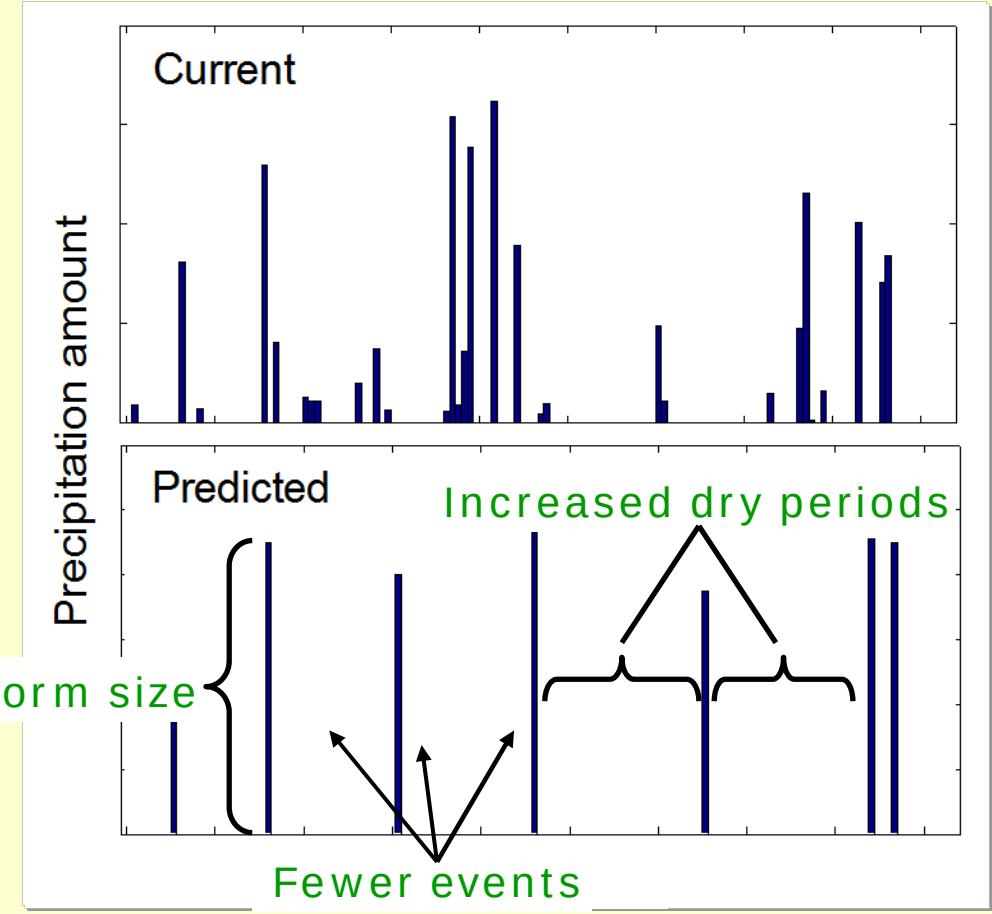


15% decrease in ANPP with fewer large events

Heisler-White et al. 2009

Why do arid vs. mesic grasslands respond differently?

Two key aspects of more extreme rainfall regimes:

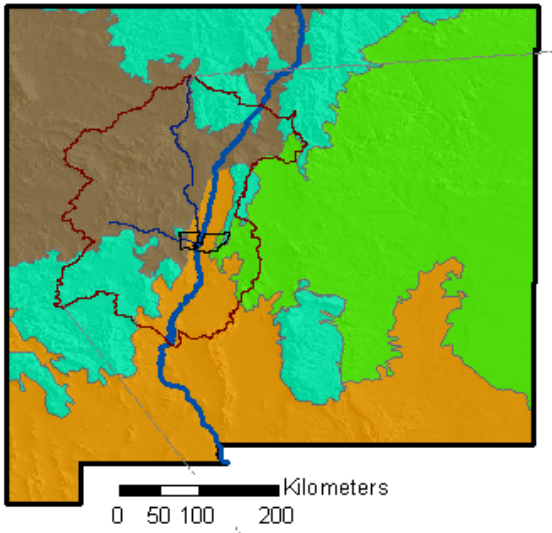


1. **Larger rain events**
2. **Longer dry periods between events**

When soils are usually moist, longer dry periods negatively impact ANPP…

When soil are usually dry, larger rain events improve soil water and increase in ANPP…

The Sevilleta LTER – the edge of the Great Plains



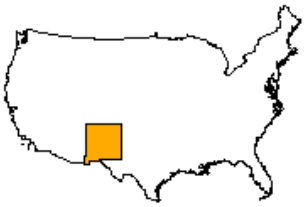
New Mexico Biomes:

- Chihuahuan Desert
- Great Plains Grassland
- Colorado Plateau Shrub-Steppe
- Conifer Woodland
- Rio Grande
- Rio Puerco & Rio Salado
- ET Flux Towers

Elevation

3715 m

1305 m



Cochiti Dam

Albuquerque

South Valley

Sevilleta N.W.R.

