Konza LTER – Terrestrial Biogeochemistry and Belowground Studies

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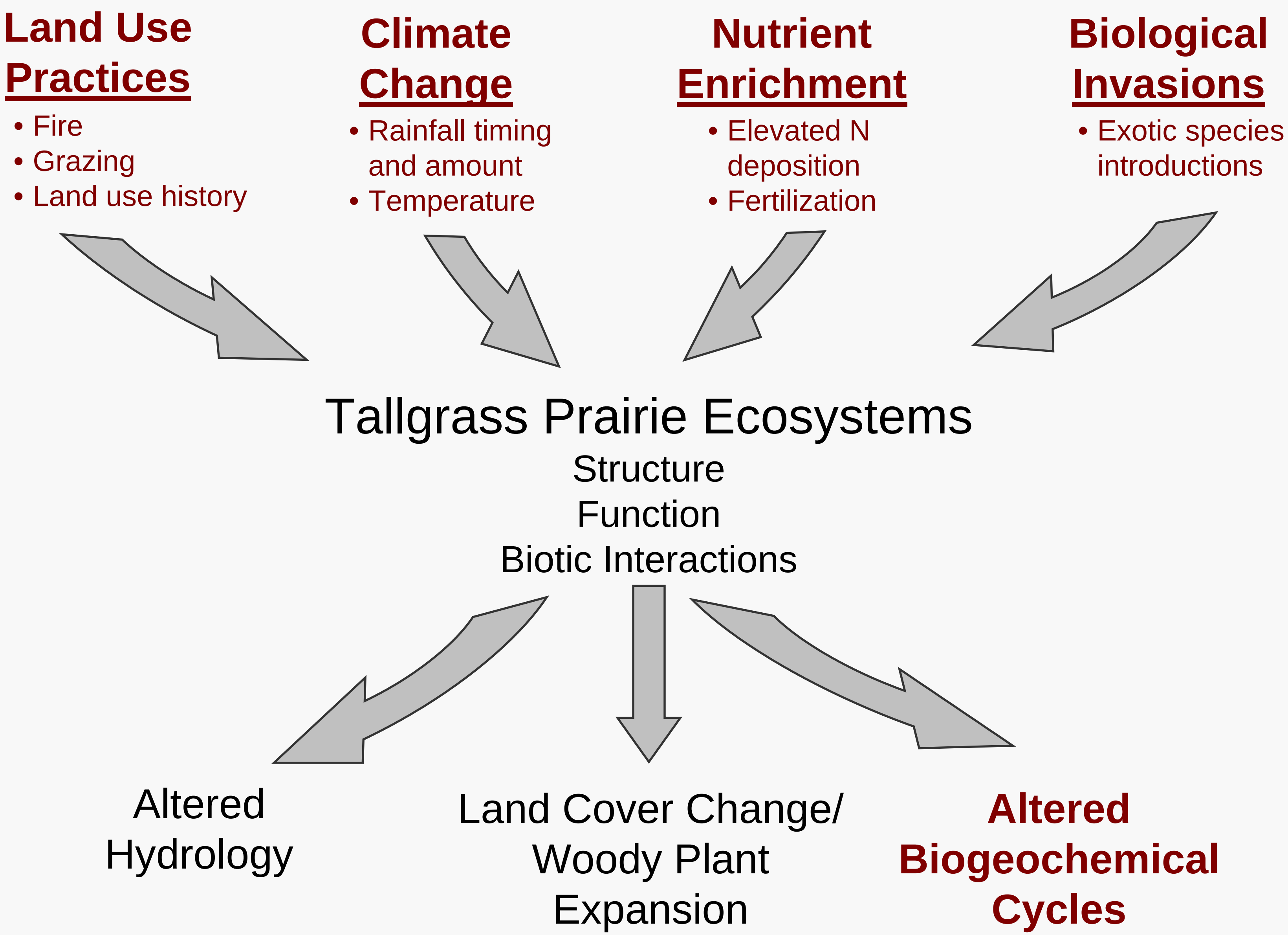
Research addresses two LTER core areas…

- Patterns and movements of inorganic inputs through soils ground- and surface waters
- Pattern and control of organic matter accumulation in surface layers and sediments

…and provides data relevant to other Konza research groups.

