Controls on carbon sequestration in native grassland

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University of Lethbridge
April 14, 2015

Research Objectives & Goals

What are the consequences of global change for ecosystem function?

- Measure ecosystem carbon, water & nutrient cycling processes
- Study moisture-temperature interactions controlling ecosystem function
- Compare local case studies with regional-scale studies

General Research Strategies Employed

1) Ecosystem observational studies

eddy covariance CO_2 flux measurements,

repeat photography (PhenoCam) studies

2) Ecosystem manipulation experiments

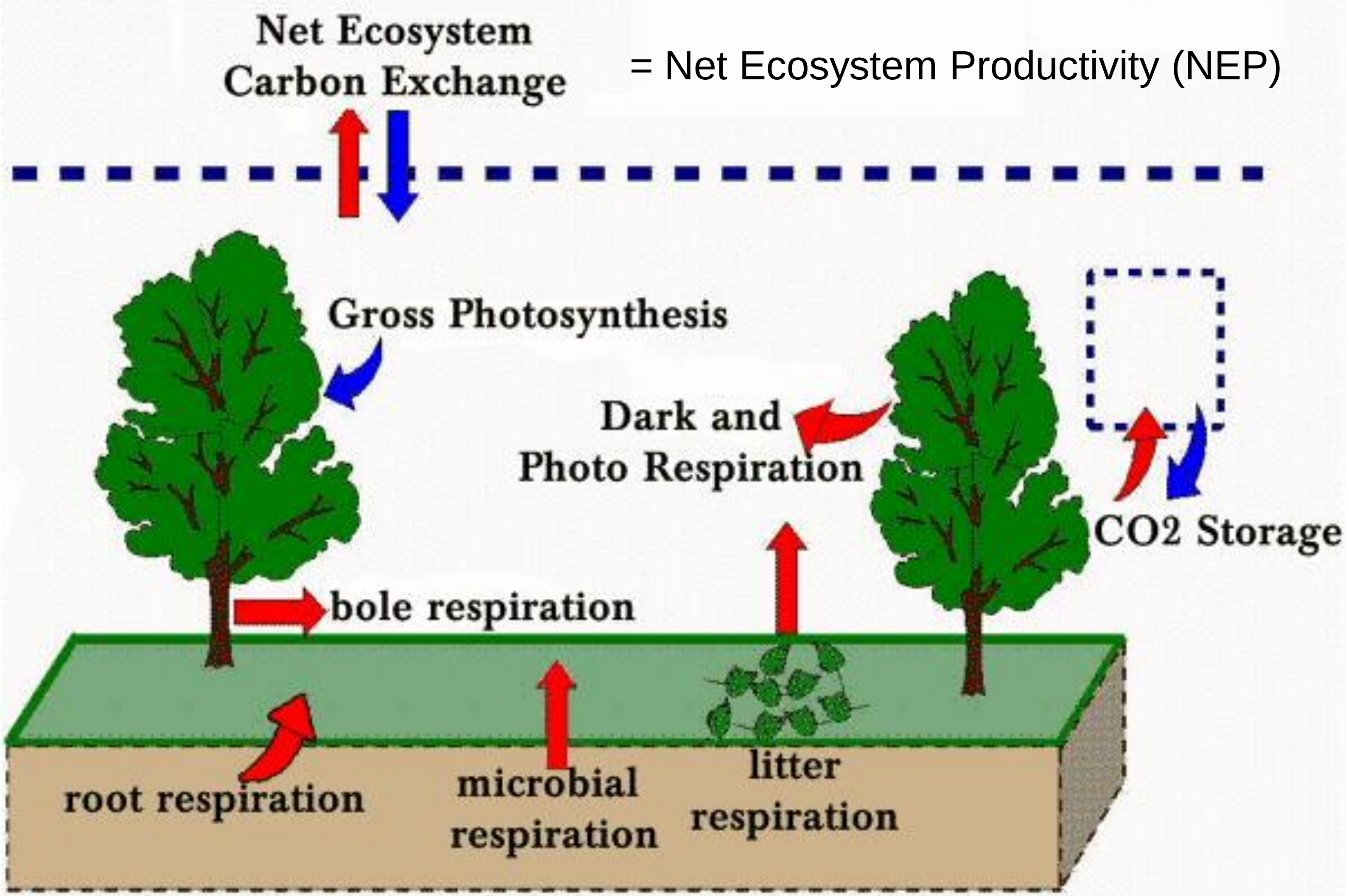
warmer temperature, altered rain

3) Develop and use models to predict ecosystem response to environmental change


Lethbridge Grassland: Fluxnet-Canada & Ameriflux
Eddy Covariance Flux Measurements

Ecosystem Carbon Balance

= Net Ecosystem Productivity (NEP)



$$NEP = GEP - TER$$

NEP = Net Ecosystem Productivity (+/-)

GEP = Gross Ecosystem Productivity (+)

TER = Total Ecosystem Respiration (+)

2013

Global Change Biology (2008) **14**, 309–320, doi: 10.1111/j.1365-2486.2007.01486.x

Infrared heater arrays for warming ecosystem field plots

BRUCE A. KIMBALL*, MATTHEW M. CONLEY*, SHIPING WANG†, XINGWU LIN†, CAIYUN LUO†, JACK MORGAN‡ and DAVID SMITH‡

**US Arid Land Agricultural Research Center, USDA, Agricultural Research Service, 21881 North Cardon Lane, Maricopa, AZ 85238, USA, †Key Laboratory of Adaptation and Evolution of Plateau Biota, Northwest Institute of Plateau Biology, Chinese Academy of Sciences, Xining 810008, Qinghai, China, ‡Crops Research Laboratory, USDA, Agricultural Research Service, Ft Collins, CO 80526, USA*

Temperature Free-Air-Controlled Enhancement (T-FACE)


28.0 °C
19.0


L

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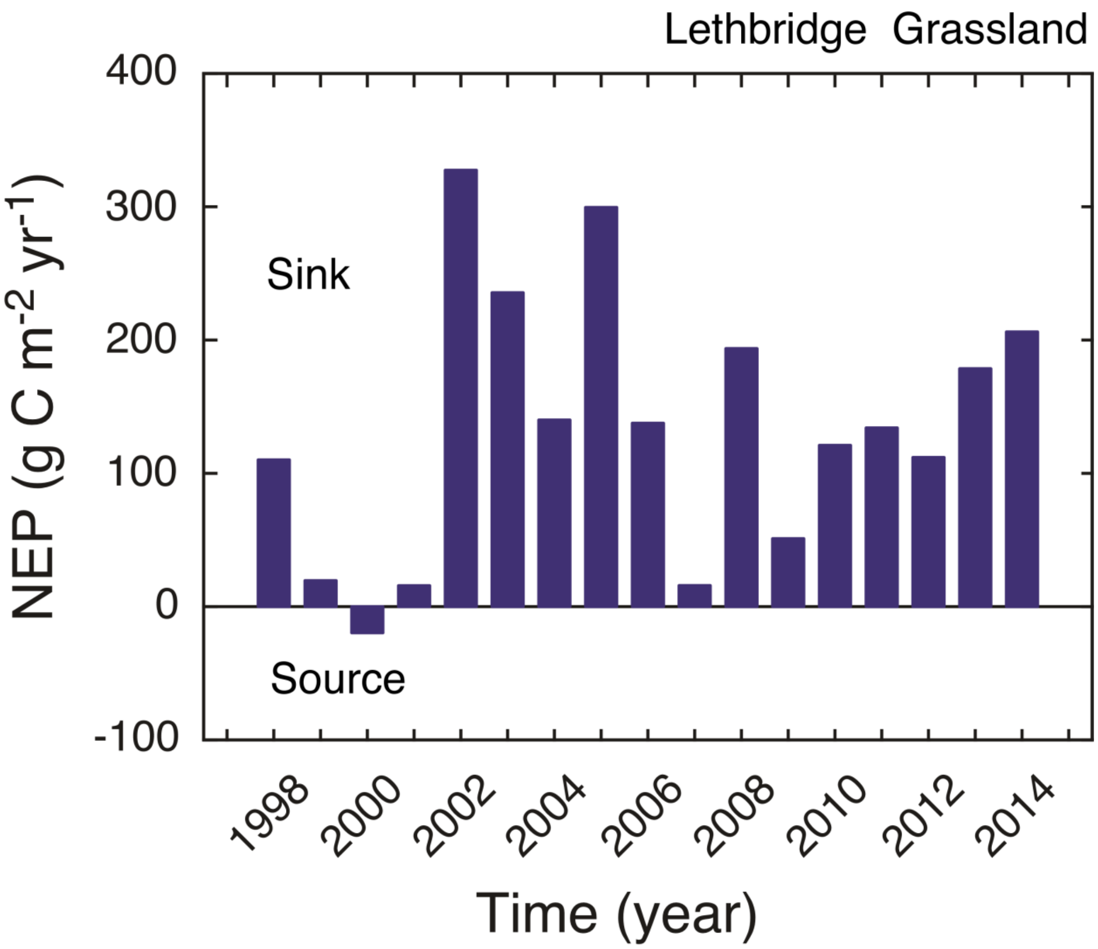
First Message