Bernardo

Rio Salado

San Acacia

Bosque del Apache

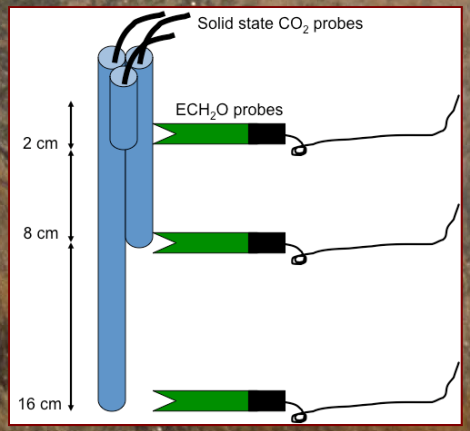
Elephant Butte Dam

Kilometers
0 25 50 100

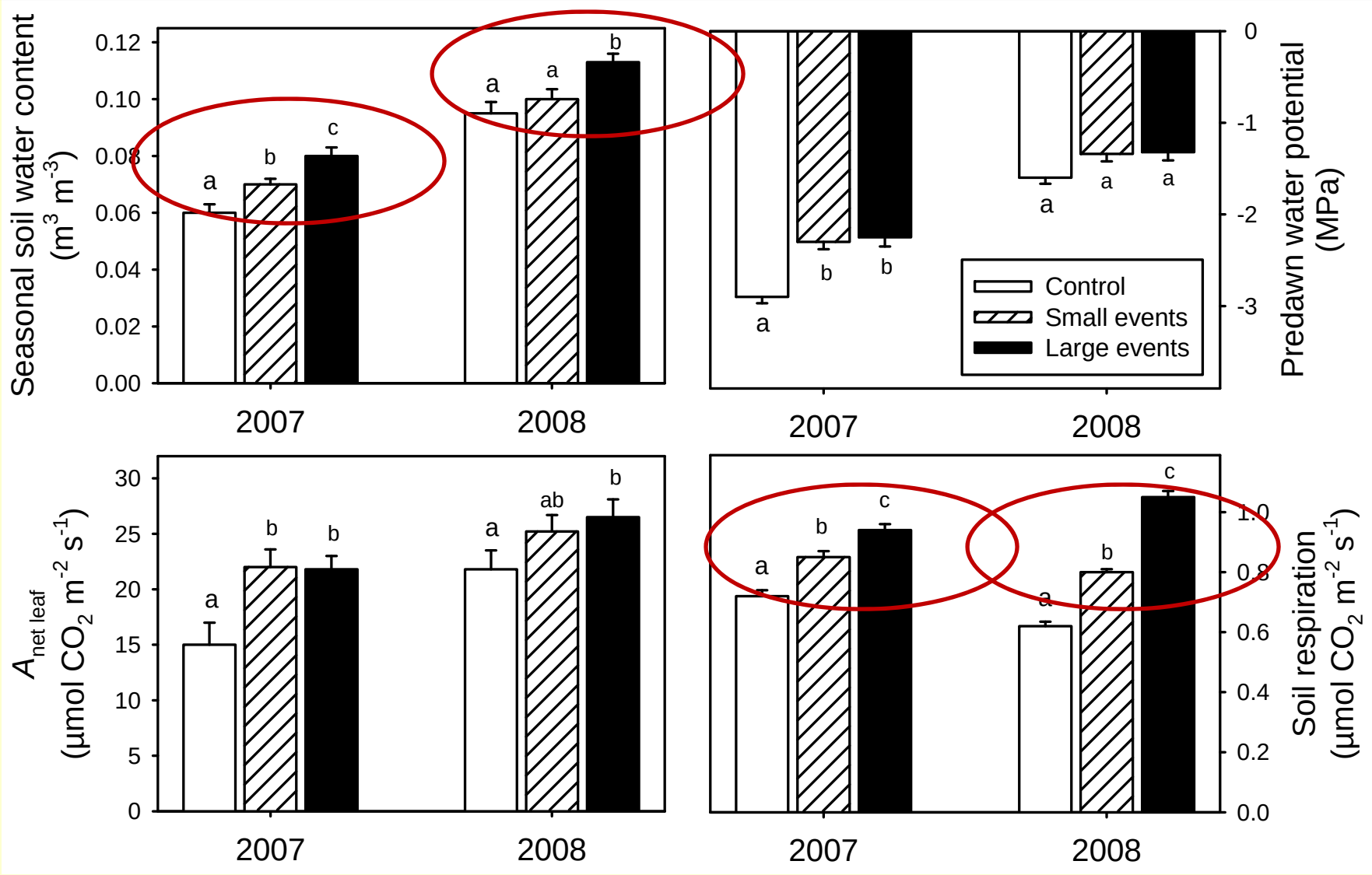
Monsoon Rainfall Manipulation Experiment

During the summer monsoon July through September:
3 plots receive ambient rainfall
5 plots receive a 5mm rainfall event every week
5 plots receive a 20 mm rainfall event every month

Scott Collins
Michell Thomey
Rodrigo Vargas
Jennifer Johnson
Renee Brown
Don Natvig
Mike Friggens