- Patterns and controls of NPP, plant and consumer responses to nutrient availability, linking terrestrial and aquatic systems, effects of land use/land cover change

Changes in nutrient cycling are relevant to many contemporary global change issues…



Relevant long-term datasets

- precipitation chemistry and nutrient inputs
    - wetfall inputs (NADP)
    - bulk precipitation
    - CASTNET estimated dry deposition
- stream water chemistry and hydrologic outputs
- soil solution chemistry
- soil chemical properties
- plant tissue chemistry

Plus many long- (5-20 years) and shorter-term (2-5 years) studies and datasets addressing specific nutrient transformations and their controls

Selected research foci during LTER IV & V

- linking changes in soil N availability and plant responses to fire frequency and fire history
- belowground plant responses and soil CO_2 flux
- grazer (bison) mediation of soil C and N transformations and fluxes
- impacts of climate change on soil C and N cycling
- effects of land use/land cover change (forest expansion, species invasions, grassland restoration,) on nutrient cycling/storage
- effects of nutrient enrichment (N, P and water x N interactions) on soil biota and ecosystem processes

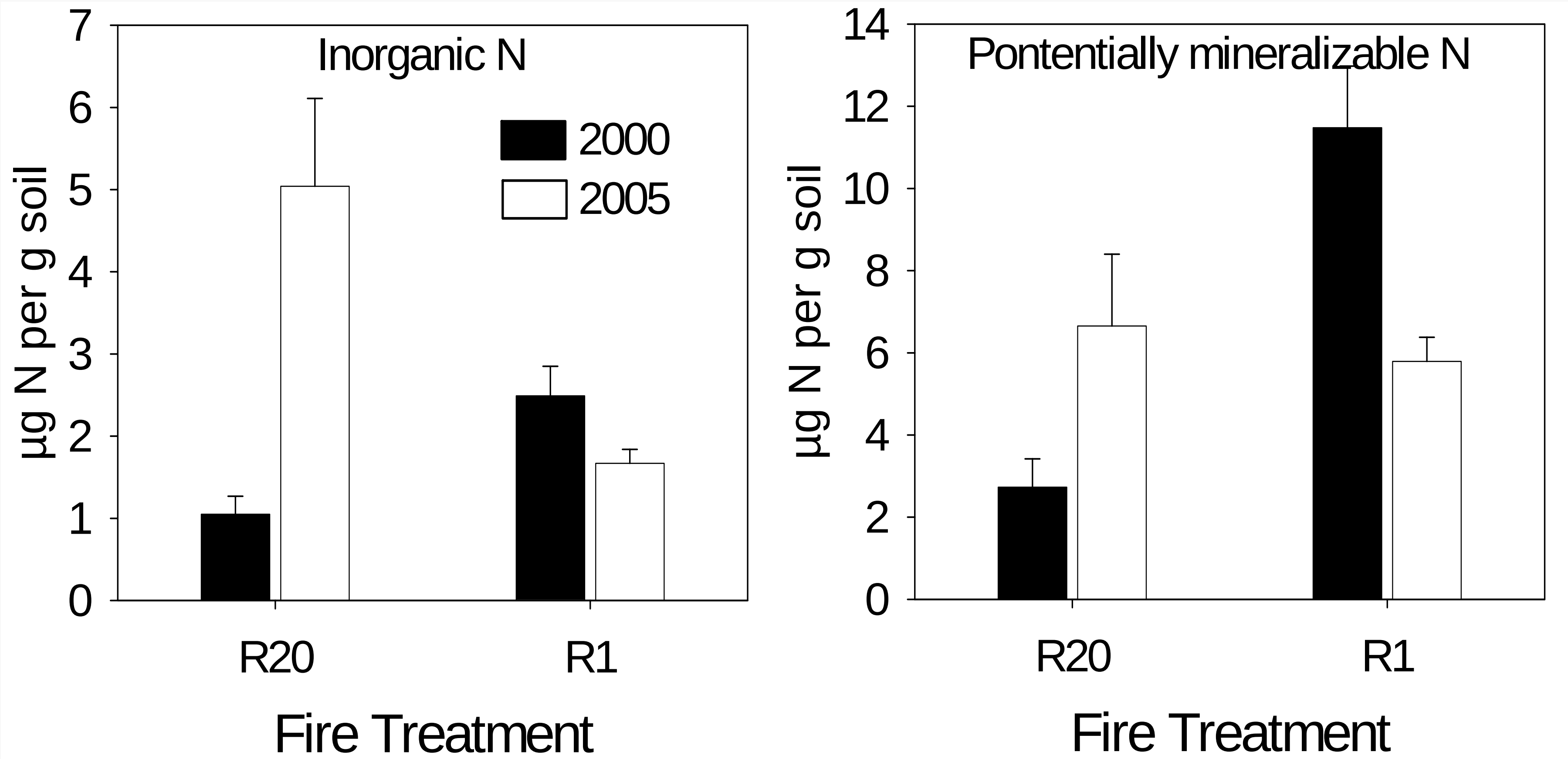
Fire and grazing as drivers of grassland N cycling and C flux…