Net carbon sequestration (NEP) in grasslands varies to a large extent on an annual basis

Mature, native grassland has the potential to sequester significant amounts of carbon for extended periods of time

Annual net carbon exchange over 17 years measured by eddy covariance



Zhang *et al*. (2011) *J. Geophys. Res*. 116, G00J03, doi:10.1029/2010JG001504

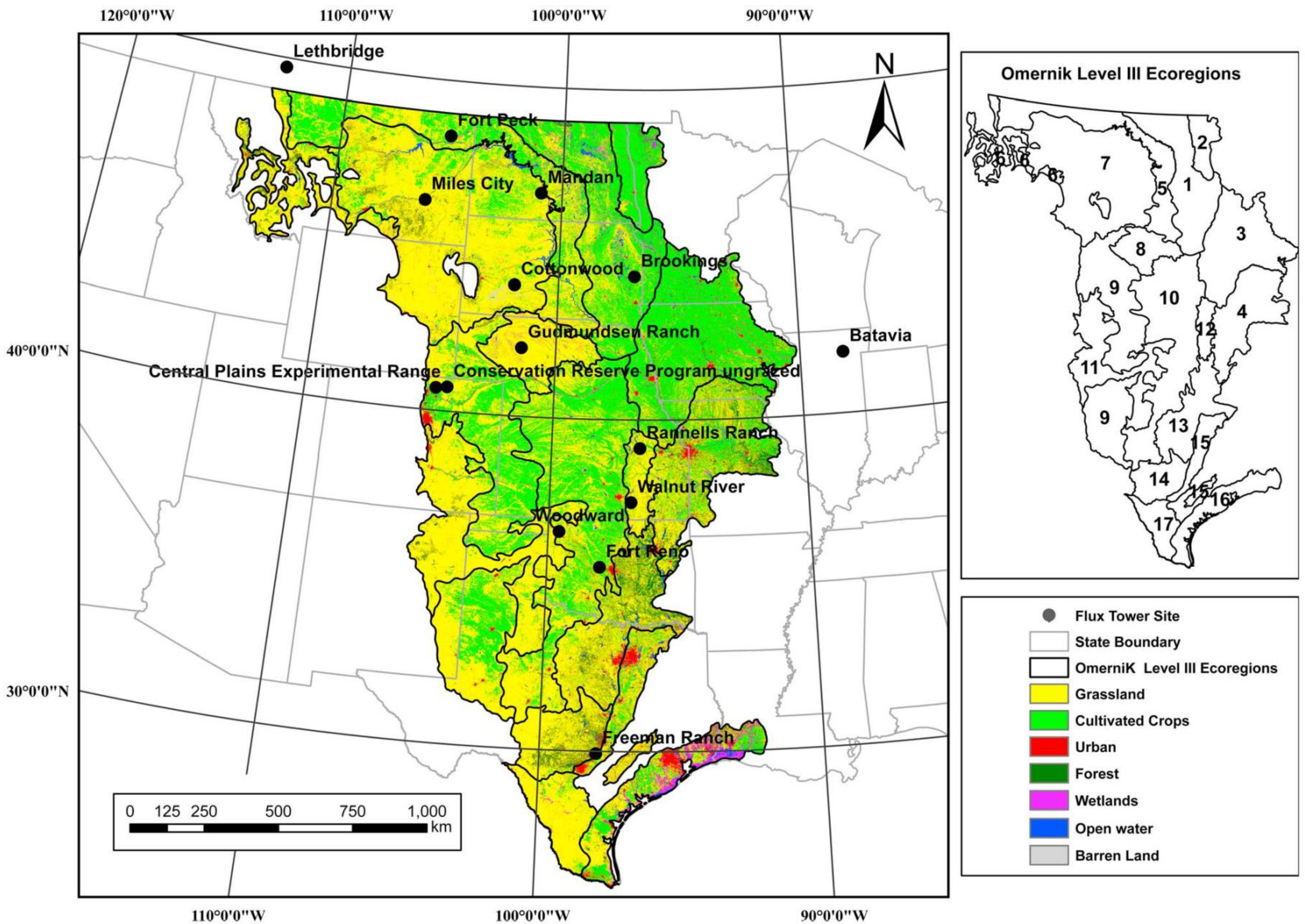
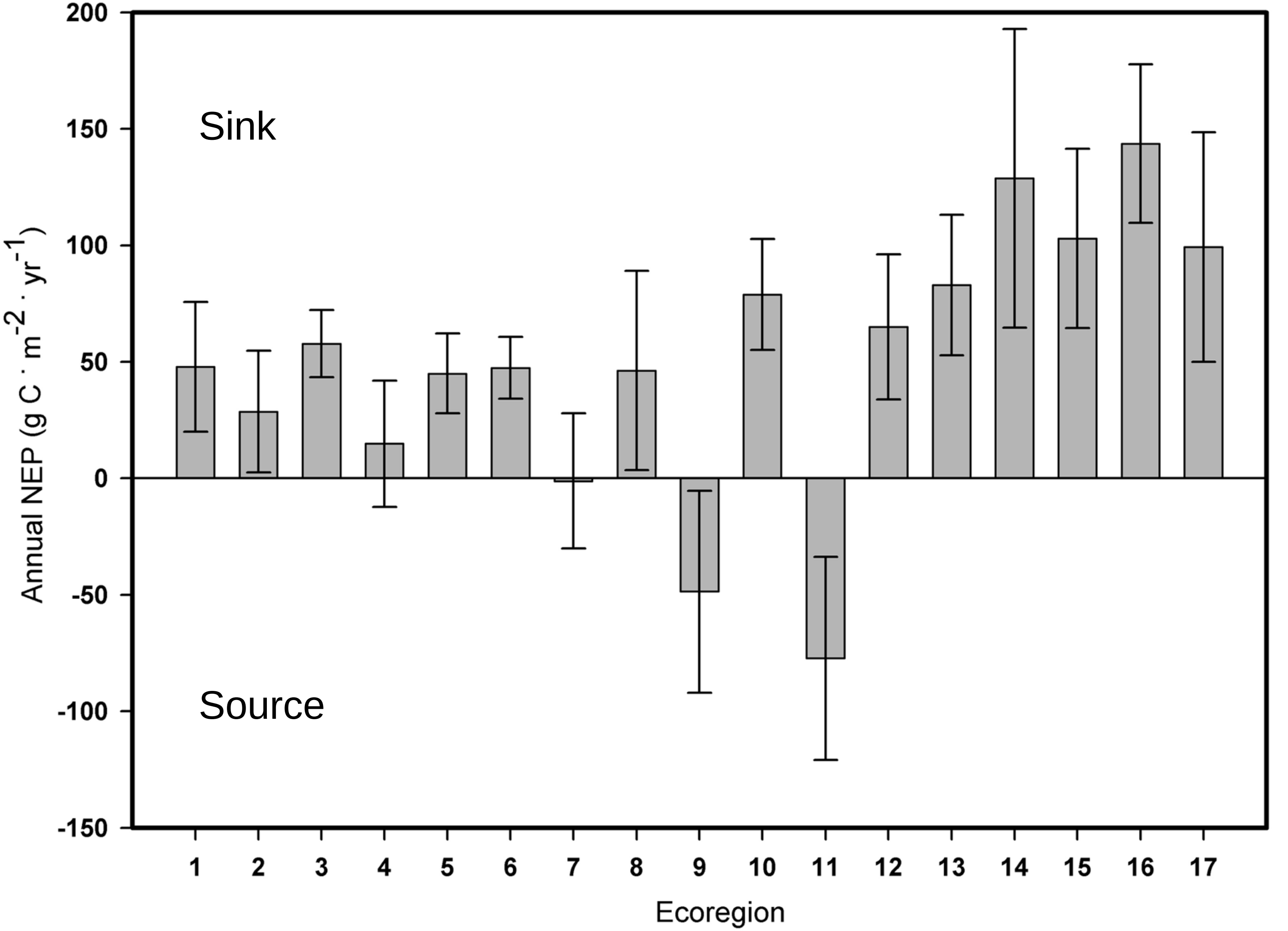
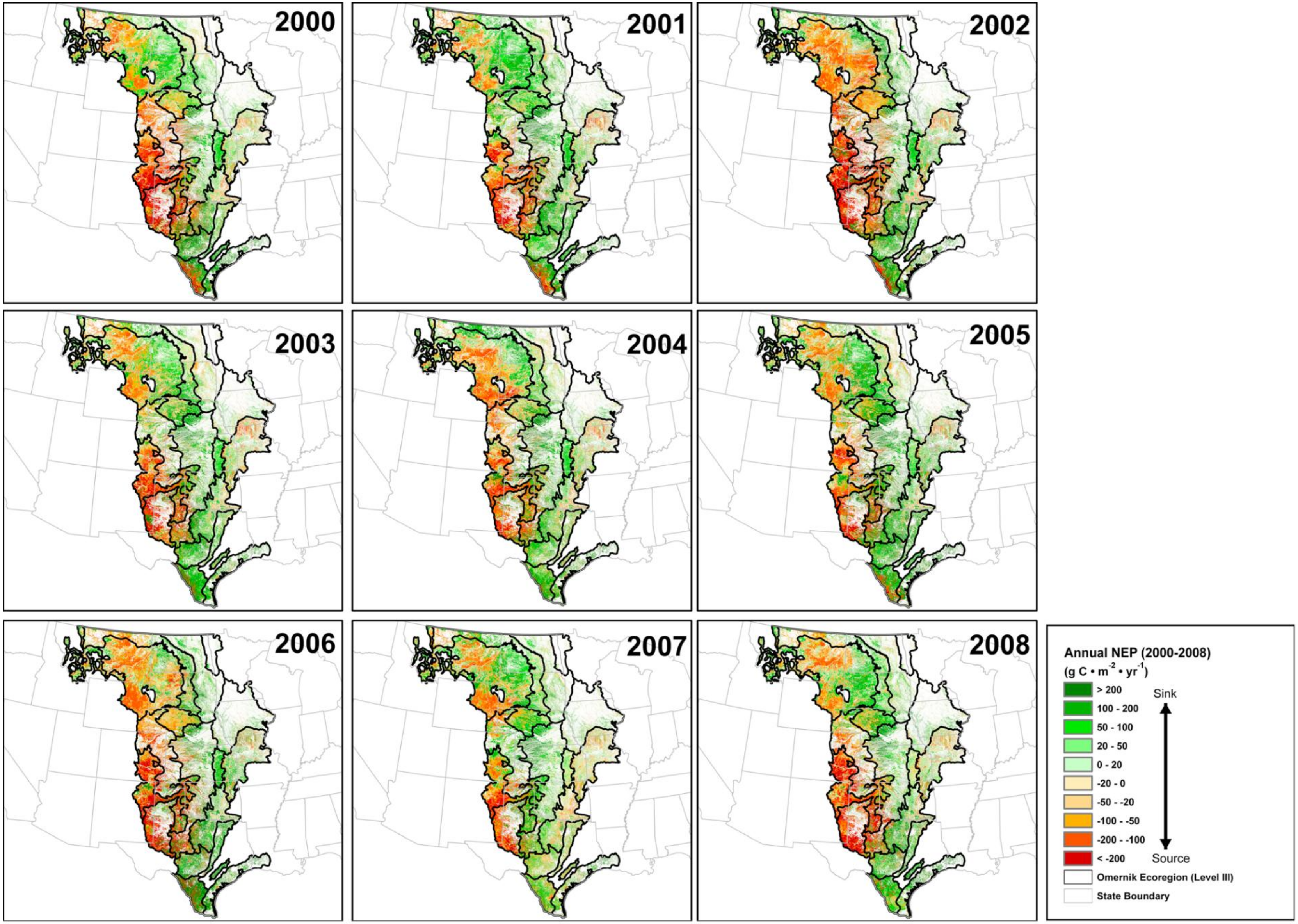