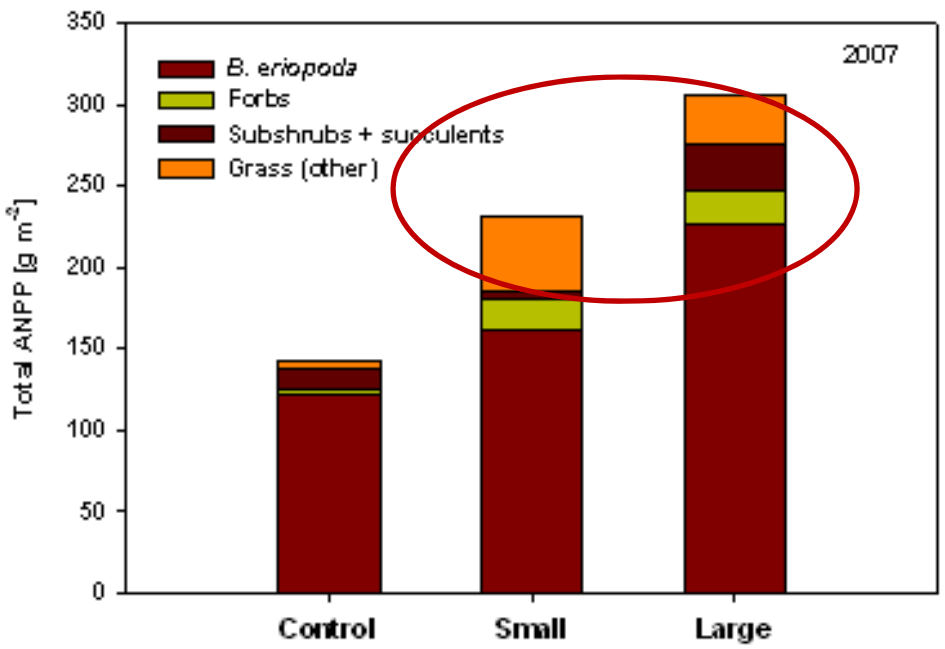
Seasonal average soil water content, predawn water potentials, leaf-level A_{net} and soil CO_2 flux were highest in plots receiving a few large events

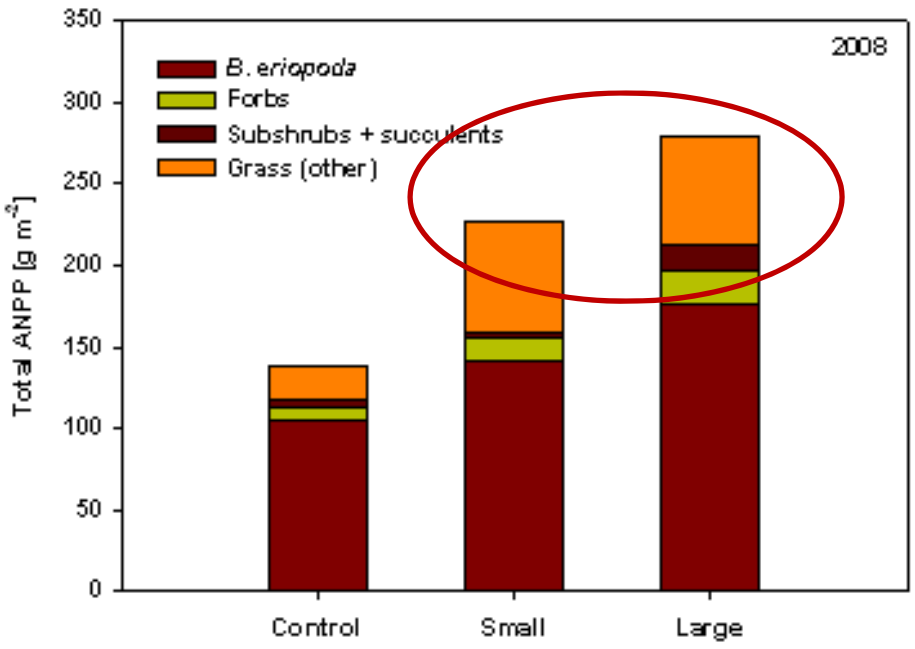


Responses similar to shortgrass steppe, but opposite mesic grasslands

Thomey et al. 2011 GCB

Total ANPP and ANPP of black grama were highest in plots receiving a few large events

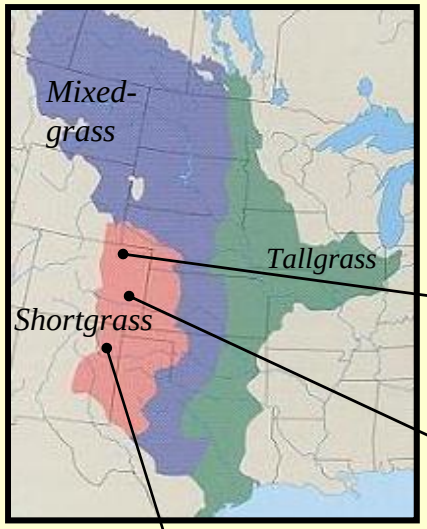




- 25 – 40% greater ANPP of black grama with few large events compared to many small events
- Similar trends for ANPP of all species combined