… historically important in mesic grasslands and key components of contemporary land use.

Some important effects of fire include…

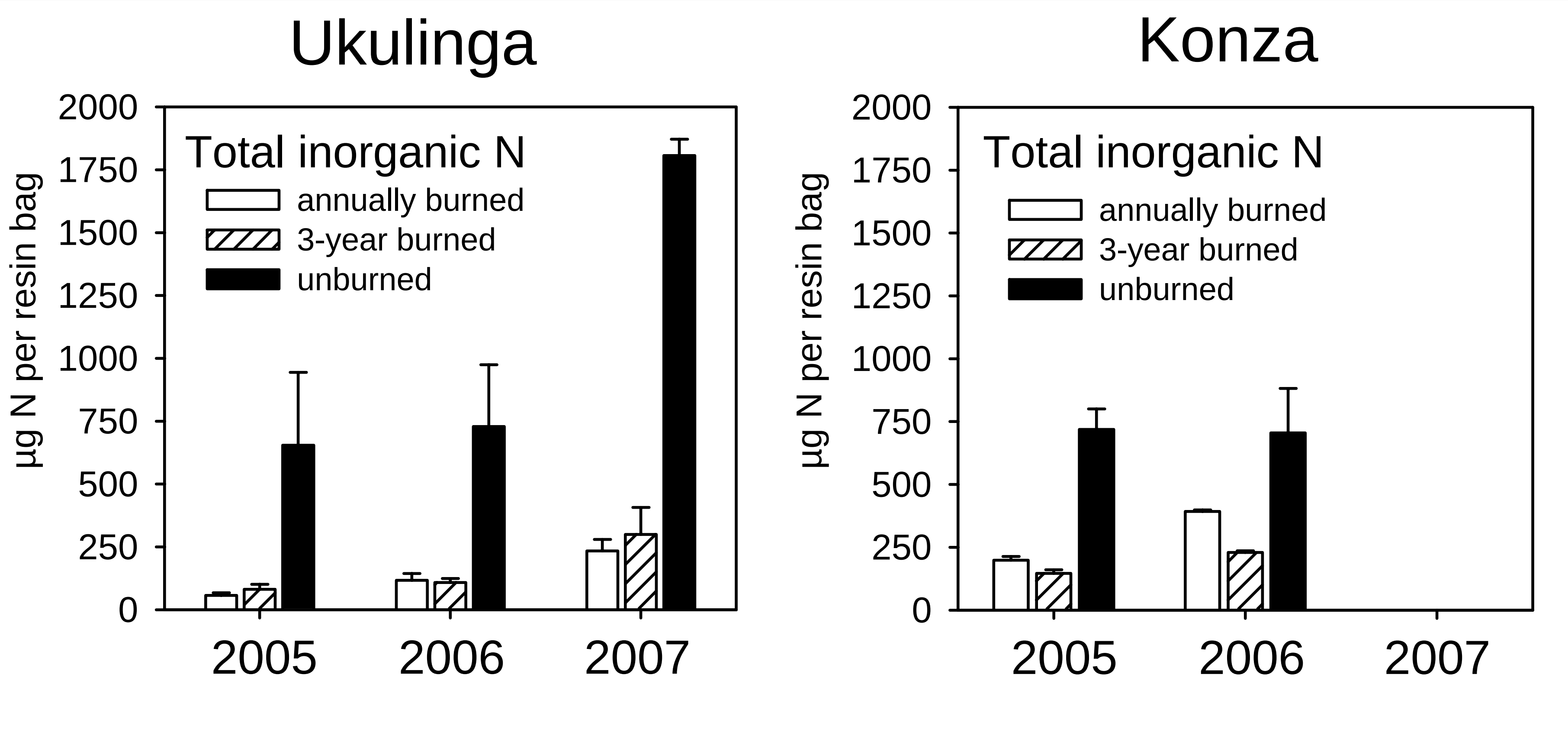
- loss of some nutrients (*e.g.*, N)
- enhanced productivity of C_4 grasses (above- and belowground)
- increased NUE of grasses (higher C/N ratios)
- decreased soil N availability (reduced net mineralization, net nitrification)
- increased soil CO_2 flux

