# Adaptive management of water resources in grasslands: Challenges in a changing world

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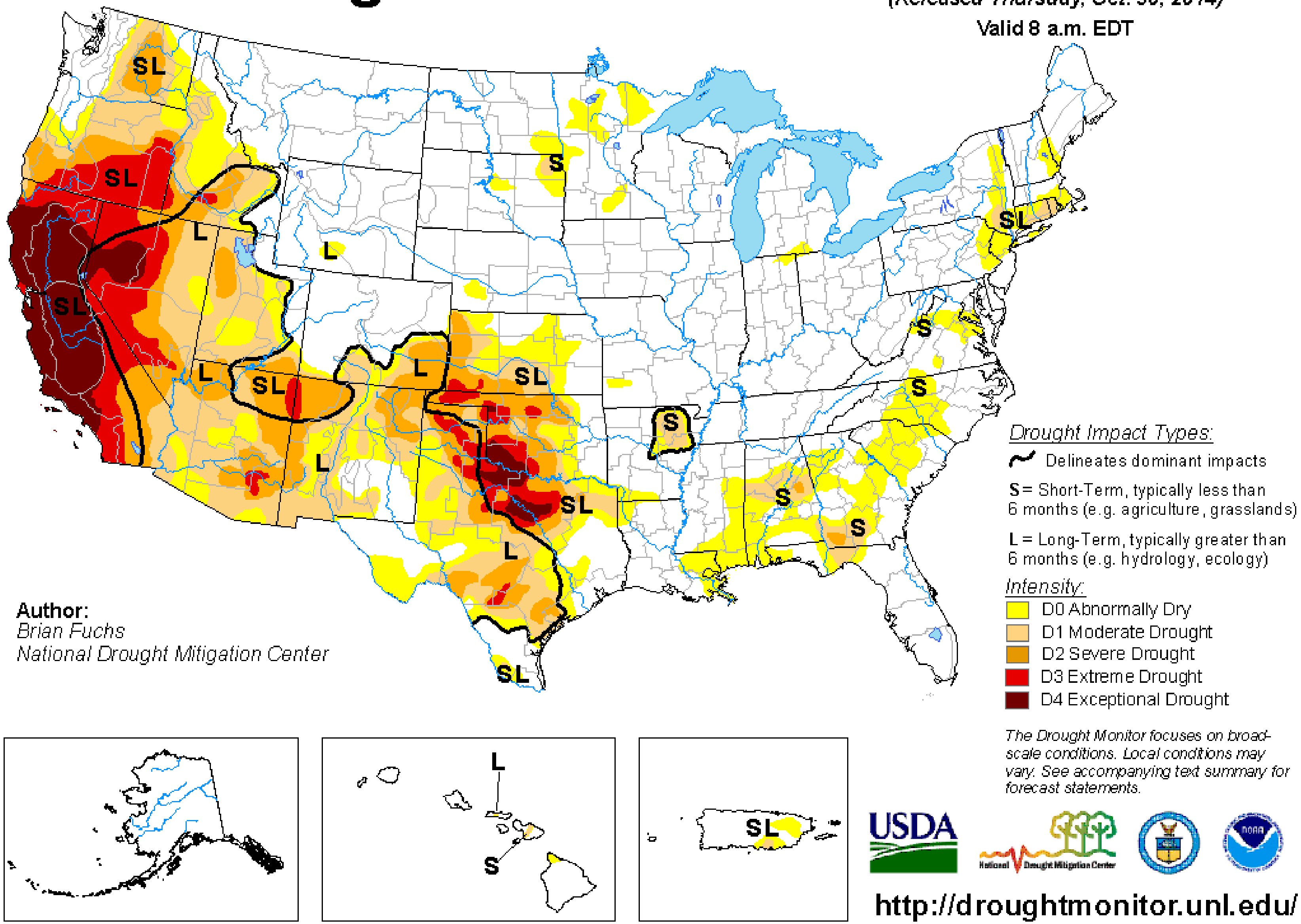
# Drought impacts environmental processes, international security, and our societal framework