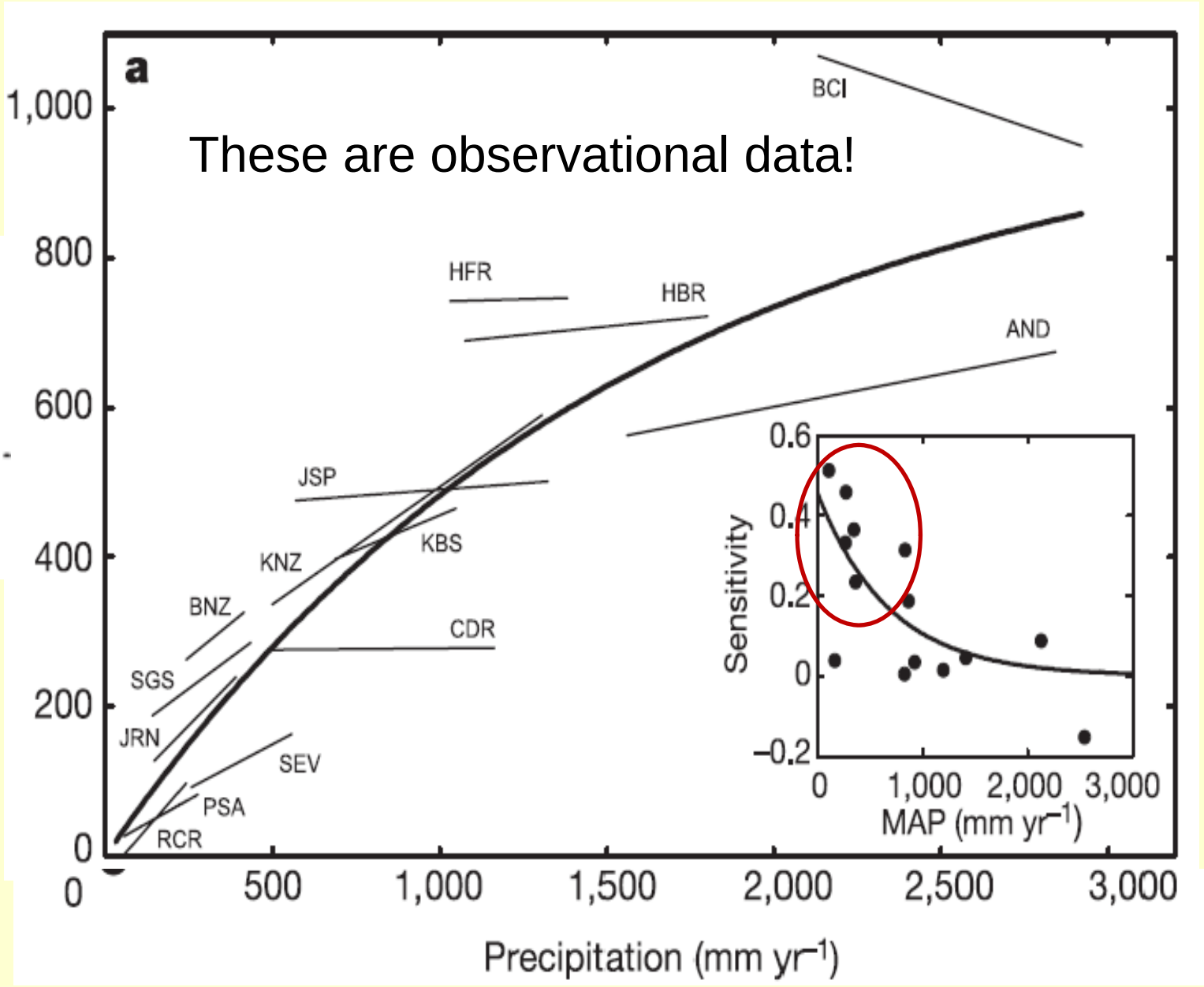
Thomey et al. 2011 GCB

Unexpected patterns of sensitivity to drought



Site	Elevation	Mean Annual Precipitation	Mean Annual Temperature	Soil Texture
Shortgrass-Steppe LTER (SGS)	1650 m	310 - 330 mm	7.2º C (45º F)	Sandy Loam
Sand Creek Massacre Nat'l Historic Site (SAND)	1219 m	330 - 360 mm	8.3º C (47º F)	Clay
Fort Union Nat'l Monument (FOUN)	2043 m	410 - 450 mm	9.4º C (49º F)	Sandy Clay Loam