Soil N availability in the “Fire Reversal Experiment”



- greater N availability in long-term unburned watersheds prior to the reversal
- N availability increased with 5 years of fire exclusion (R20), decreased with annual burning (R1)

Collaborative Research: Convergence and Contingencies in Savanna Grasslands



Some important effects of grazing include…

- reduced combustion losses of N
- increased soil N availability (enhanced net mineralization, net nitrification)
- Increased plant tissue N content (lower C/N ratio)
- reduced root productivity and root biomass
- decreased soil CO_2 flux

Important landscape-level interactions of fire and grazing

Preferential grazing
of burned areas

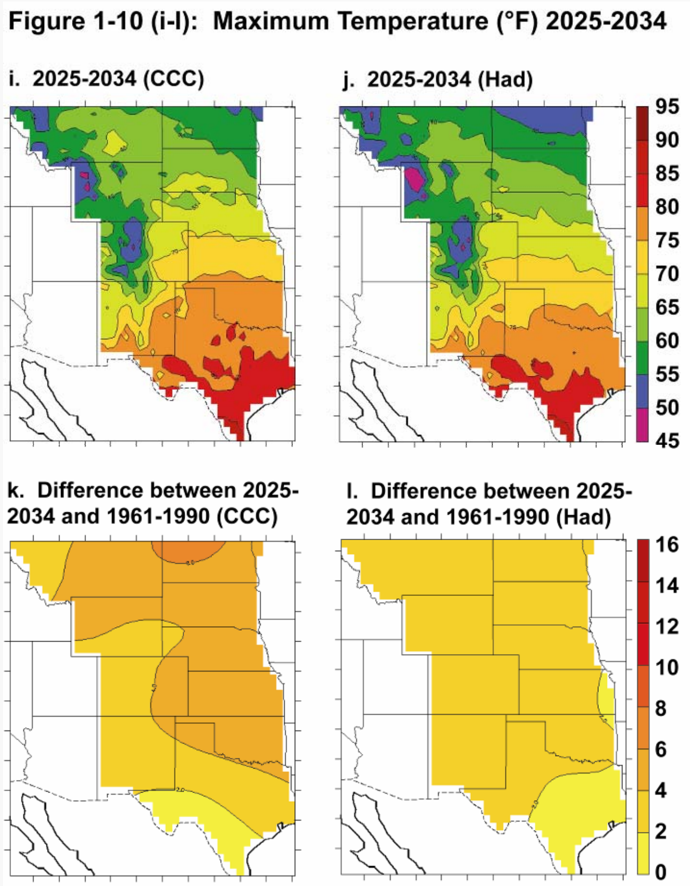
Patchy fires,
increased heterogeneity

Future Fire and Grazing Studies

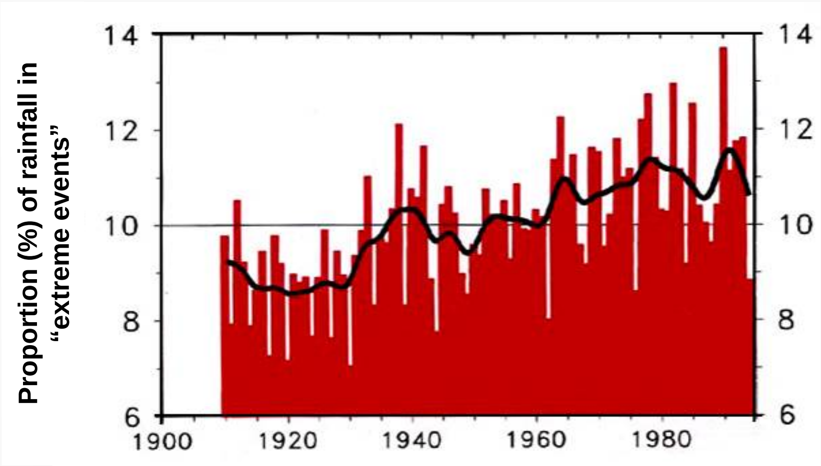