Figure 1. Study area, grassland flux towers, and land cover over the Great Plains. The land cover map was derived from the 2001 National Land Cover Database. The numbers labeled in the Omernik Level III Ecoregions map represent the following: 1, Northern Glaciated Plains; 2, Lake Agassiz Plain; 3, Western Corn Belt Plains; 4, Central Irregular Plains; 5, Northwestern Glaciated Plains; 6, Montana Valley and Foothill; 7, Northwestern Great Plains; 8, Nebraska Sandhills; 9, Western High Plains; 10, Central Great Plains; 11, Southwestern Tablelands; 12, Flint Hills; 13, Central Oklahoma/Texas Plains; 14, Edwards Plateau; 15, Texas Blackland Prairies; 16, Western Gulf Coastal Plain; and 17, Southern Texas Plains.



Average annual NEP from 2000 to 2008 in 17 eco-regions. The error bar shows 1 standard deviation of the estimated annual NEP for the 9 years. The numbers on the x axis represent the eco-region numbers as shown in Figure 1.

Zhang *et al*. (2011) *J. Geophys. Res*. 116, G00J03, doi:10.1029/2010JG001504



Maps of annual NEP over the Great Plains grasslands during 2000–2008.

Zhang *et al*. (2011) *J. Geophys. Res*. 116, G00J03, doi:10.1029/2010JG001504

Up-scaling carbon fluxes over the Great Plains grasslands: Sinks and sources

L. Zhang, B.K. Wylie, L. Ji, T.G. Gilmanov, L.L. Tieszen, D.M. Howard (2011)
J. Geophys. Res. 116, G00J03, doi:10.1029/2010JG001504

The Great Plains had an average annual NEP of 24 ± 14 g C m^{-2} yr^{-1} (net sink), with annual variation in NEP ranging from 0.3 to 47.7 g C m^{-2} yr^{-1}.

The average NEP for the entire Great Plains grassland was estimated to be 336 Tg C yr^{-1} from 2000 to 2008.

In the 9 year study, including 4 dry years, the annual NEP was very variable in both space and time.

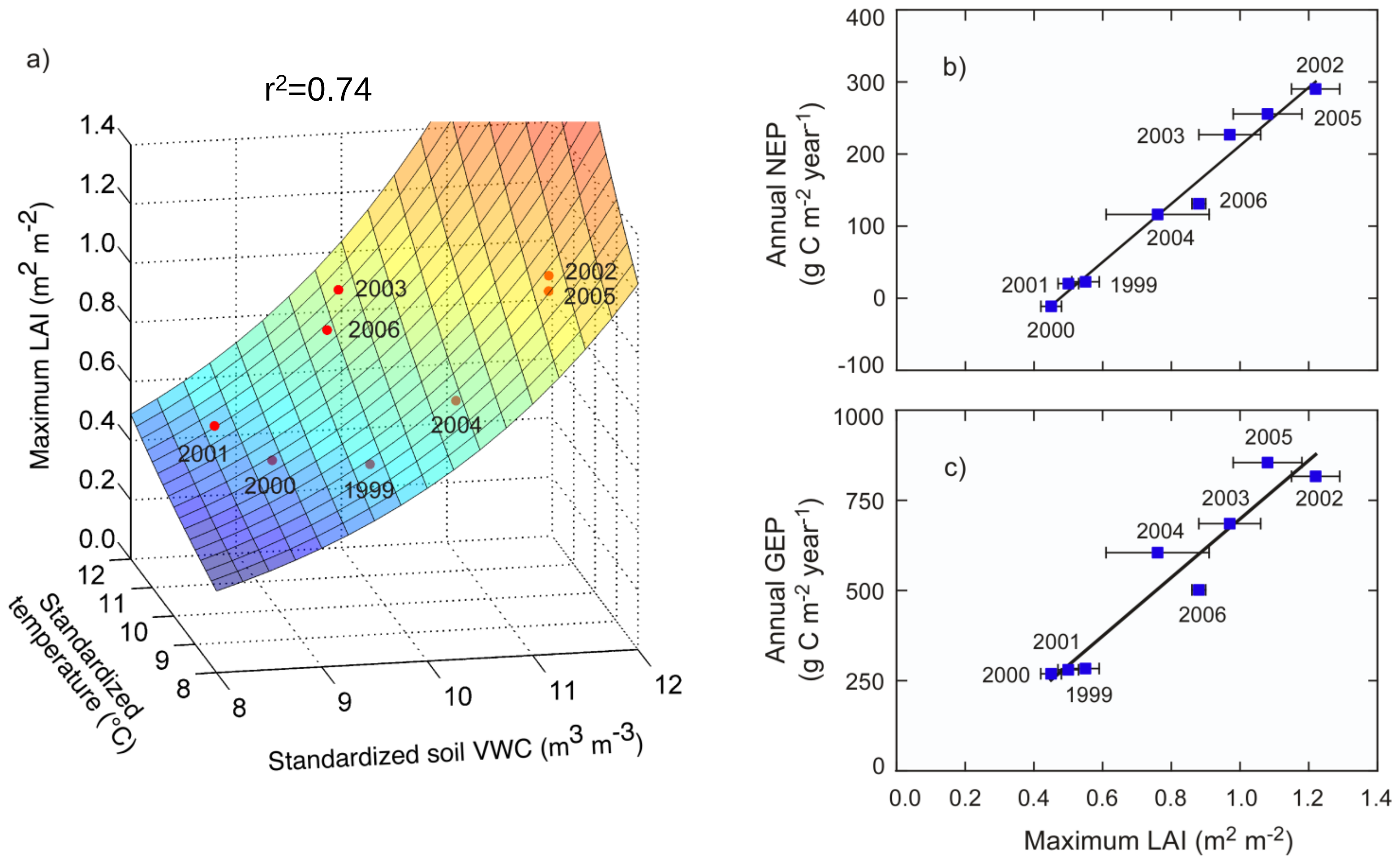
The droughts in 2000, 2002, 2006, and 2008 resulted in net carbon losses over drought-affected areas, and the Great Plains grasslands turned into a relatively low sink with NEP values of 15.8, 0.3, 20.1, and 10.2 g C m^{-2} yr^{-1} for the 4 years, respectively.