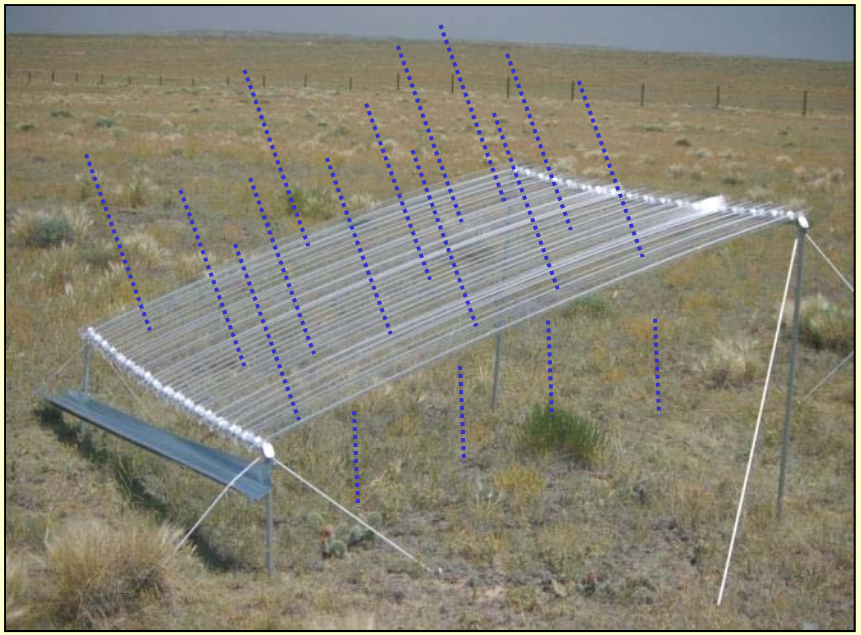
Karie Cherwin



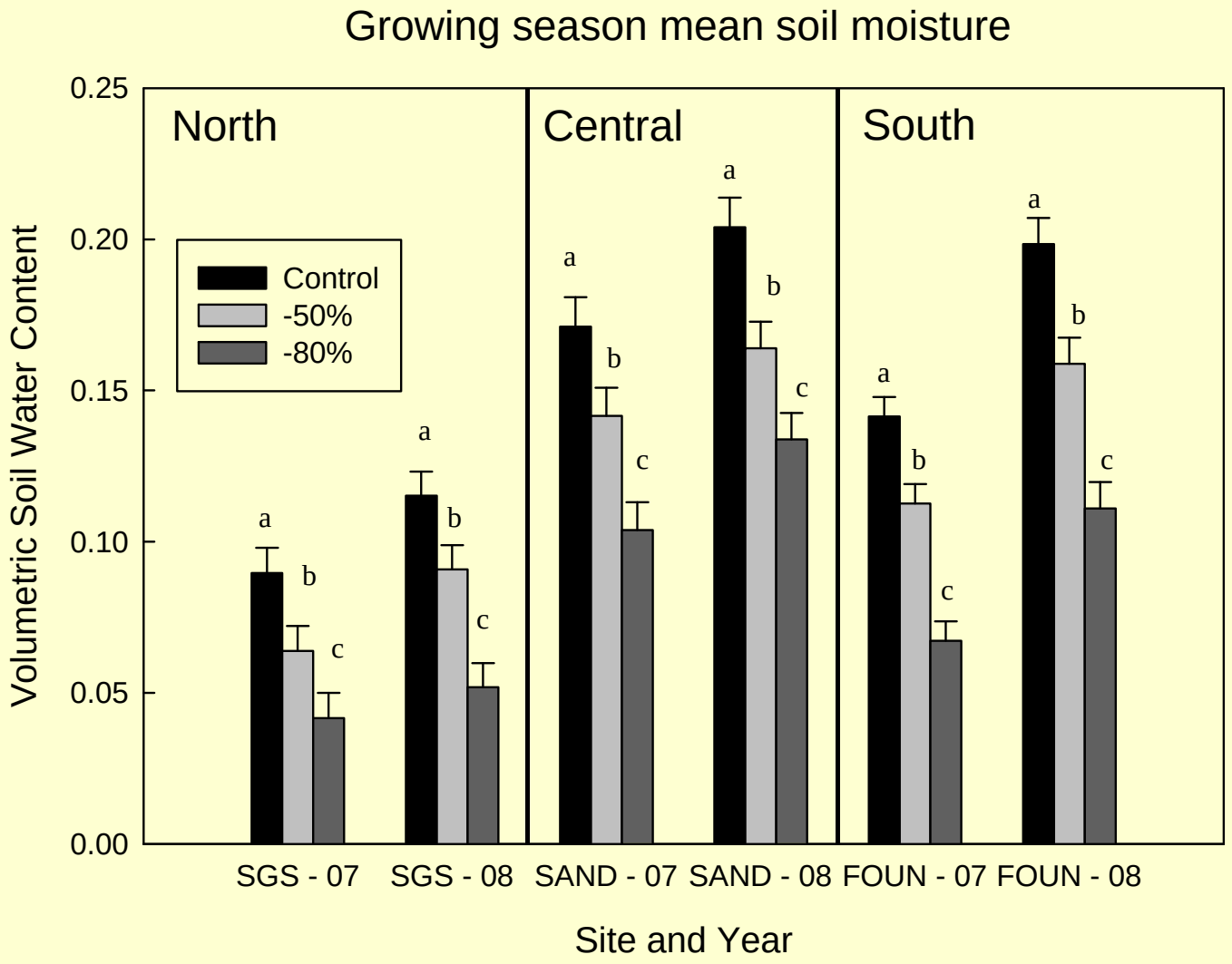
From Huxman et al (2004)

Testing this inference of high sensitivity

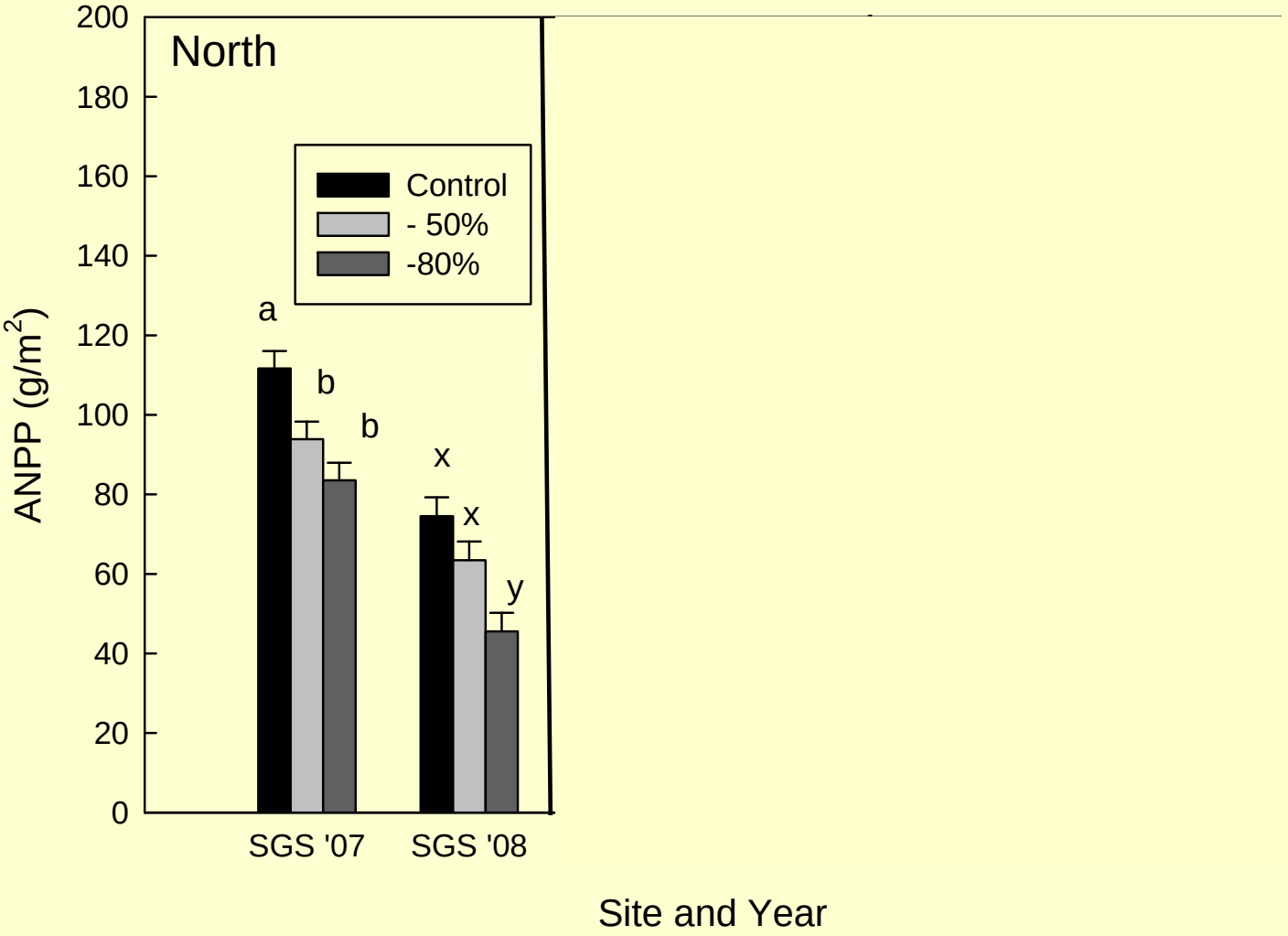
- 30 plots at each site
  - 10 controls
  - 20 rainout shelters
    - 10 at 50% Reduced-PPT
    - 10 at 80% Reduced-PPT
- Two-year drought
- Response Variables
  - Net Primary Productivity
  - Soil Moisture