# U.S. Drought Monitor

**October 28, 2014**

*(Released Thursday, Oct. 30, 2014)*

Valid 8 a.m. EDT

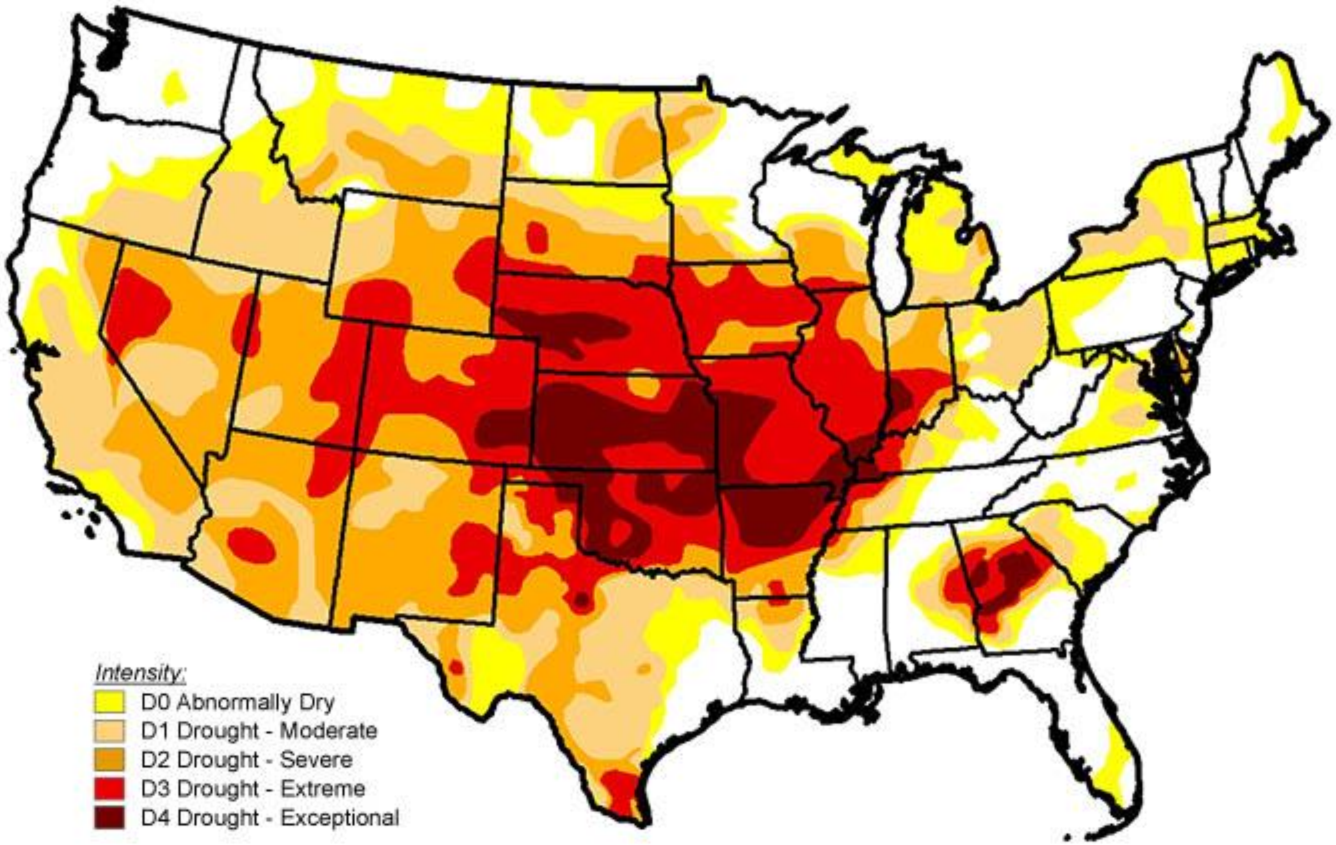



USDA

http://droughtmonitor.unl.edu/


www.mattblack.com

# Aug 21, 2012




*National Drought Mitigation Center*

# Climate change impacts the hydrological cycle and land-surface ET

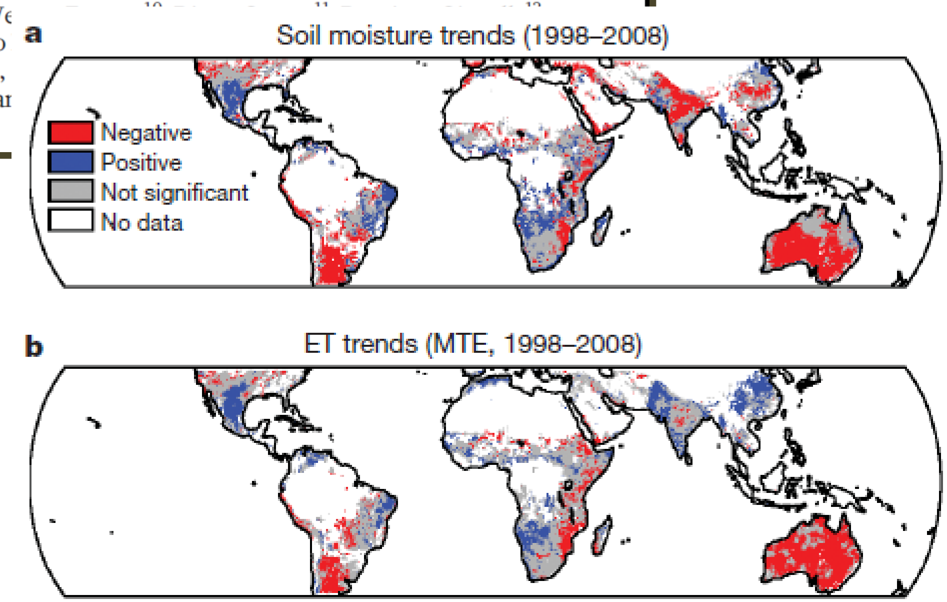
LETTER

doi:10.1038/nature09396

## Recent decline in the global land evapotranspiration trend due to limited moisture supply

Martin Jung[1], Markus Reichstein[1], Philippe Ciais[2], Sonia I. Seneviratne[3], Justin Sheffield[4], Michael L. Goulden[5], Gordon Bonan[6],
Alessandro Cescatti[7], Jiquan Chen[8], Richard de Jeu[9], A. Johannes Dolman[9], We
Nadine Gobron[13], Jens Heinke[11], John Kimball[14], Beverly E. Law[15], Leonardo
Keith Oleson[6], Dario Papale[18], Andrew D. Richardson[19], Olivier Roupsard[20],
Ulrich Weber[1], Christopher Williams[21], Eric Wood[4], Sönke Zaehle[1] & Ke Zhar

- Reduced soil moisture has reduced global ET since 1997.
- Reduced SM reduces the 'buffer' between atmosphere and land surface, increasing air temperatures.
- Warmer temp.'s with less SM will reduce ecosystem productivity.




Jung et al. 2010 Nature 467:951-954

# Re-occurrence of Kansas Dust Storms?



**1930's**

**2004, 2011, 2012**

*Can we predict and effectively respond to future droughts?*

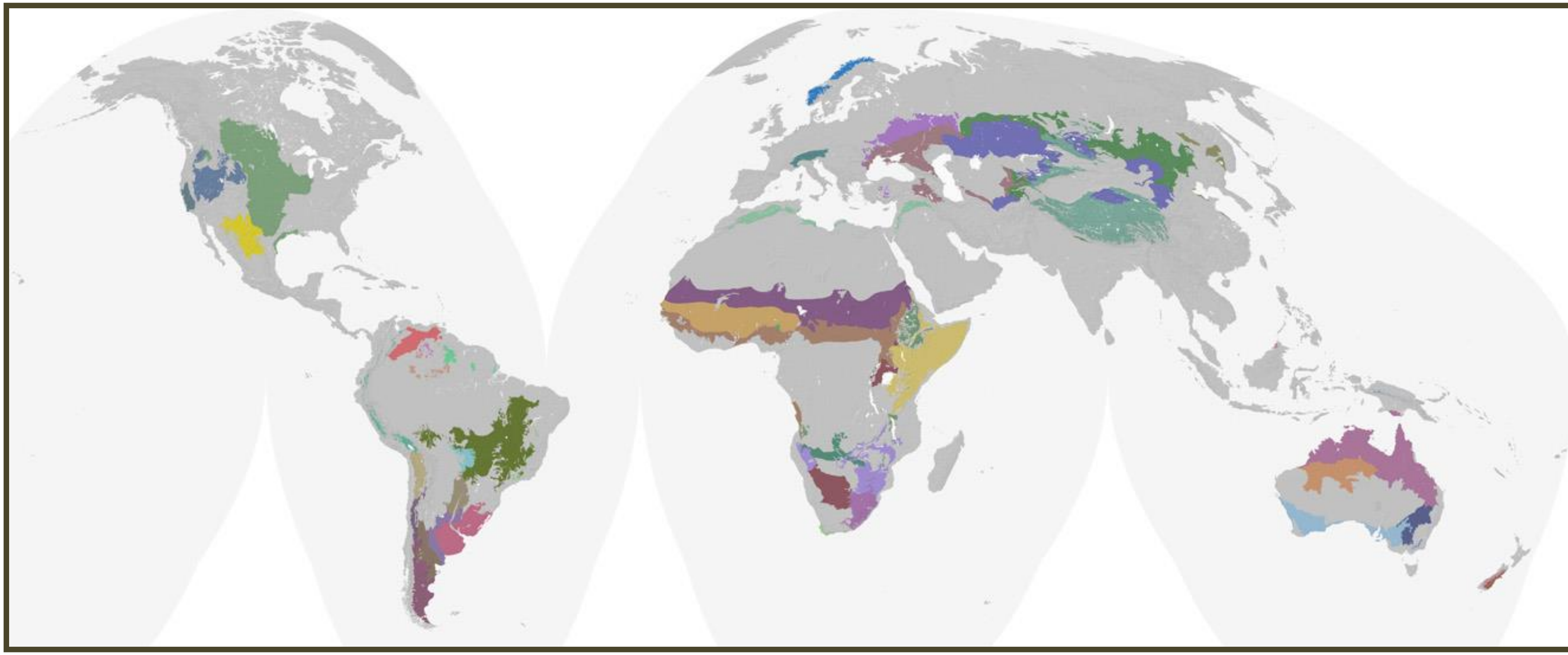
# Water resource management in grasslands

i. current and projected water budgets for grassland systems,

ii. the impacts of water stress and drought on grassland productivity and stability, and

iii. potential strategies to maintain viable grasslands and their goods and services.