Second Message

Variation in moisture and moisture-temperature interactions are major factors controlling grassland net carbon sequestration

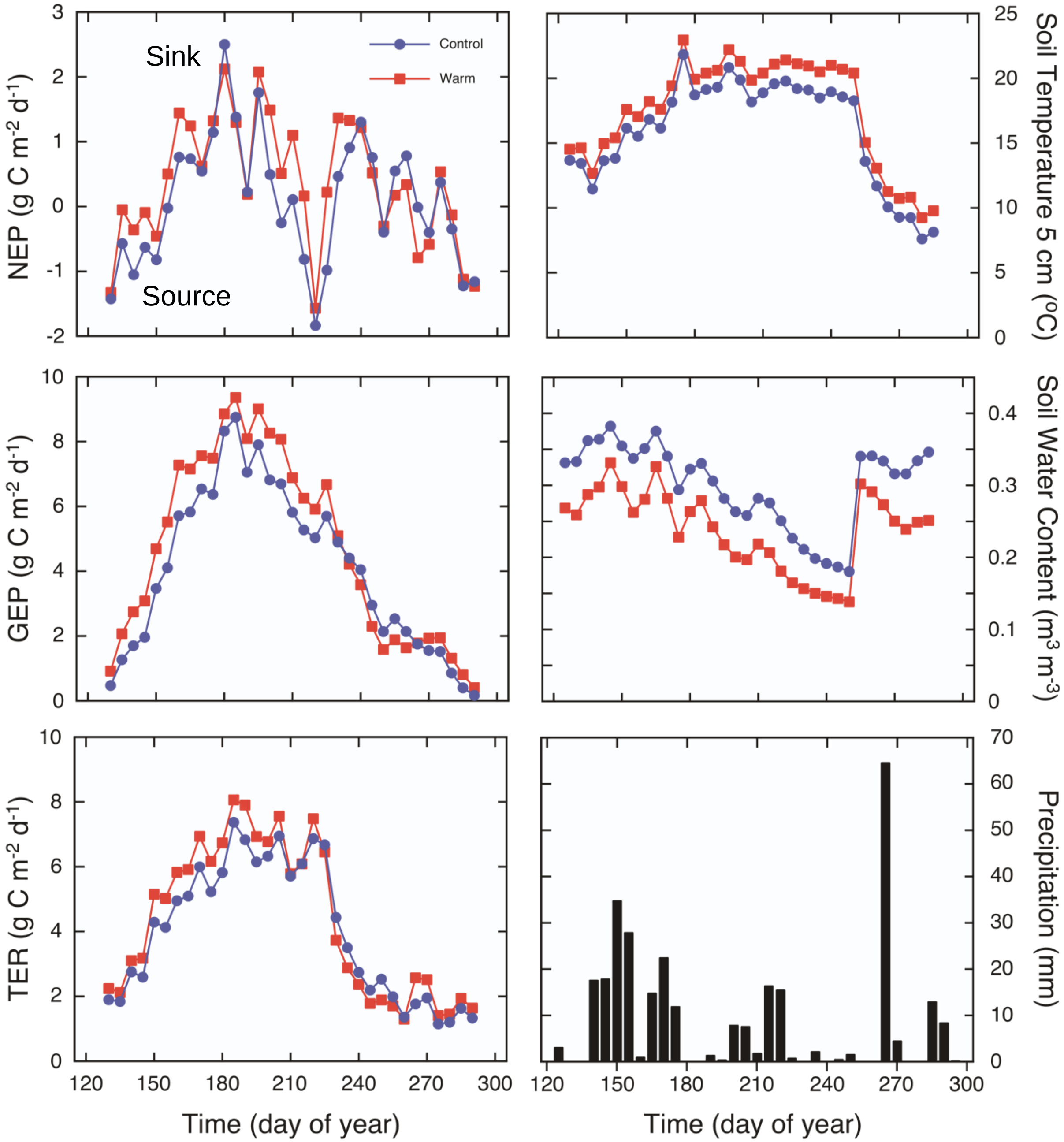
If moisture remains near “normal” conditions, carbon sequestration can increase significantly in response to warmer conditions

What controls annual variation in Lethbridge grassland C sequestration?



Flanagan & Adkinson (2011) Global Change Biology 17: 3293

NEP = GEP – TER   Lethbridge 2013



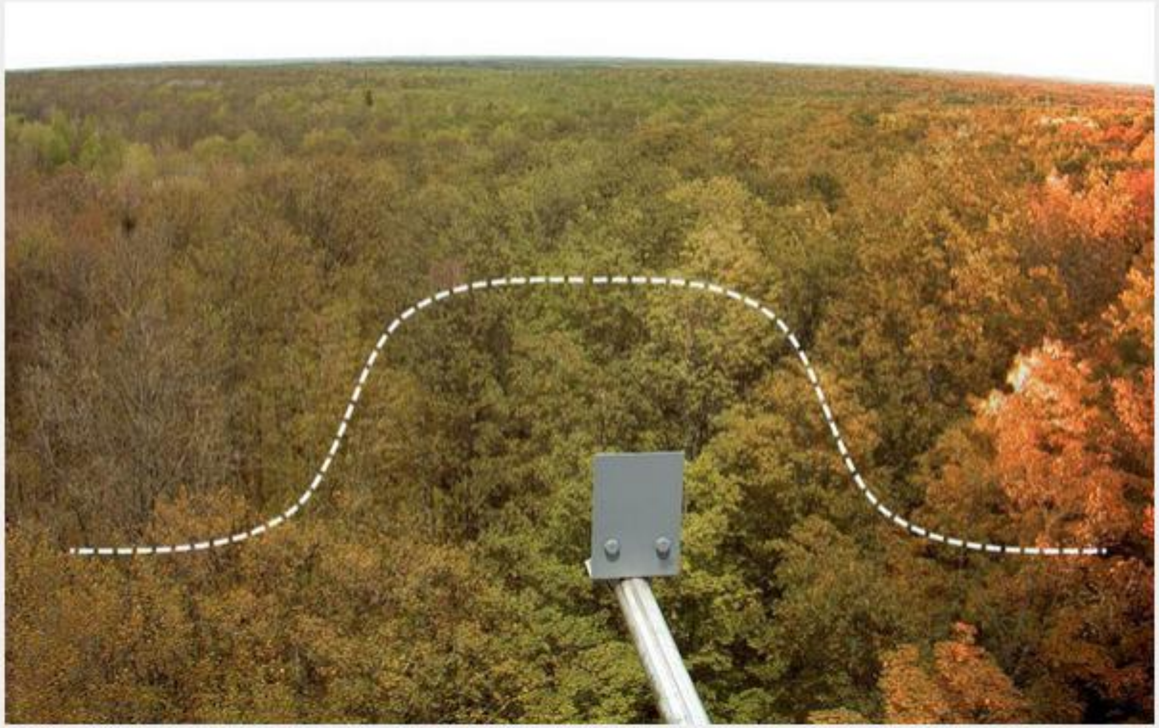
Third Message

Despite projected increases in aridity under climate change, modeled responses predict higher grassland leaf area and productivity