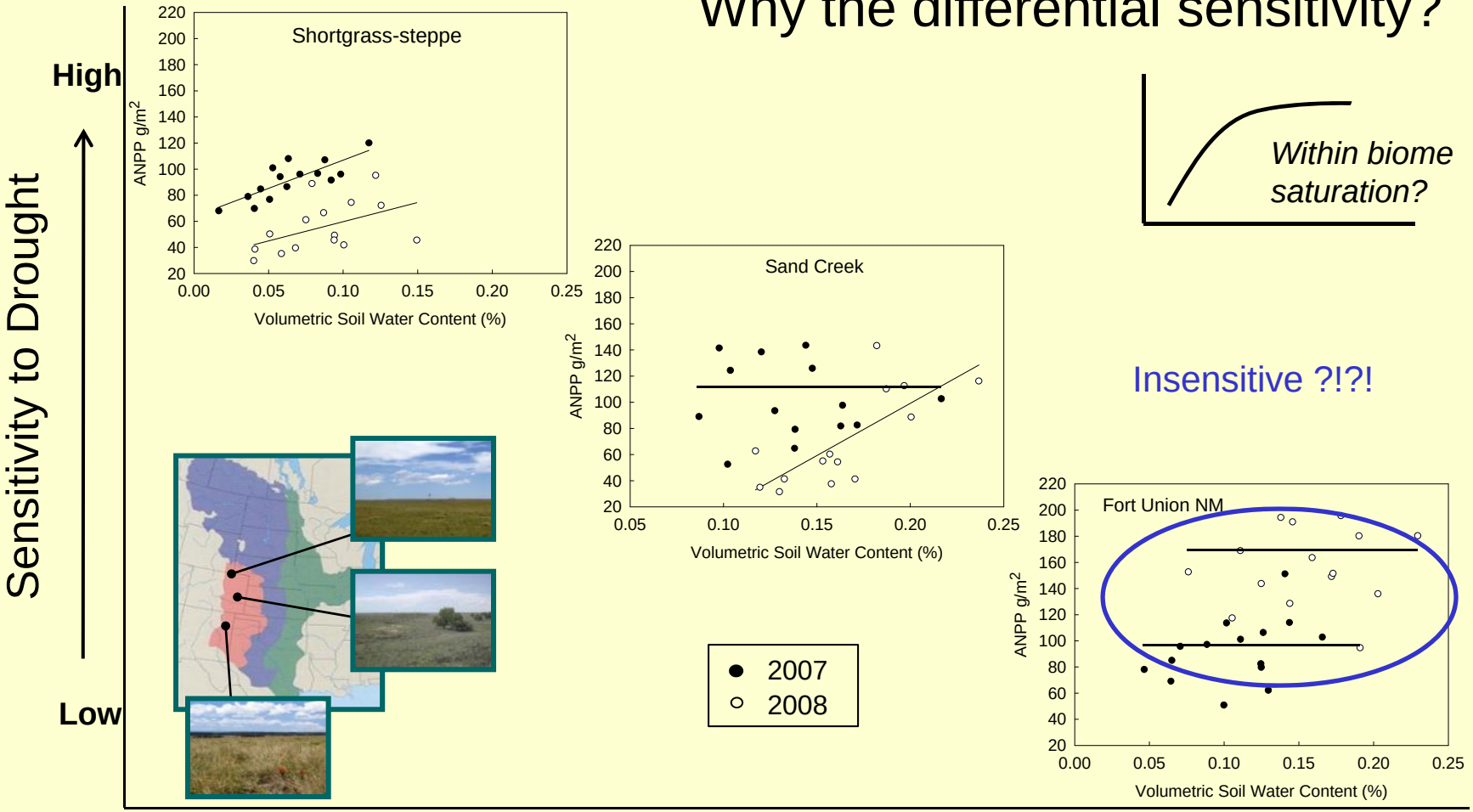
- *No change in timing/pattern*
- *Reduces event size & total amount*