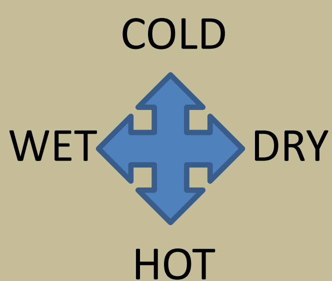
# Global grassland distribution



Dixon et al. 2014 *J. Biogeography* 41:2003-19

# Grasslands, grazers, and humans

~30% of terrestrial land surface is grasslands





- Habitat
- Bio-geochemical cycling
- Human evolution
- Ecological theory

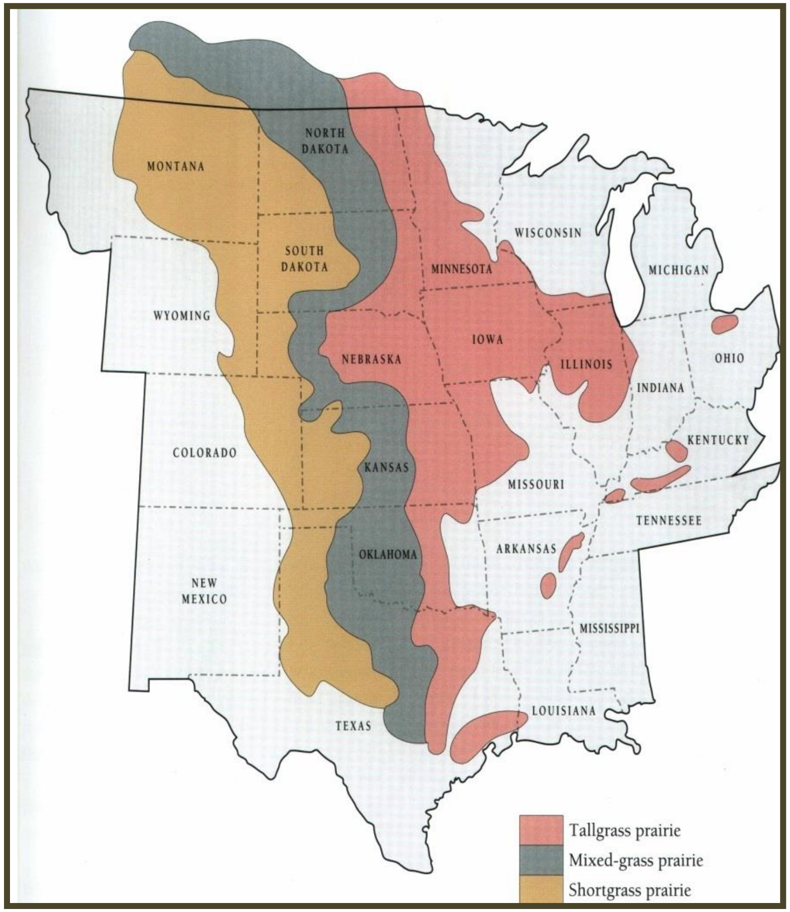
Human Services