- Long-term assessment of changes in soil C and N fractions/transformations under changing fire regimes (Fire Reversal Experiment)
- Cross-site studies of fire x grazing interactions in North American and South African grasslands (with additional NSF funding)
- Greater emphasis on fire-grazing interactions, spatial heterogeneity and scale (potential for linking spatial changes in nutrient availability to consumer dynamics)

Impacts of climate change on belowground processes?

1. Max and min temps are expected to increase



2. Increased variability and frequency of extreme events

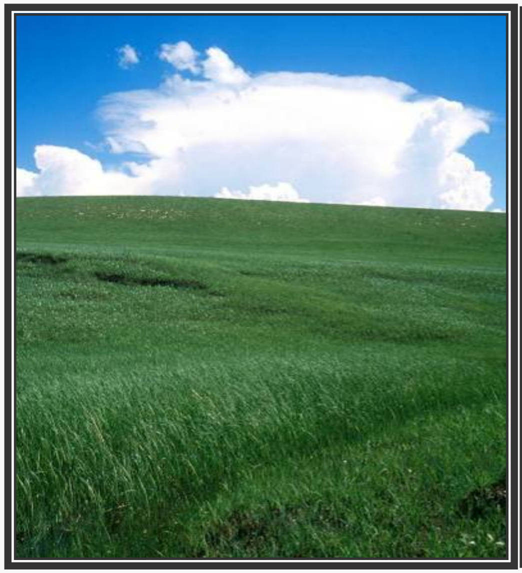


Proportion of total rainfall in the US from large (>5 cm) rainfall events

Key Questions:

To what extent will increased *precipitation variability* alter belowground processes (e.g., soil respiration) in “mesic” grasslands?

What will be the impacts of *warmer temperatures* alone and when coupled with increases in precipitation variability?