Shifts in vegetation growth to earlier spring emergence can compensate for drought-induced reduction in growth in summer time, particularly in northern regions of the Great Plains

Andrew Richardson, Harvard University

PHENOCAM

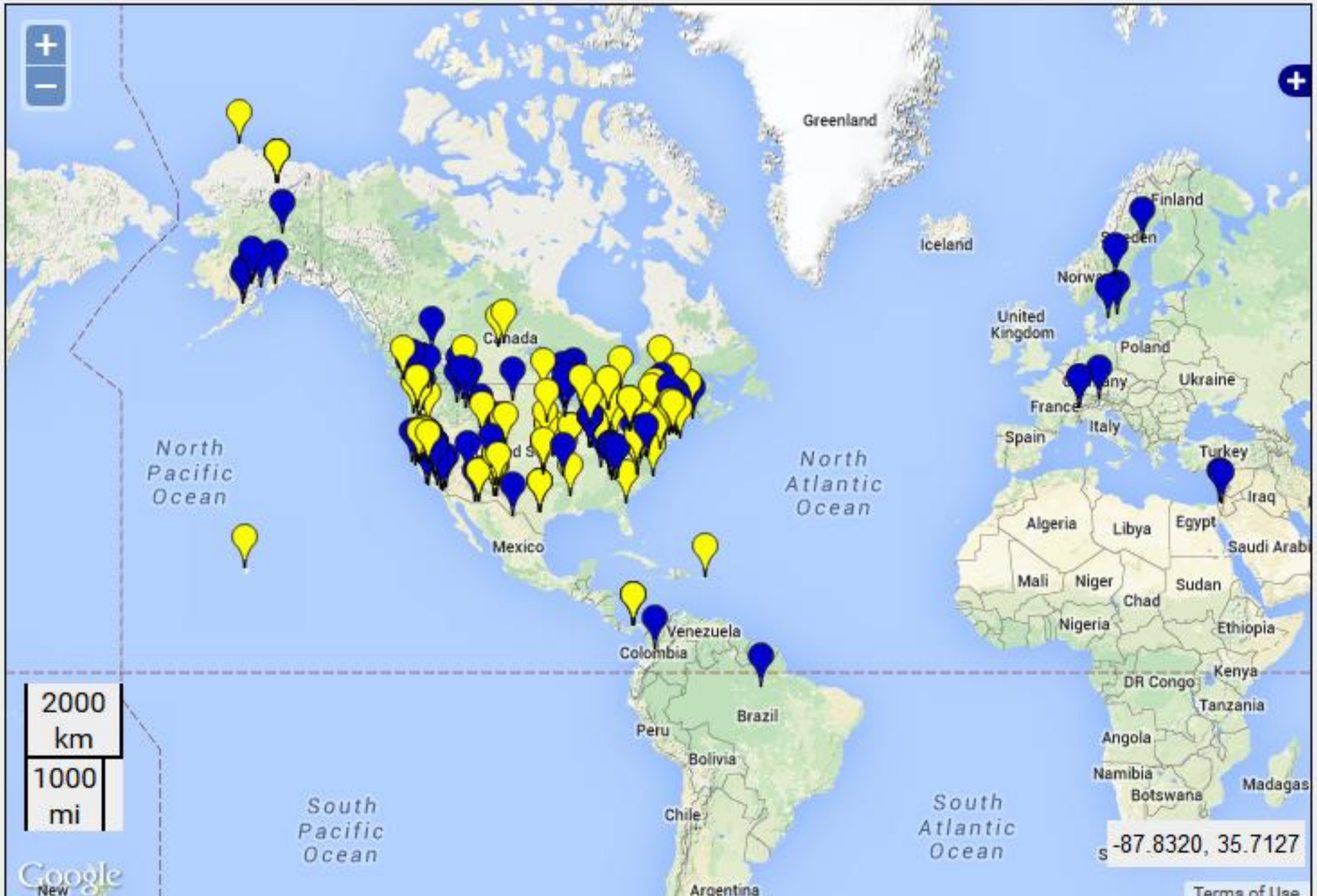


An ecosystem phenology web camera network

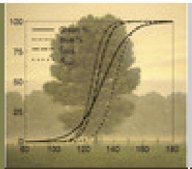
About • Gallery • Map • FAQ • Tools • Data • Site Table • Admin

PhenoCam - Site Map

About | Gallery | Map | FAQ | Tools | Data | Site Table | Admin   Welcome, Guest (login)



Site types: Core Affiliated (show inactive sites)



PHENOCAM - ROI Information

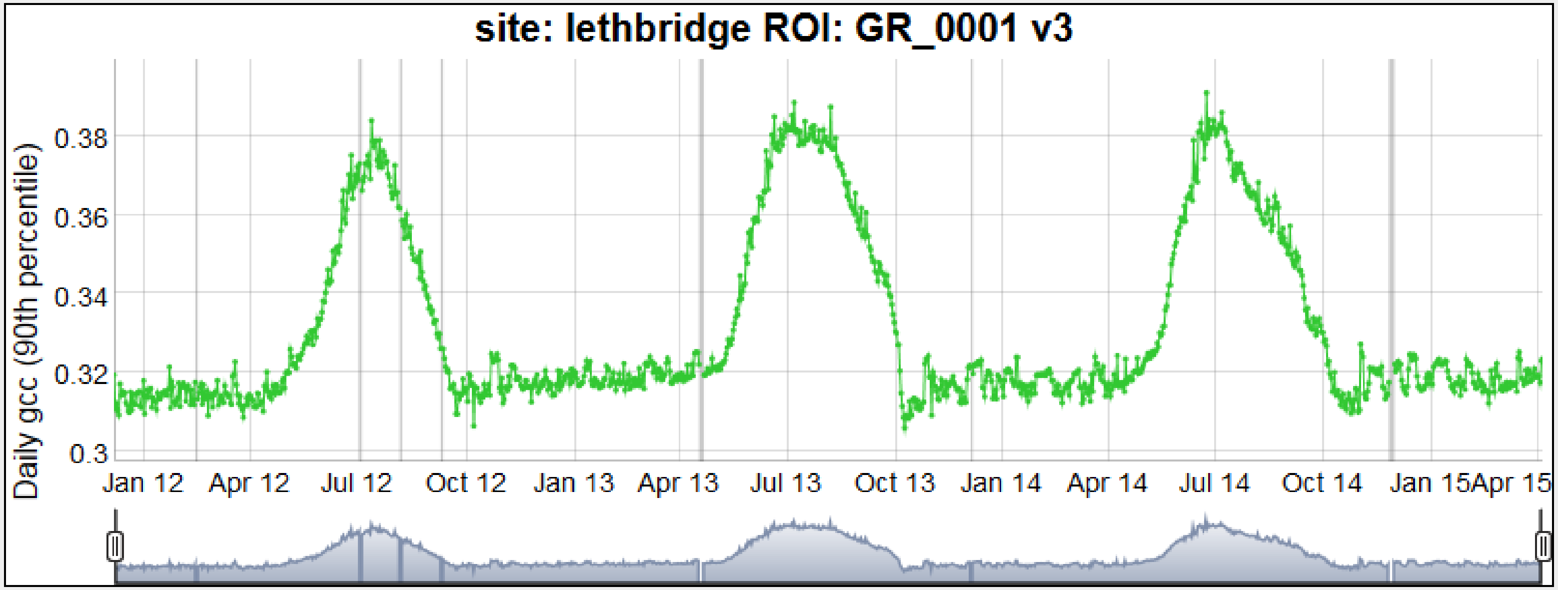
About | Gallery | Map | FAQ | Tools | Data | Site Table | Admin

Site Name: lethbridge
Location: Lethbridge, Alberta, Canada
Lat: 49.70919 Lon: -112.94025 Elev(m): 950

Image Count: 42728 Start Date: 2011-12-07 Last Date: 2015-04-06

ROI Name: GR_0001 (TBD)

gcc (green chromatic coordinate) timeseries plot



PNG Plot

gcc = Green/(Red+Blue+Green)