Growing season mean soil moisture
North
Central
South
Control
-50%
-80%
Volumetric Soil Water Content
0.25
0.20
0.15
0.10
0.05
0.00
a
b
c
SGS - 07
SGS - 08
SAND - 07
SAND - 08
FOUN - 07
FOUN - 08
Site and Year

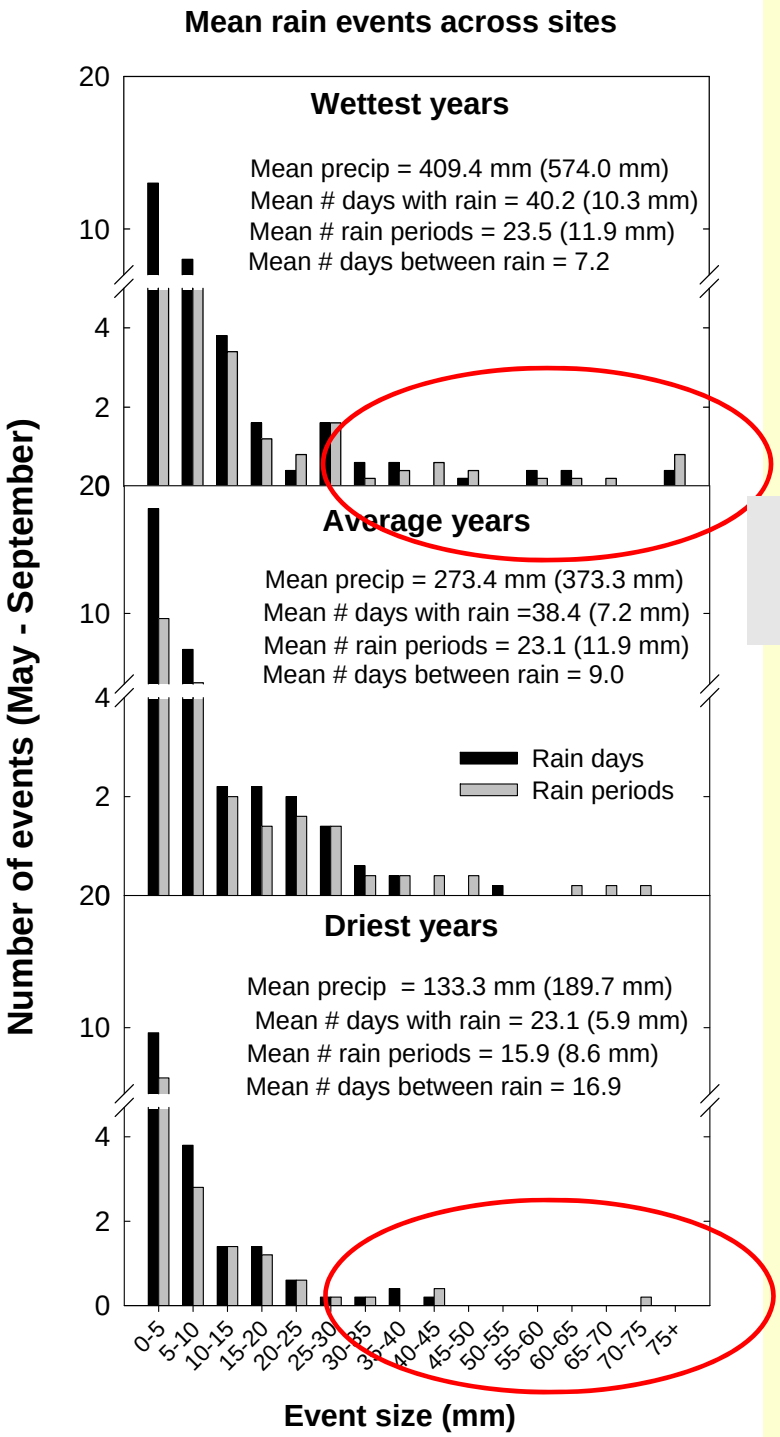
2007 & 2008 ANPP



Why the differential sensitivity?



Latitude:	40° N	38° N	35° N
Temperature:	7.2° C	8.3° C	9.4° C
Precipitation:	310 - 330 mm	330 - 360 mm	410 - 450 mm
Elevation:	1650 m	1219 m	2043 m
Soil Texture:	Coarse (Sandy Loam)	Fine (Clay)	Intermediate (Sandy Clay Loam)