Pastures

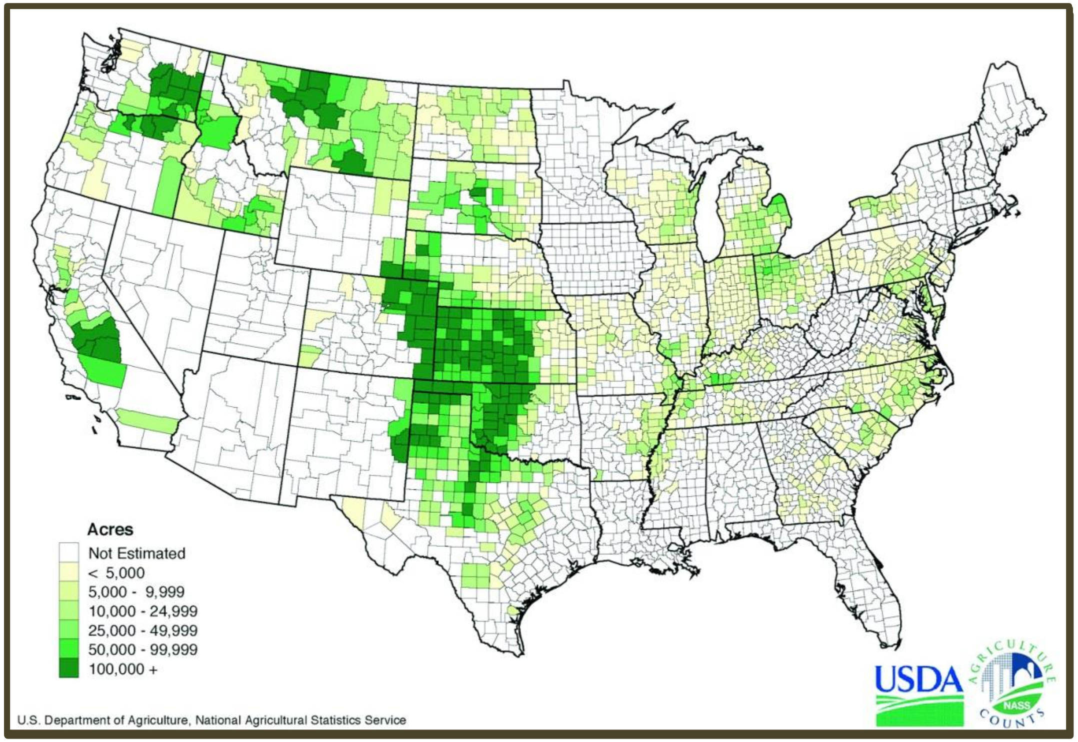
Agriculture

Mixed-use

# Grasslands and Agriculture in the U.S.




Grassland types

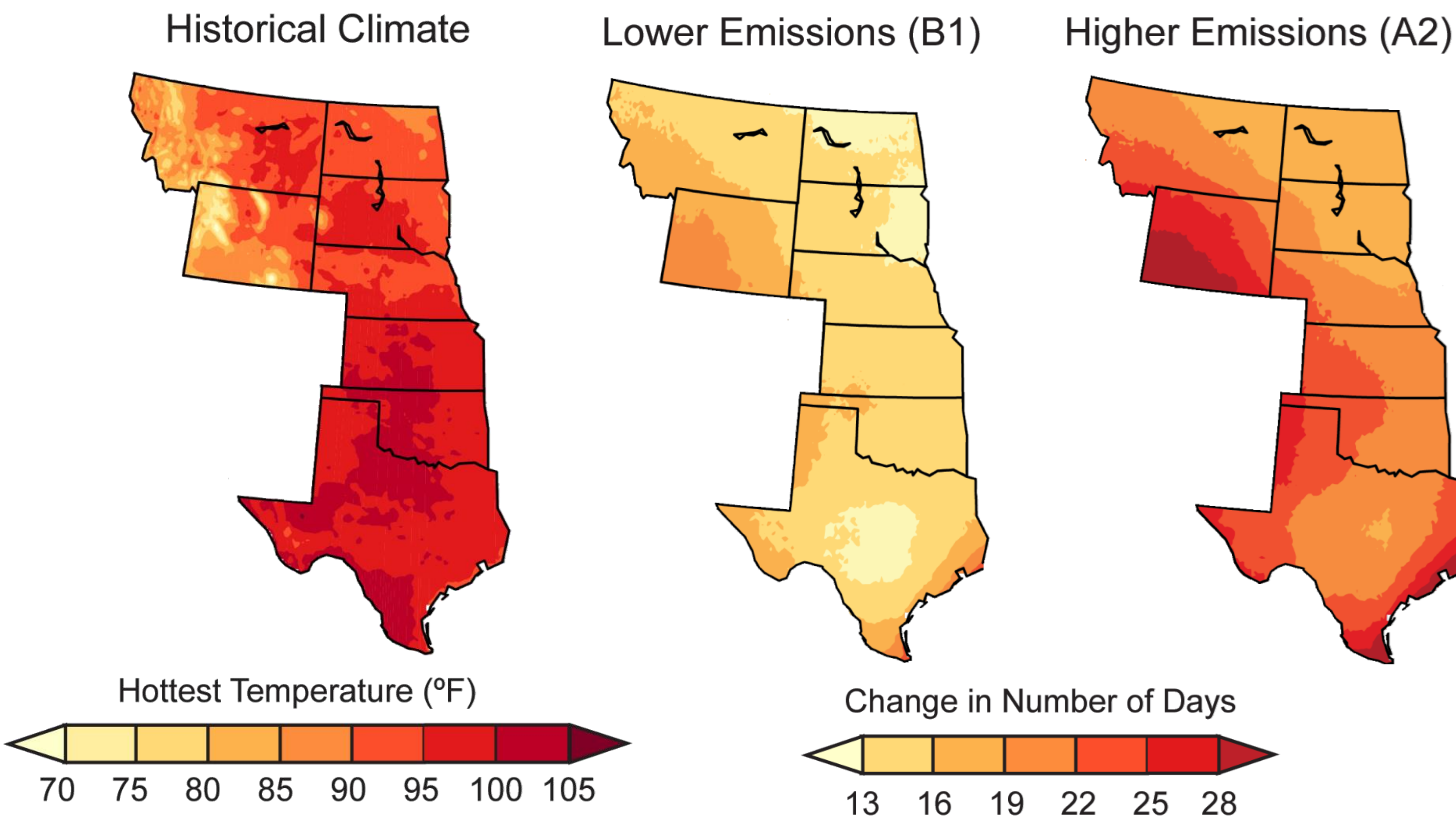



Winter Wheat Production

**http://www.nass.usda.gov/**

USDA Statistics Service

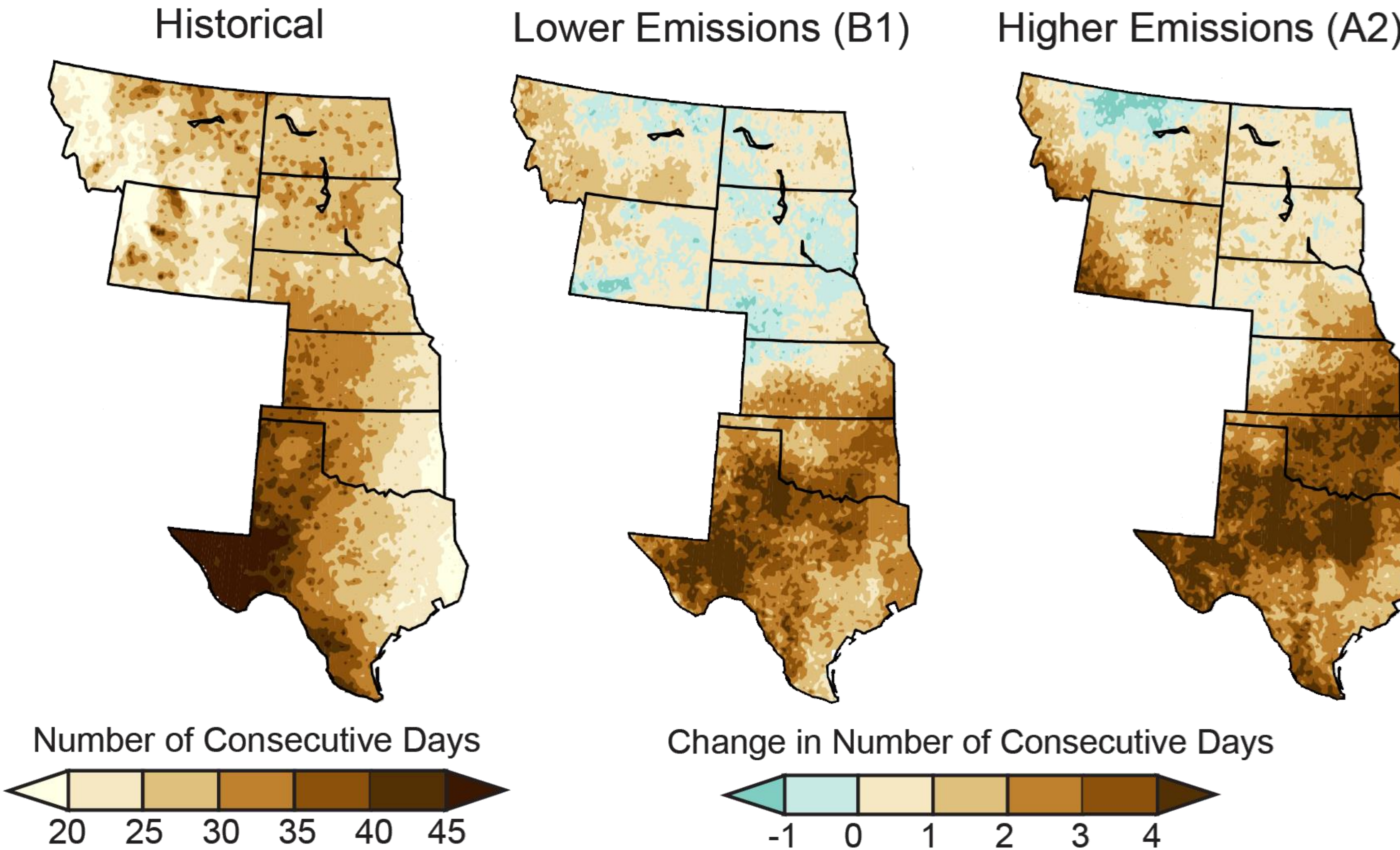
# Projected change in number of hot days