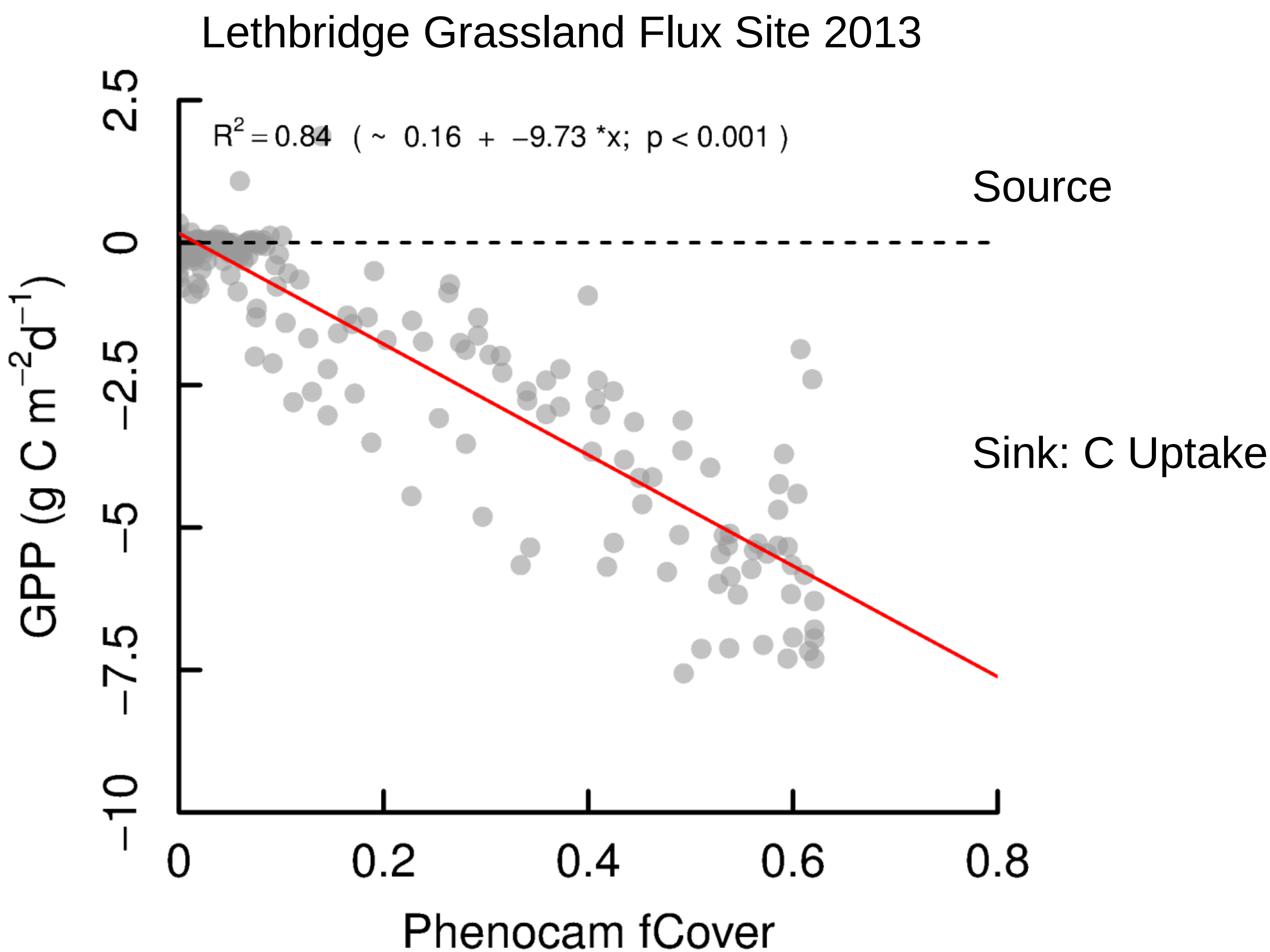
Despite increasing aridity, climate change promotes growth of North American grasslands

K. Hufkens, T.F. Keenan, L.B. Flanagan, A.D. Richardson (2015) *in review*

PhenoCam greenness observations were used to parameterize a vegetation-hydrology model (daily time-step)

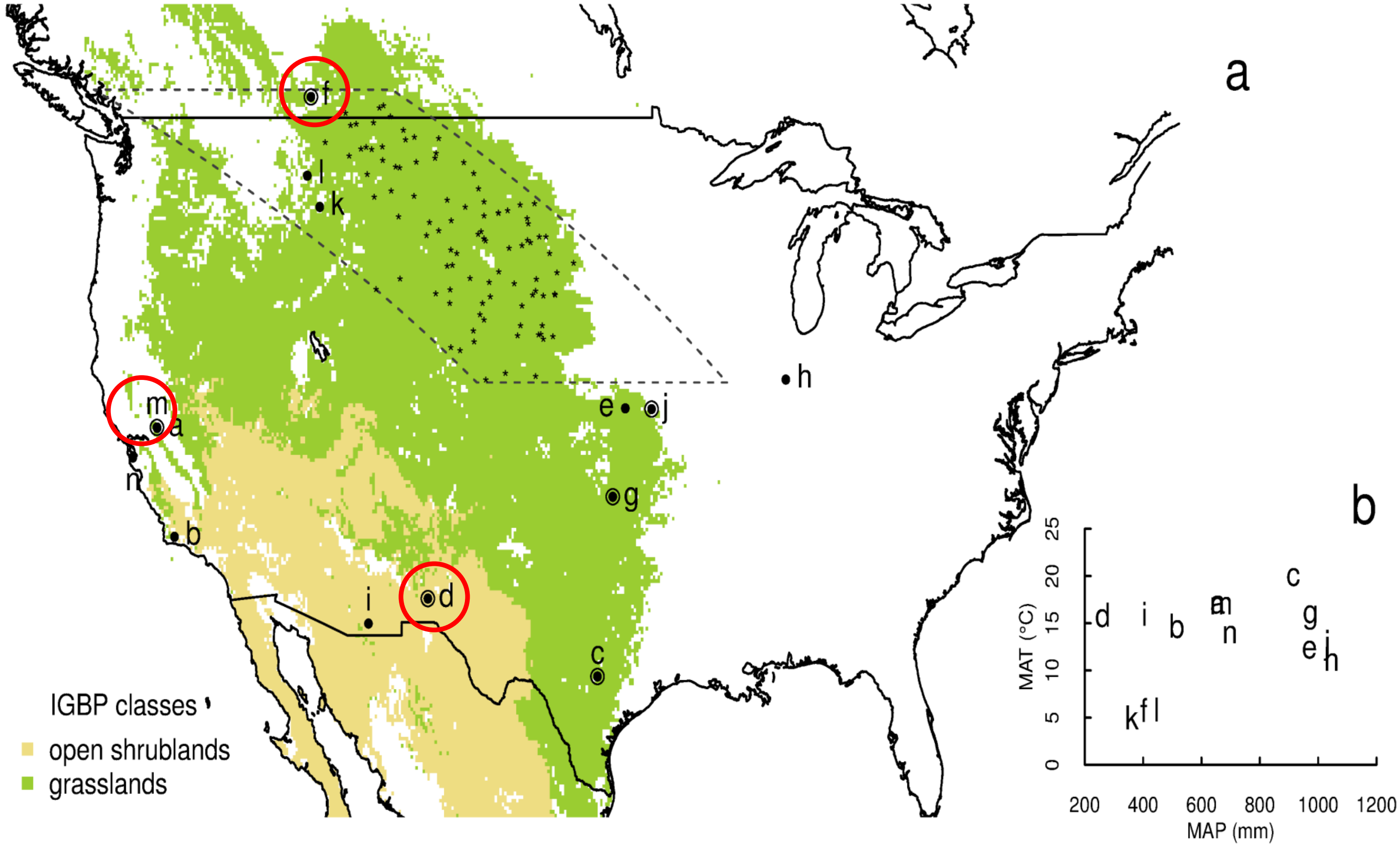
The model predicted plant fractional ground coverage (fCover) – similar in concept to Leaf Area Index (LAI)

Daily changes in fCover (growing season) were strongly correlated with measurements of ecosystem photosynthesis



Relationship between plant fractional cover (fCover) and gross primary productivity (GPP) at the Lethbridge site. A fitted ordinary least squares regression is shown as a full red line.