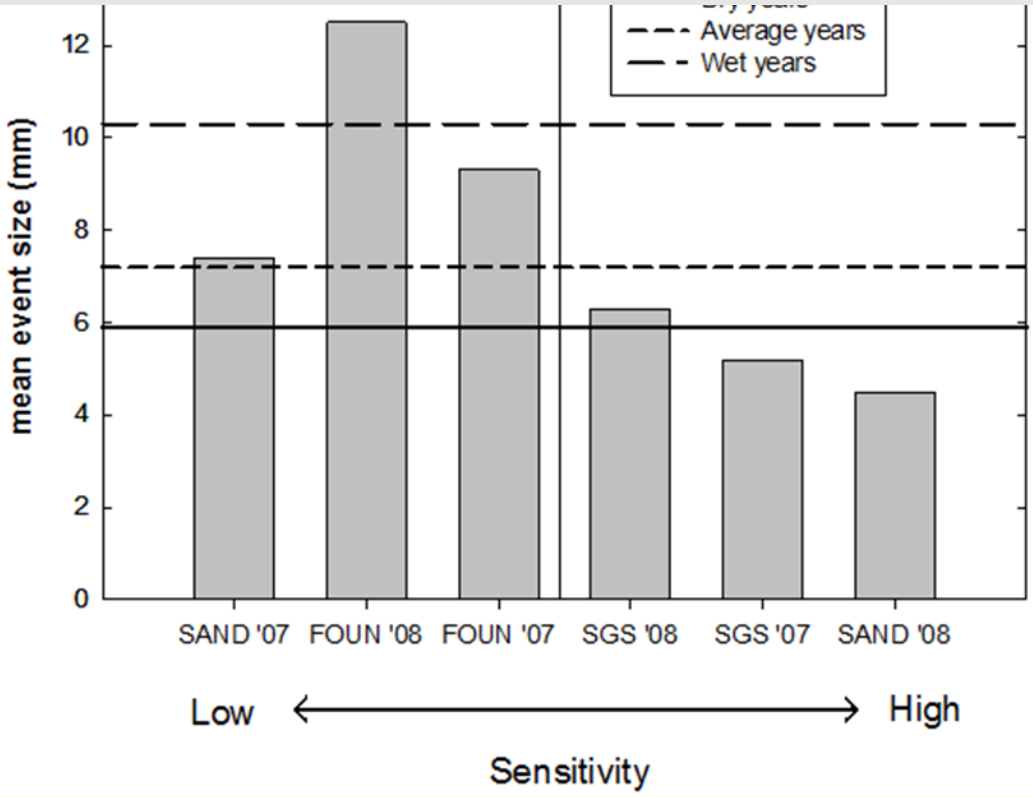


Rainfall regimes – there's more to them than amount…

In addition to more rain, wet years have more large events compared to average years.

33.6 events
9.7 mm

41.0 events
5.3 mm



Summary -

There is still much we need to learn about precipitation regimes, soil moisture and ecosystem responses if we are to forecast the future… ***But x-site studies and experiments can provide insight that single-site research cannot.***

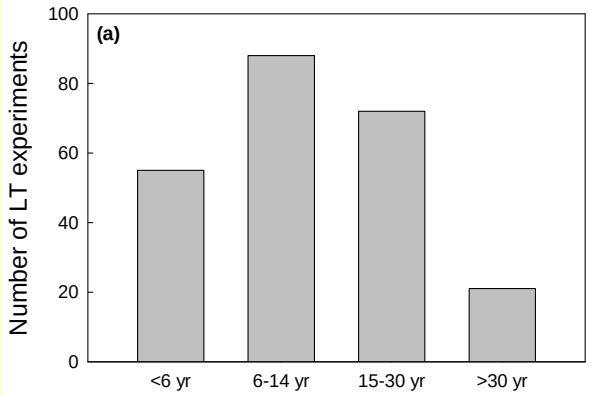
- Alterations in rainfall patterns (and of course amounts) may change productivity in biome specific ways…
- Alterations in rainfall patterns may even alter sensitivity to drought…
- Much of what we know is from observation and correlation… We need to challenge this knowledge

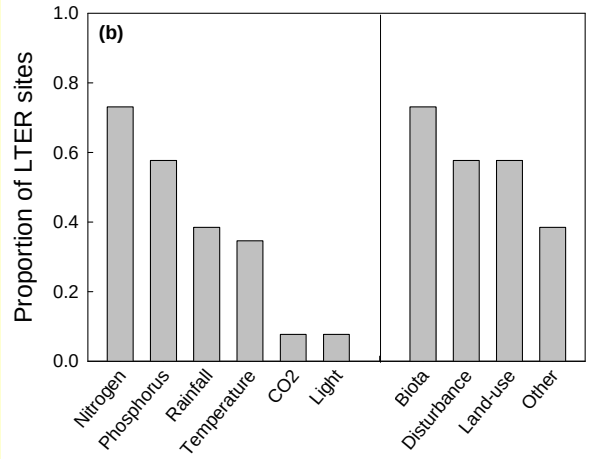
My Agenda?

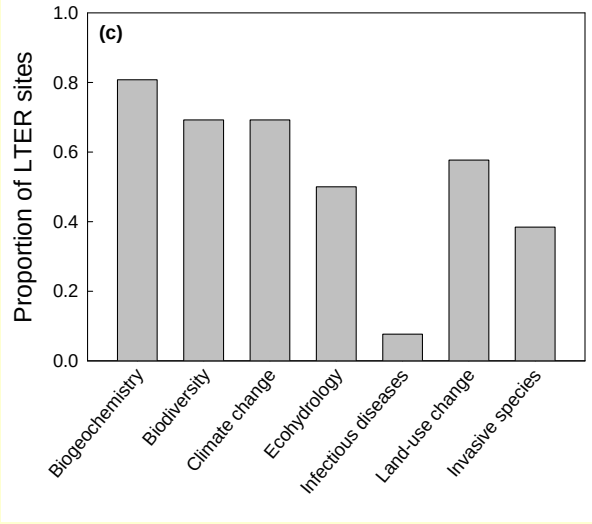
We need more *climate change* experiments where we “push” ecosystems… in both magnitude and pattern…

We need comparative analyses of ecosystem responses to climate change within and across biomes…

Clear need for long-term, multi-site and coordinated studies and experiments… **And the LTER Network should be leading the way…**







We are already doing this…

The LTER Network has >240 long-term experiments (with many more short-term experiments)

>70% of our sites are conducting long-term climate change experiments

60% of sites are involved in multi-site experiments

But for the most part, our experiments and studies are not coordinated at the network level…