**http://nca2014.globalchange.gov/**

Fig. 19.2 – National Climate Change Assessment Report 2014

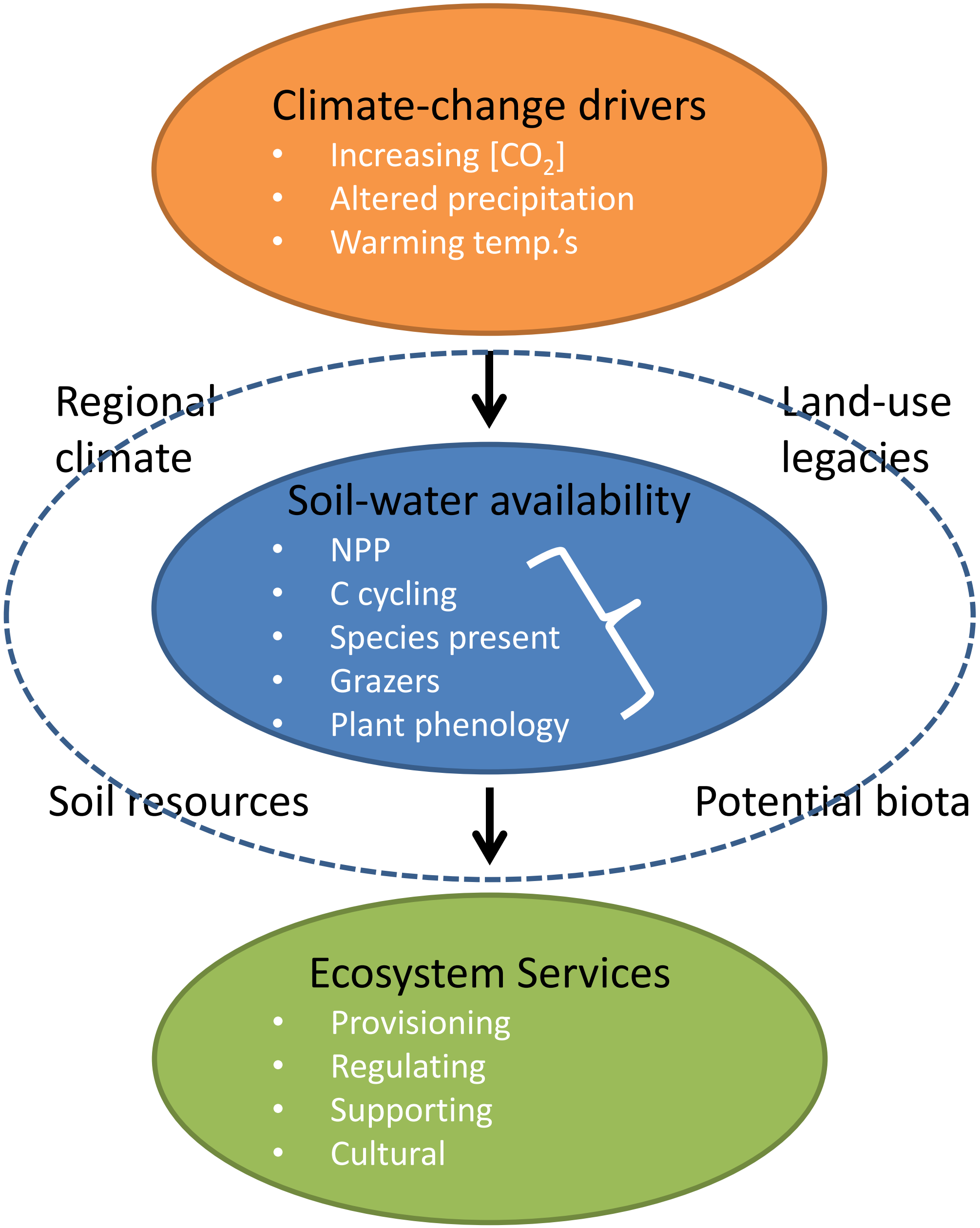
# Change in consecutive dry days



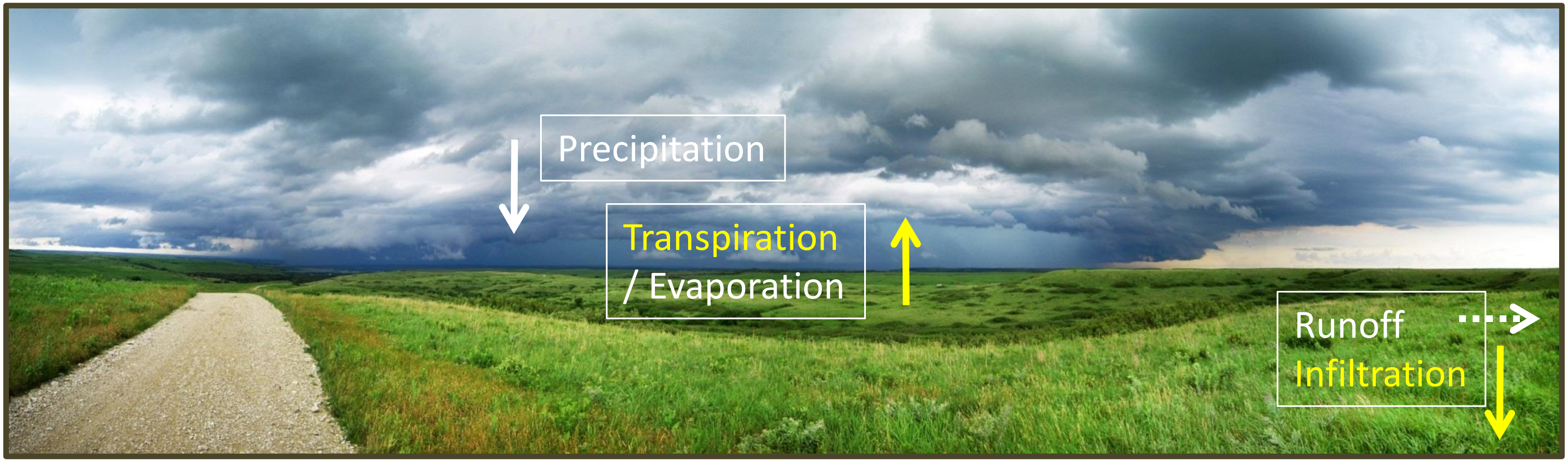

**http://nca2014.globalchange.gov/**

Fig. 19.5 – National Climate Change Assessment Report 2014

# Soil moisture integrates responses from vegetation to atmosphere



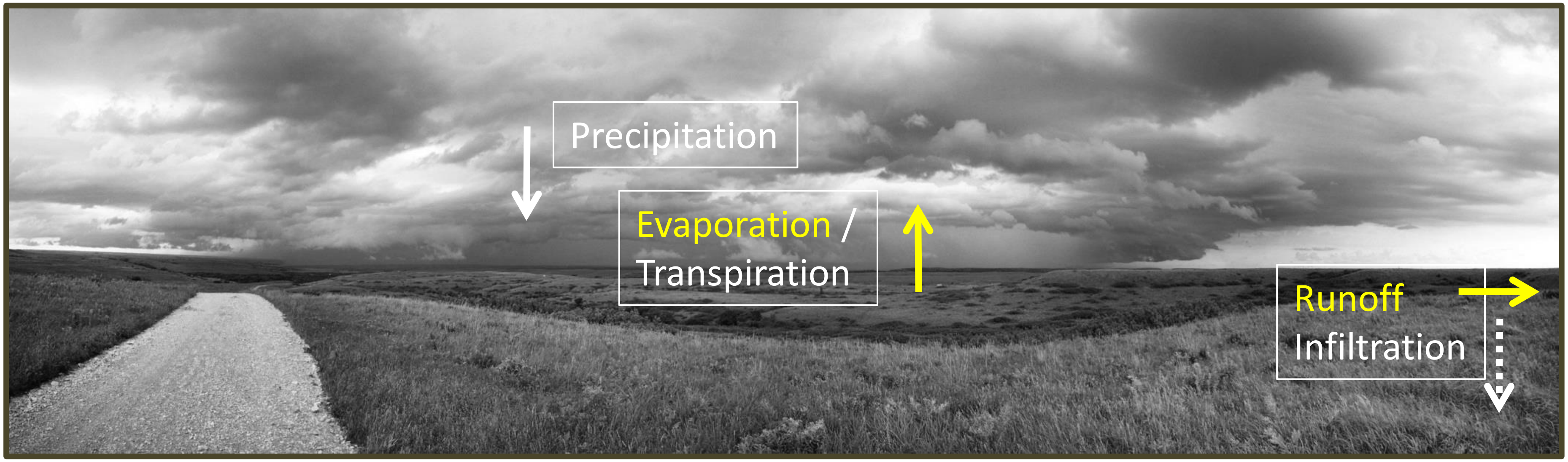

[Fig. 5] Polley et al. 2013 *J. Rangeland Mgt.* 66:493-511 photo by: Eva Horne



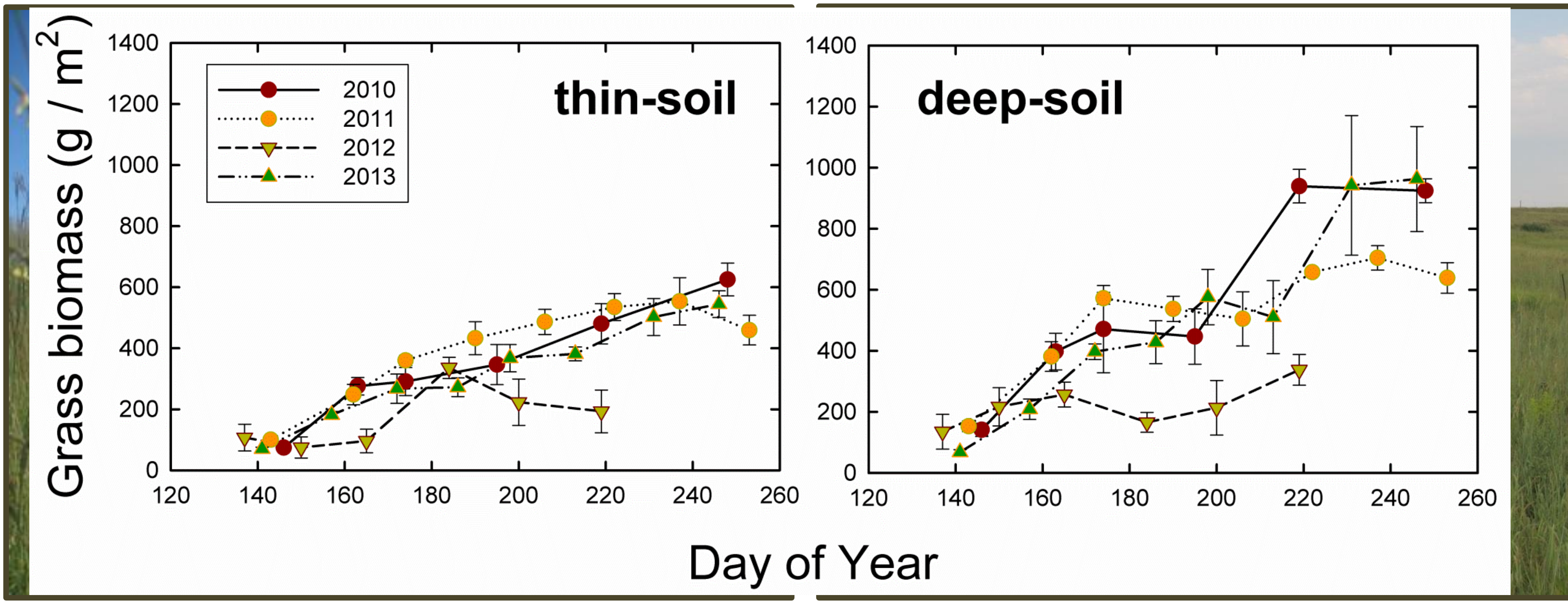

**Temperate grassland hydrological cycle reflects rainfall amount and timing**

## Future ?

increased event sizes, decreased frequency, altered seasonality, increased air temperatures



# *How does water stress impact grassland productivity and physiology?*




Annually-burned grassland, Konza Prairie – eastern KS, USA

Sept., 2008

ANPP – 1000 g $m^{-2}$ – $yr^{-1}$

+25% annual rainfall