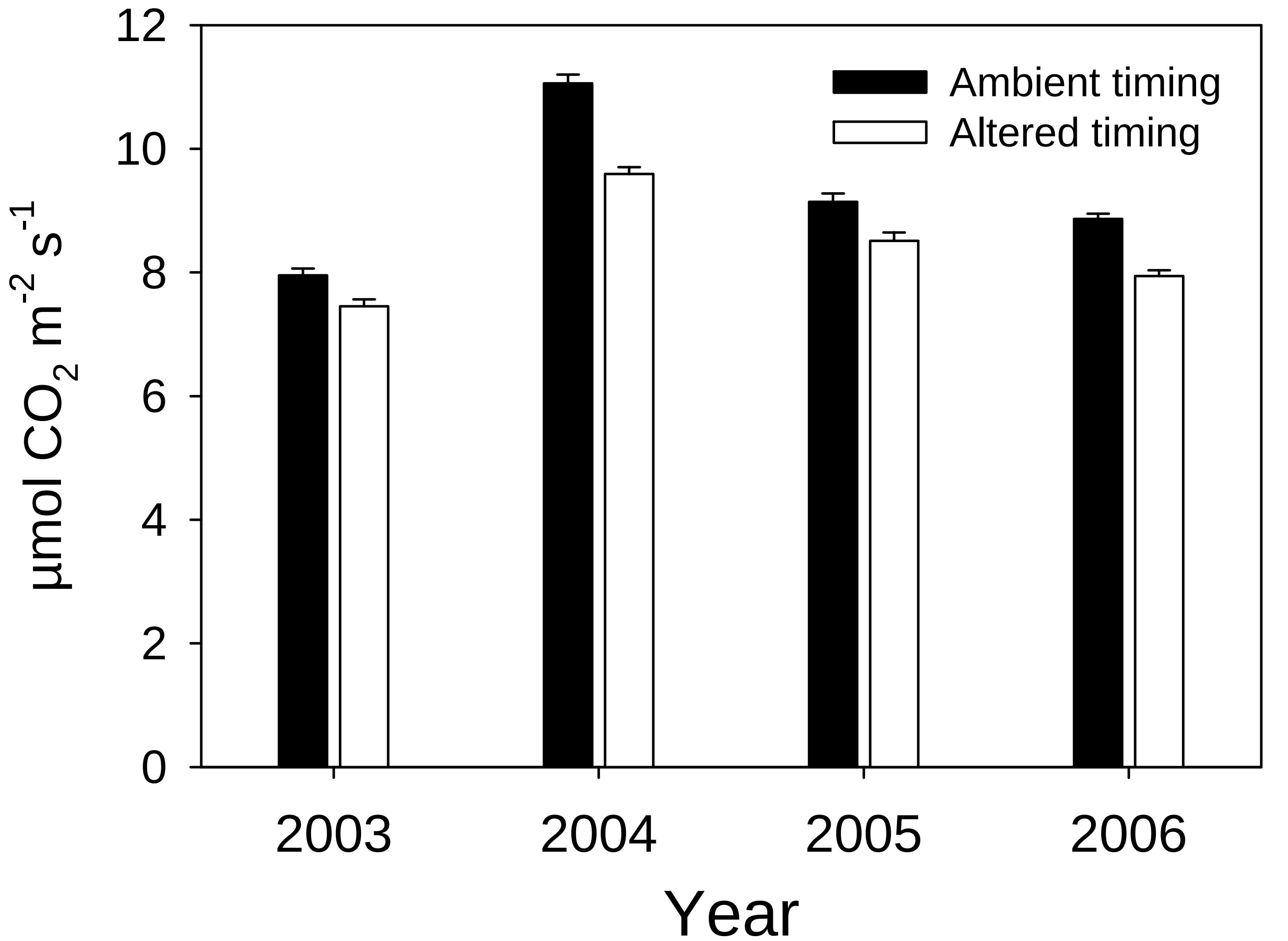
The Rainfall Manipulation Plot (RaMP) Experiment