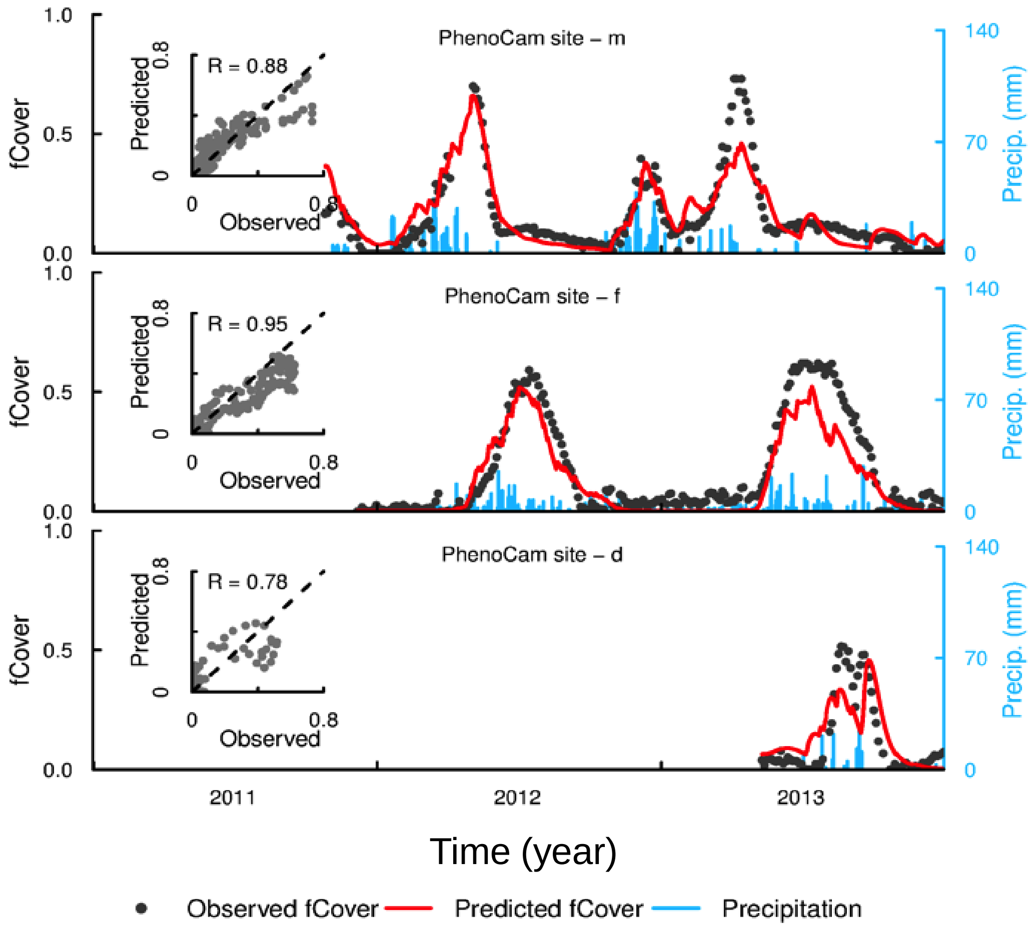
Hufkens *et al*. (2015) in review



Overview of the PhenoCam validation sites and their corresponding climate regimes

a. PhenoCam locations are marked with black dots. The black asterisks (*) denote the 100 random MODIS validation pixels locations within tile h10v04 (dashed polygon).
b. Climatic conditions at the PhenoCam sites as characterized by mean annual precipitation (MAP) and mean annual temperature (MAT). Note that the study area does not include significant fractions of tall grass prairie as few undisturbed tall grass prairie sites remain.

Hufkens *et al*. (2015) in review



Lower Foothills of Sierra Nevada Mtns, CA, USA

Lethbridge, AB, CAN

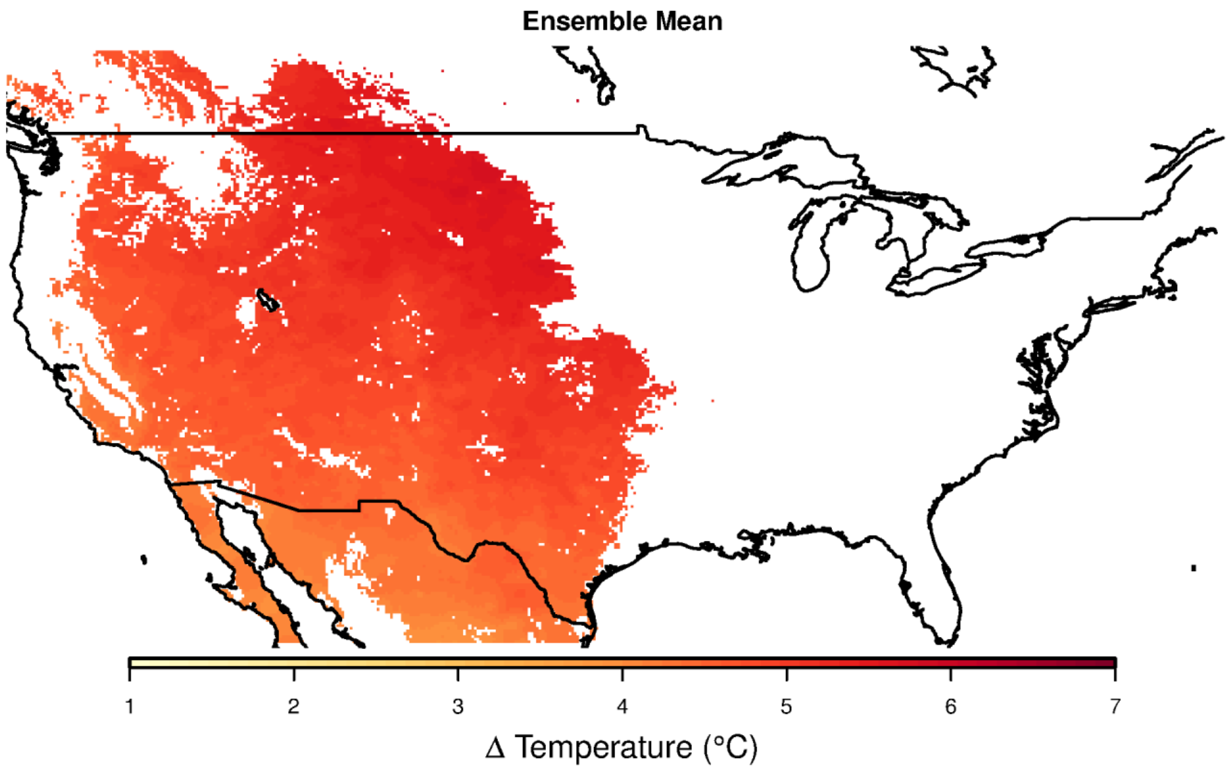
Jornada, NM, USA

Observed and predicted fCover time series for 3 sites in contrasting climate regimes and with different grassland growth dynamics

Hufkens *et al*. (2015) in review

Hufkens *et al*. (2015) in review

Coupled Model Inter-comparison Project Phase 5 (CMIP5)

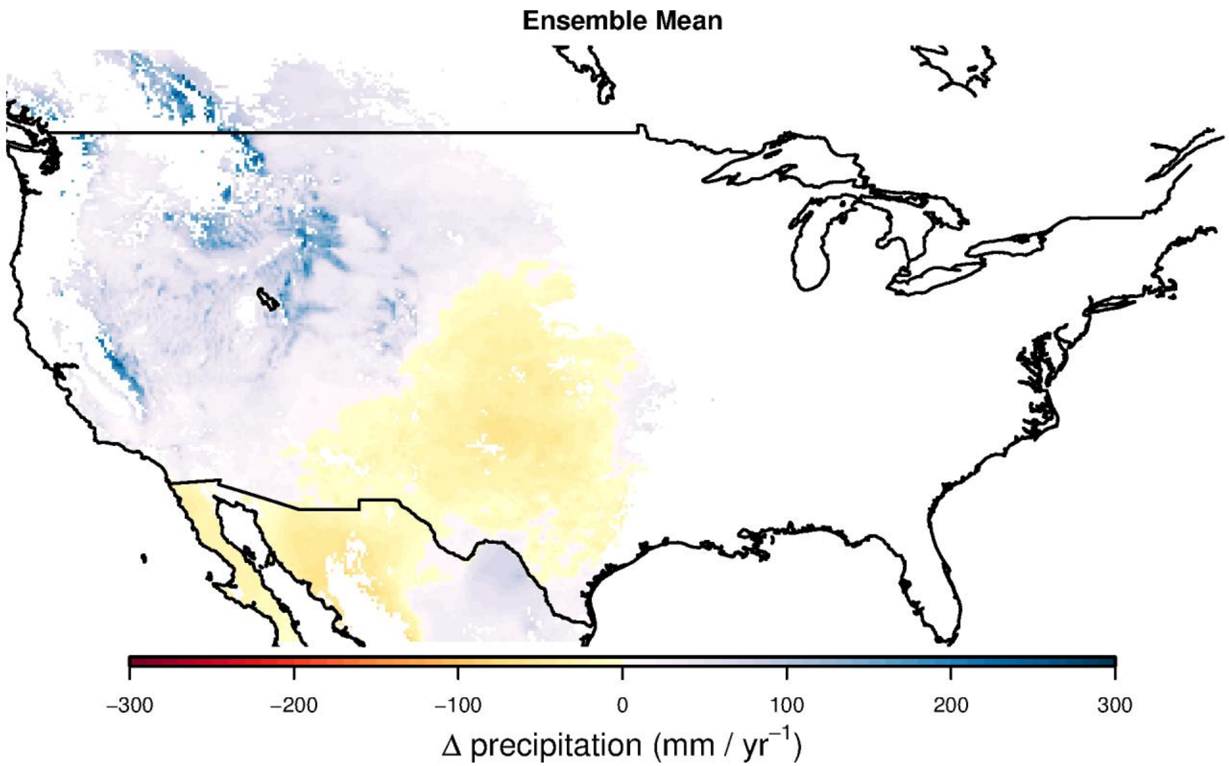


Changes in mean annual temperature towards the end of the 21st century.