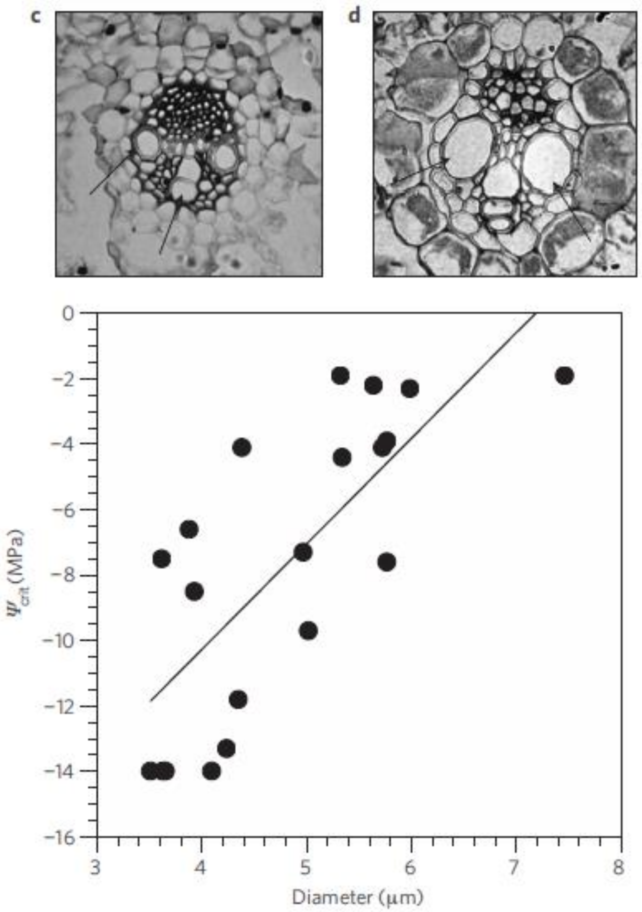
Sept., 2012

ANPP – 400 g $m^{-2}$ – $yr^{-1}$

-50% annual rainfall

# *How does water stress impact grassland productivity and physiology?*

## Drought tolerance

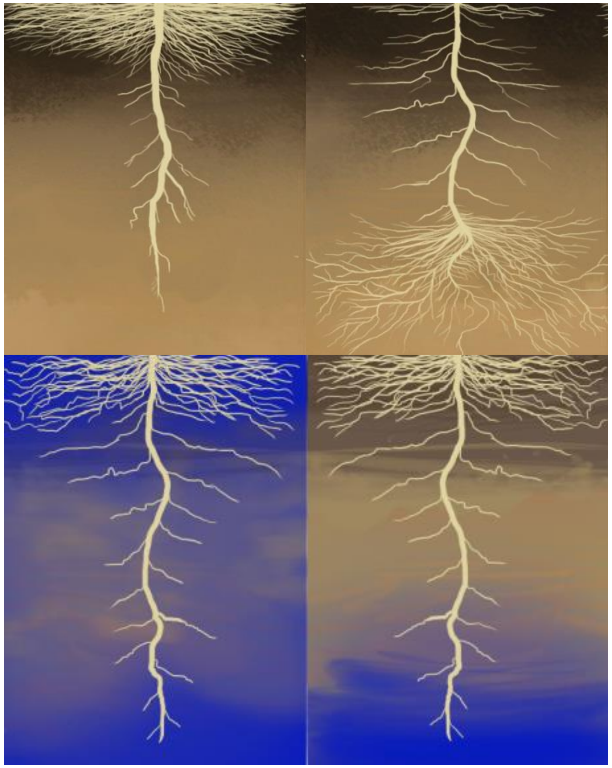



Craine et al. 2013 *Nature Climate Change* 3:63-67

## Drought avoidance

Root allocation

Root plasticity

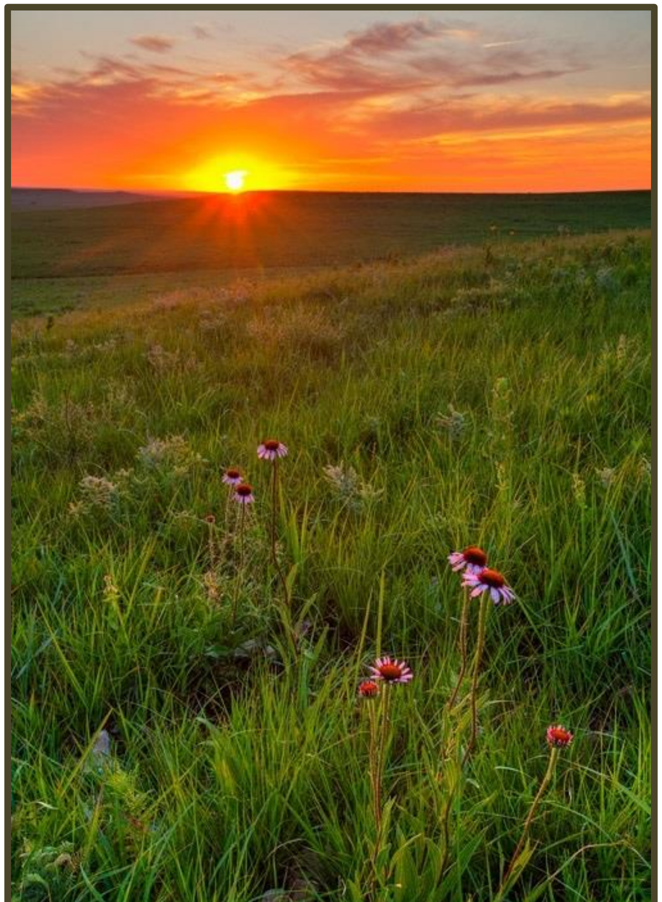


Art by: John J. Girvin III

Nippert & Holdo *in press Functional Ecology*

# Major Challenges

Prediction



Production

Photo credits: Judd Patterson

New Phytologist
Research

A new look at water transport regulation in plants

School of

ECOLOGY LETTERS
*Ecology Letters*, (2014) doi: 10.1111/ele.12374

LETTER

**Global analysis of plasticity in turgor loss point, a key drought tolerance trait**

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Global Change Biology
celebrating 20 years
Global Change Biology (2014) 20, 1992–2003, doi: 10.1111/gcb.12498