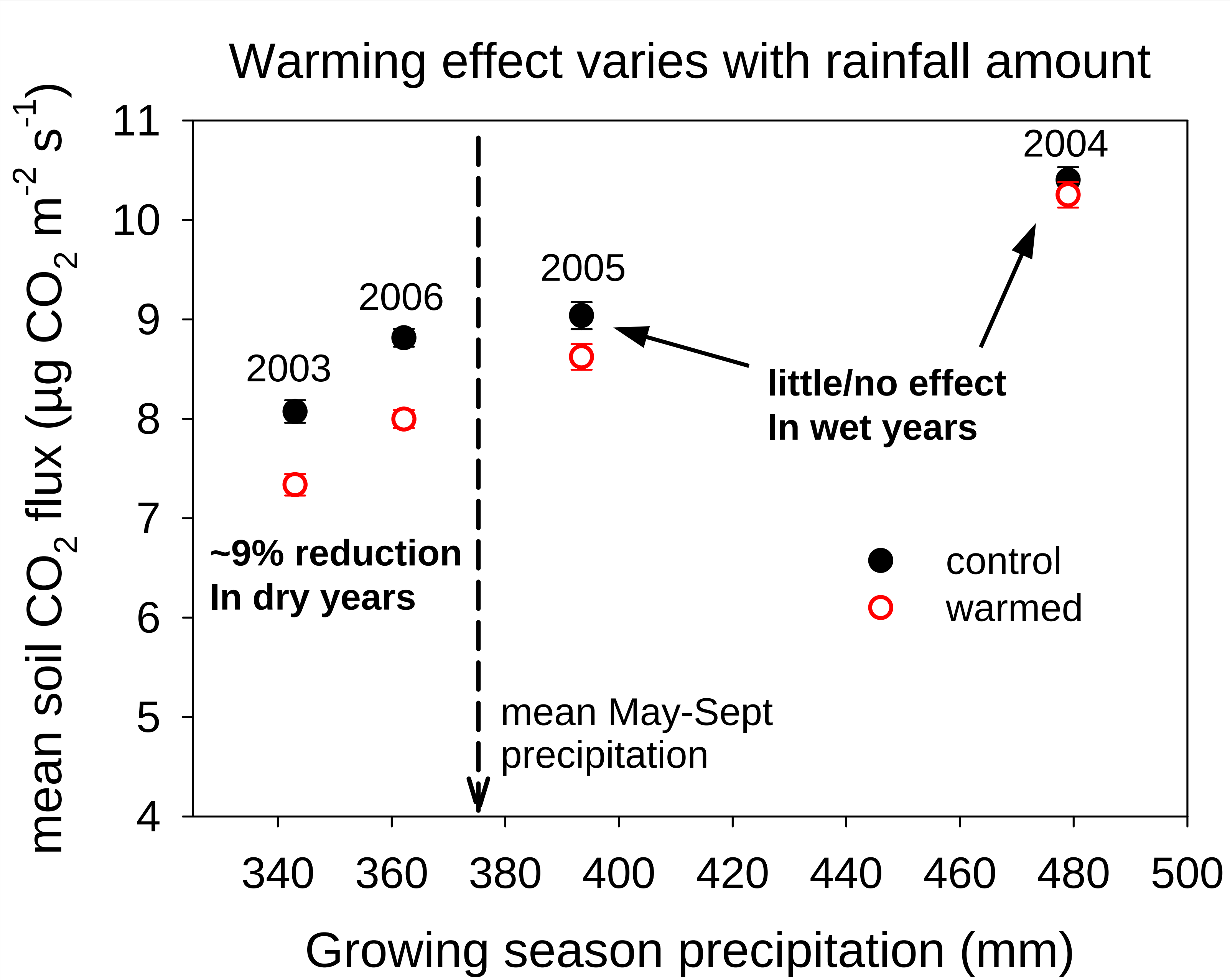
Address the impact of changes in ***size and timing*** of growing season rainfall events and ***elevated temperature***

- 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

Altered rainfall timing reduced mean growing season CO_2 flux by ~10% across all years

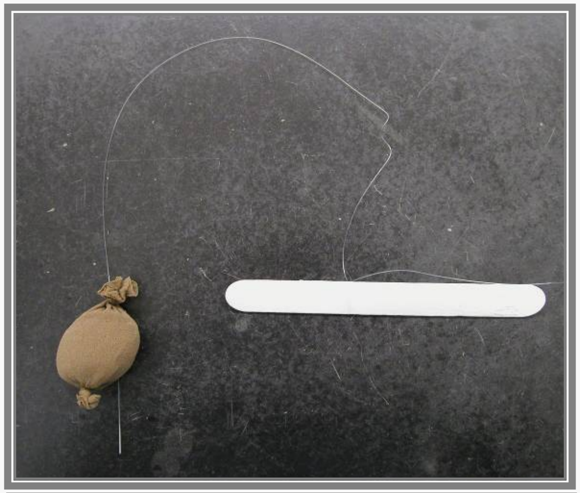
(consistent with results from 1998-2002; *Harper et al.* 2005)