Mean annual temperature changes (°C) between the end (2090-2100) and start (2010-2020) of the 21st century for the ensemble mean of ten climate scenarios.

Hufkens *et al*. (2015) in review

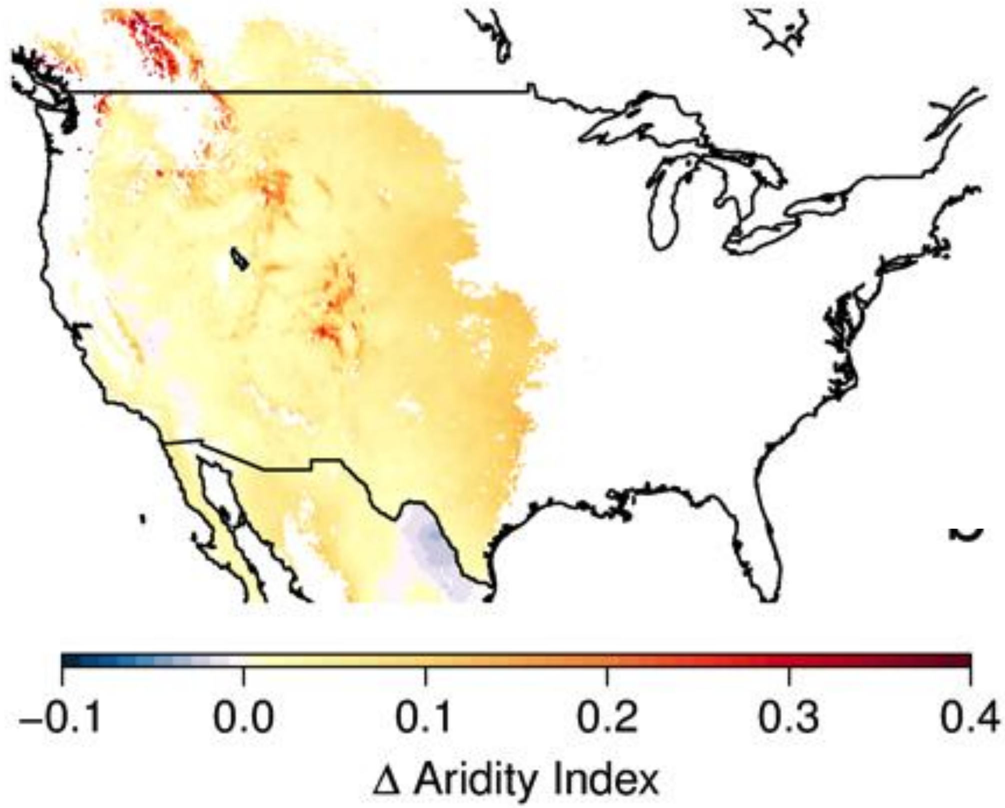
Coupled Model Inter-comparison Project Phase 5 (CMIP5)



Changes in mean annual precipitation towards the end of the 21st century.

Mean annual precipitation changes (mm / yr^{-1}) between the end (2090-2100) and start (2010-2020) of the 21st century for the ensemble of ten climate scenarios.

Hufkens *et al*. (2015) in review



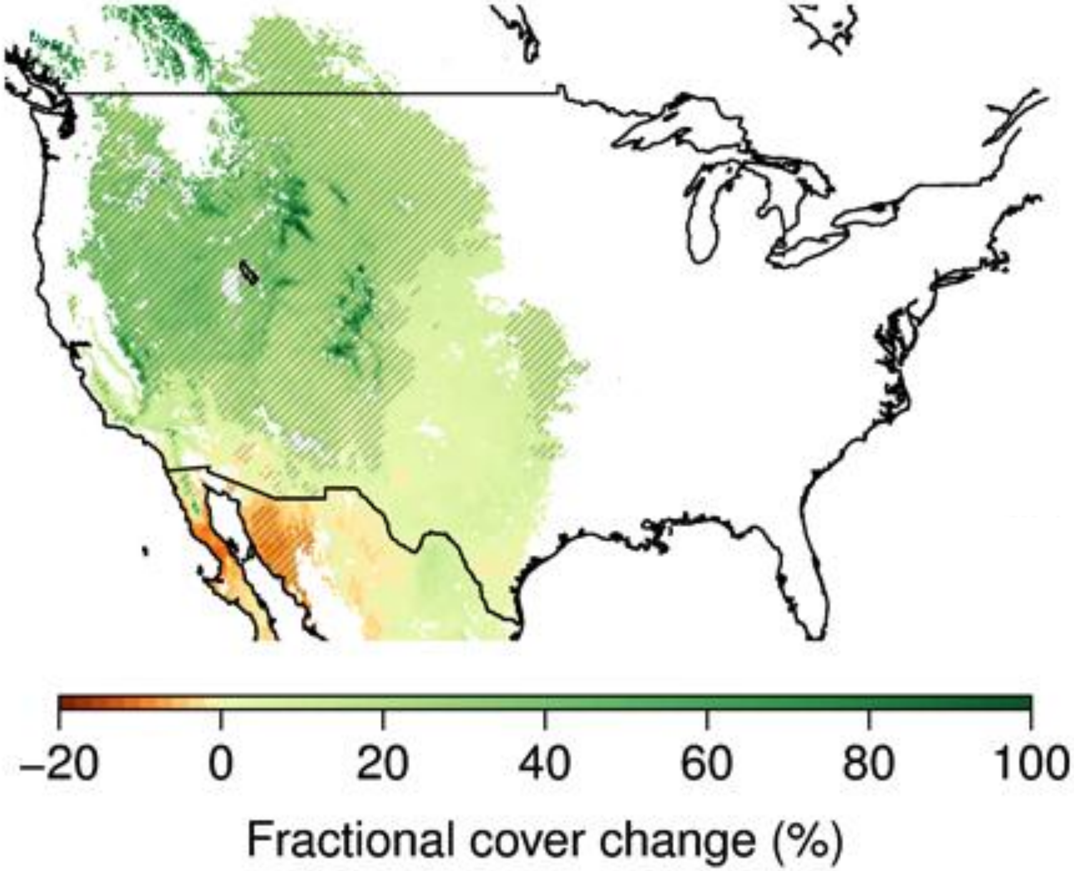
Predicted changes in aridity at the end of the 21st century

Changes in the mean annual aridity index between the start (2010-2020) and the end (2090-2100) of the 21st century. Increases in the aridity index signify increased aridity.

Aridity Index = mean annual potential evapo-transpiration/ mean annual precipitation

Coupled Model Inter-comparison Project Phase 5 (CMIP5)

Hufkens *et al*. (2015) in review



Predicted changes in grassland fractional cover at the end of the 21st century

Change in mean annual grassland plant fractional cover between the end (2090-2100) and the start (2010-2020) of the 21st century.

Despite increasing aridity, climate change promotes growth of North American grasslands

K. Hufkens, T.F. Keenan, L.B. Flanagan, A.D. Richardson (2015) *in review*

Model calculations indicate a 23% increase in annual grassland fCover by the year 2100 (integral of daily fCover over the year)

Warmer and wetter springtime led to earlier and higher peak productivity, particularly in the northern portion of the study area

Model predictions at the Lethbridge site indicate an average increase in GEP of 121 g C m^{-2} yr^{-1} by the year 2100 (mean GEP $\pm$ SD = 500 $\pm$ 240 g C m^{-2} yr^{-1})

Summary & Conclusions

- Mature, native grassland has the potential to sequester significant amounts of carbon for extended periods of time

- Variation in moisture and moisture-temperature interactions are major factors controlling grassland net carbon sequestration

- Despite projected increases in aridity under future climate change, modeled responses predict higher grassland leaf area and GEP