**Physiological advantages of $C_4$ grasses in the field: a**

New Phytologist
Review

*Tansley review*

Root structural and functional dynamics in terrestrial biosphere models – evaluation and

esa
ECOSPHERE

Anticipating changes in variability of grassland production due to increases in interannual precipitation variability

JOANNA S. HSU[1,†] AND PETER B. ADLER

*Department of Wildland Resources and the Ecology Center, Utah State University, Logan, Utah 84322 USA*

**Citation:** Hsu, J. S., and P. B. Adler. 2014. Anticipating changes in variability of grassland production due to increases in interannual precipitation variability. Ecosphere 5(5):58. http://dx.doi.org/10.1890/ES13-00210.1

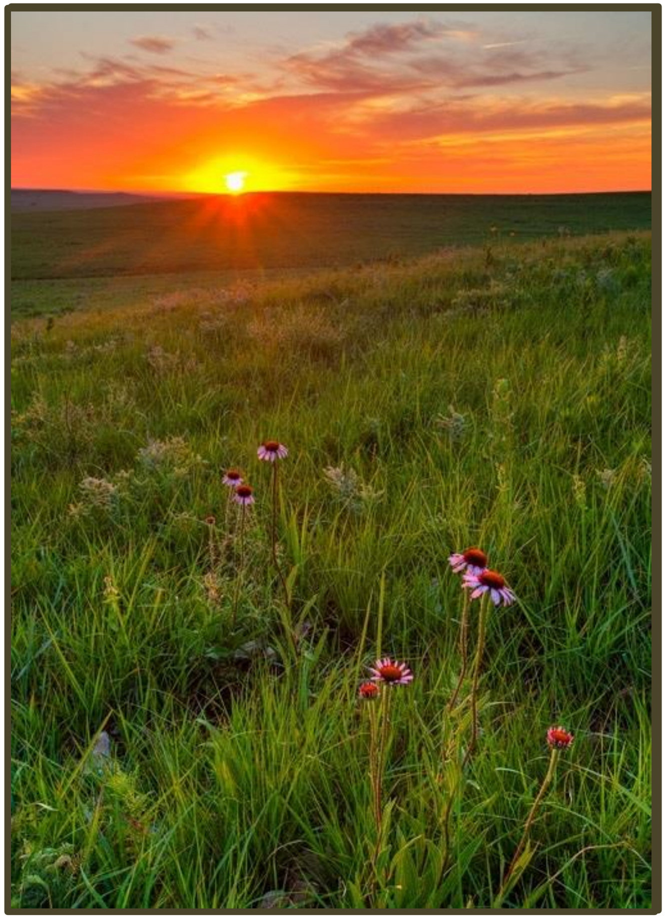
**Abstract.** Expected increases in interannual precipitation variability due to climate change will lead to increases in the variability of primary production, with potentially important consequences for natural

## PREDICTION

- Physiology
- Traits
- Drought experiments
- Root dynamics
- Forecasting grassland responses

# Major Challenges

Prediction



Production

Photo credits: Judd Patterson

COMMENTARY:

# The global groundwater crisis

J. S. Fami

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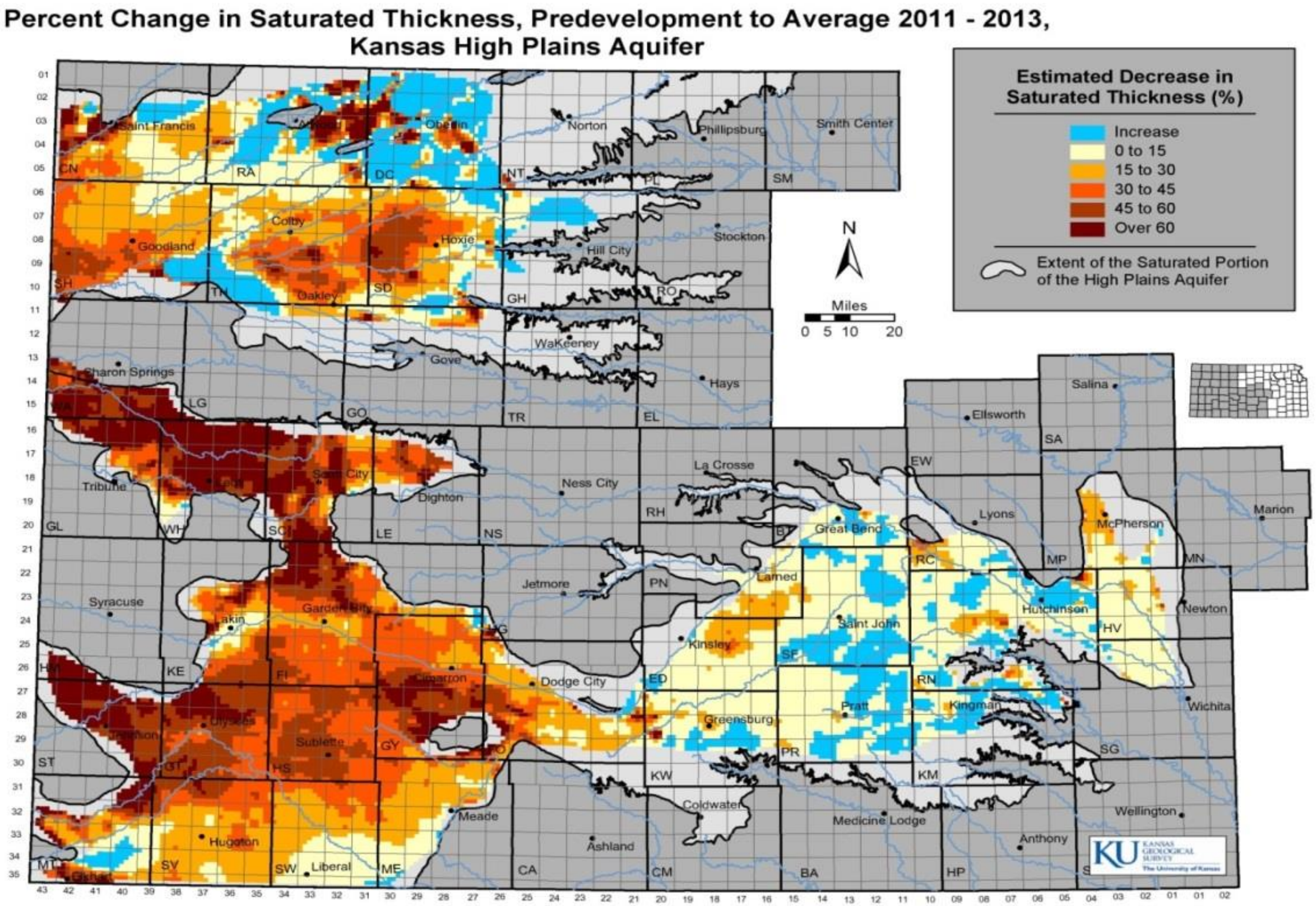



Butler *et al.* 2014

# Greater Sensitivity to Drought Accompanies Maize Yield

Agriculture, Ecosystems and Environment 193 (2014) 37–41

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

ELSEVIER

Short communication

# Spatial heterogeneity stabilizes livestock productivity

ıdorf[b],

# Climate Change Impacts on Global Food Security

Tim Wheeler[1,2]* and Joachim von Braun[3]

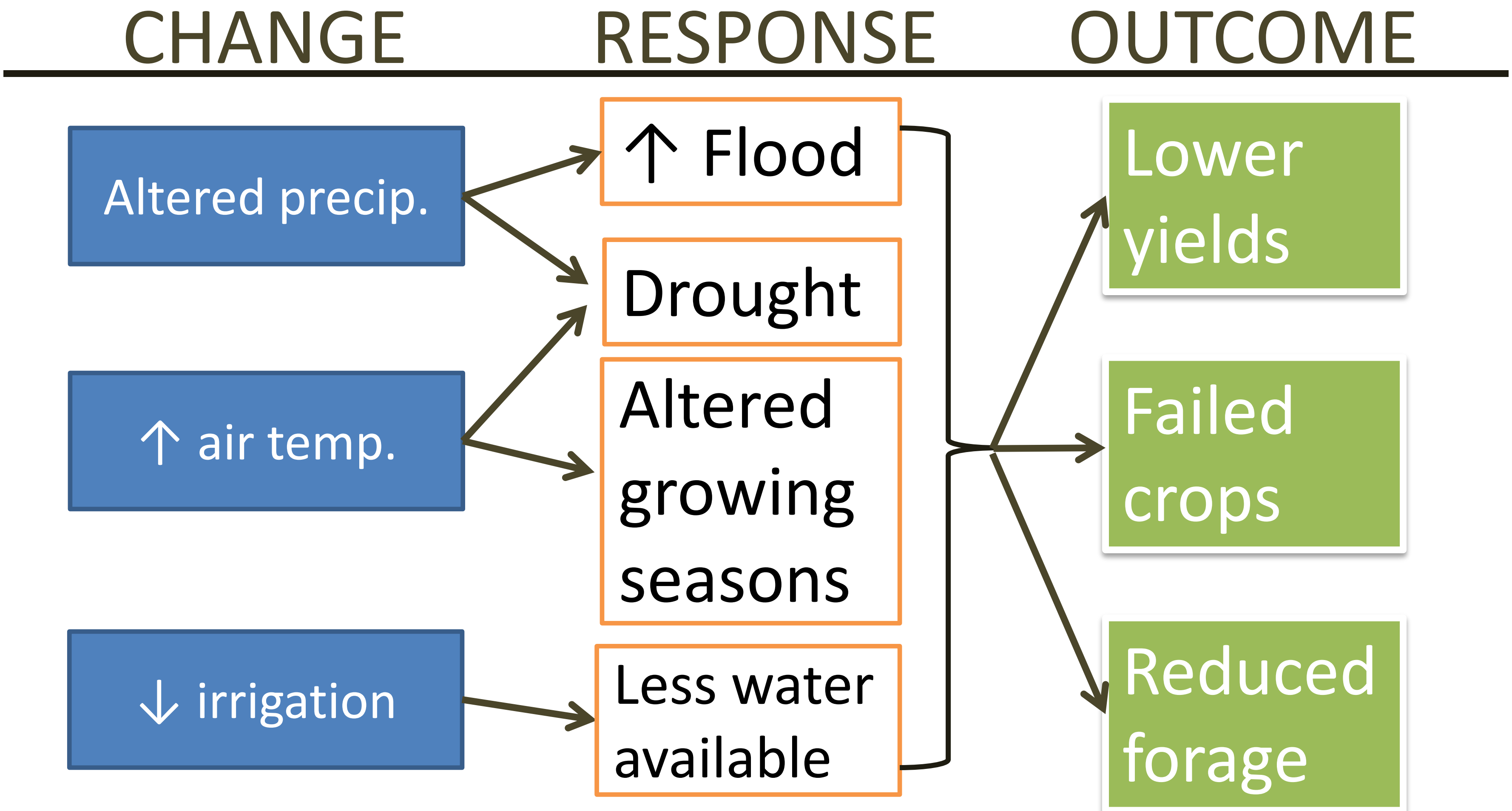
Climate change could potentially interrupt progress toward a world without hunger. A robust and coherent global pattern is discernible of the impacts of climate change on crop productivity that could have consequences for food availability. The stability of whole food systems may be at risk under climate change because of short-term variability in supply. However, the potential impact is less clear at regional scales, but it is likely that climate variability and change will exacerbate food insecurity in areas currently vulnerable to hunger and undernutrition. Likewise, it can be anticipated that food access and utilization will be affected indirectly via collateral effects on household and individual incomes, and food utilization could be impaired by loss of access to drinking water and damage to health. The evidence supports the need for considerable investment in adaptation and mitigation actions toward a "climate-smart food system" that is more resilient to climate change influences on food security.

Tackling hunger is one of the greatest challenges of our time (*1*). Hunger has multiple dimensions and causes, ranging from deficiencies in macro- and micro-nutrients, through short-term shocks on food access, to chronic shortages. Causes range from constraints on the supply



## PRODUCTION

- Improved cultivars
- Sensitivity to drought
- Grassland management
- ↑system resilience




GRASSLAND SUSTAINABILITY WILL REQUIRE -

**NEW METHODS** **NEW GENOTYPES** **NEW CROPS**

# *Next Frontiers?*

THE LAND INSTITUTE

## Perennial Polycultures

- Greater ET than annuals

***But,***

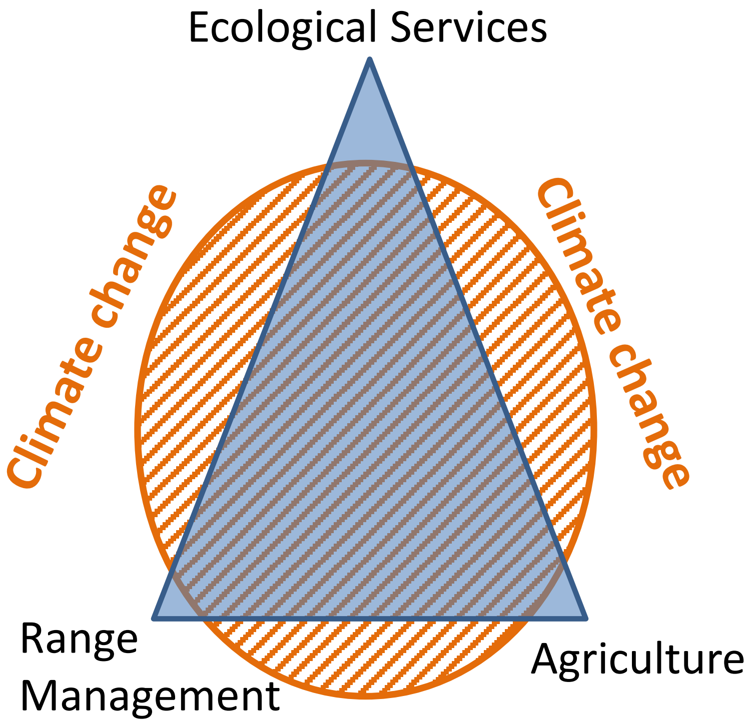
- more water available
  - no tillage,
  - increased soil structure,
  - increased SOM,
  - incr. water holding capacity
- During bad years, crops used for forage
- Potential for niche partitioning maximizes total water-use

www.landinstitute.org

Domesticating native species (*Silphium*)

Perennialzing current annual crops (Kernza)

# *Strategy for Adaptive Management*




**<u>Grassland mgt will require:</u>**

- Balanced goals
- Effective communication
- Improved efficiency
- Intensification
- Interdisciplinarity
- Novel solutions
- Social investment

# Thanks!

*Eco-phys Lab*
Kim O'Keefe
Troy Ocheltree
Zak Ratajczak

John Blair
John Briggs

Tim Crews

Ricardo Holdo