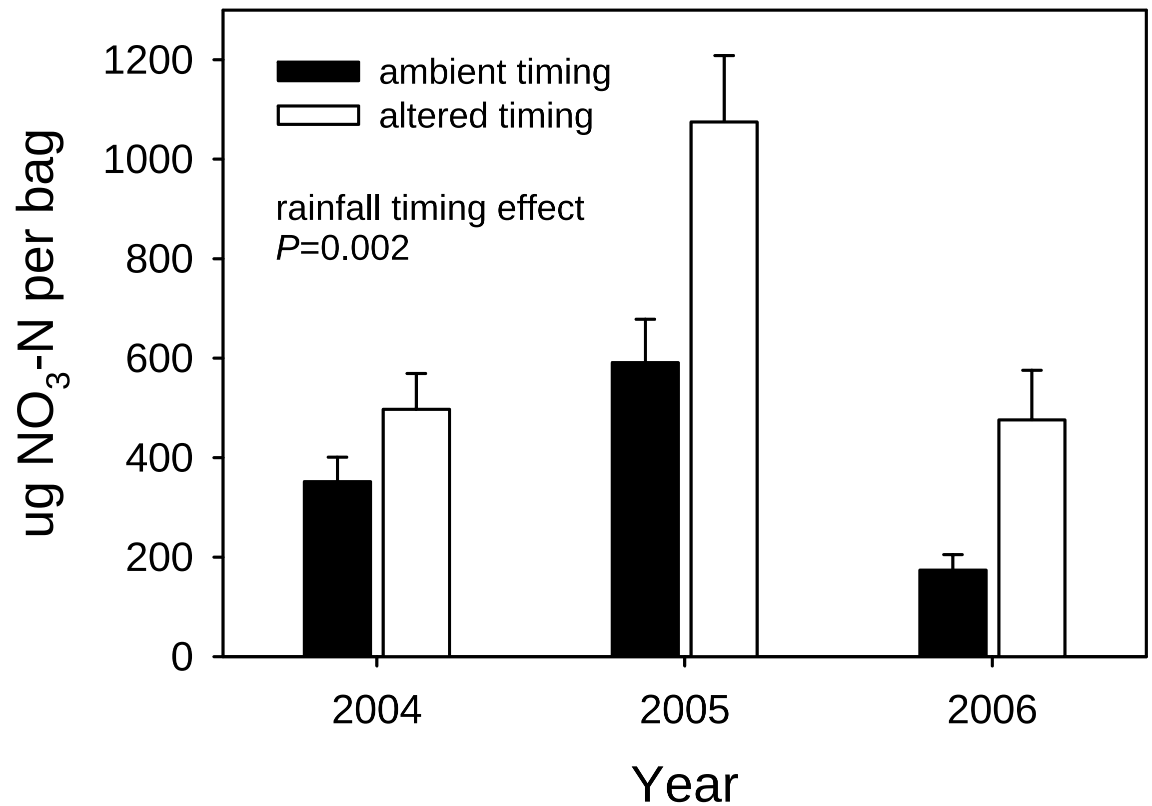




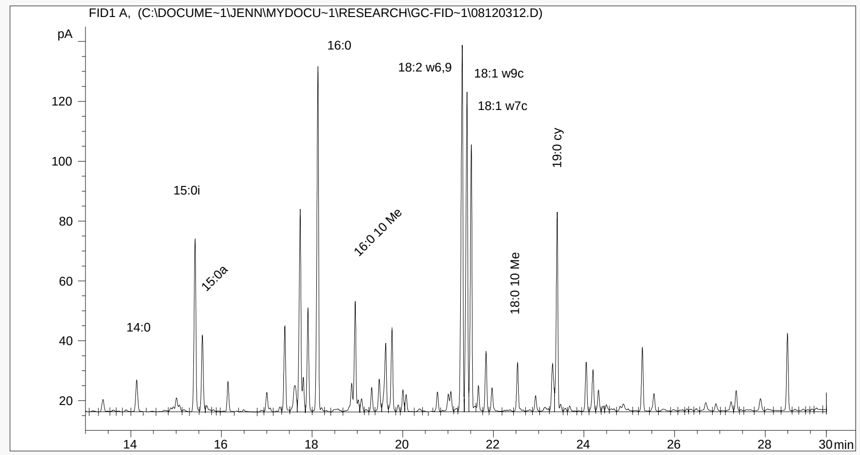
Warming effect varies with rainfall amount
mean soil CO_2 flux (µg CO_2 m^{-2} s^{-1})
11
10
9
8
7
6
5
4
340
360
380
400
420
440
460
480
500
Growing season precipitation (mm)
2003
2006
2005
2004
~9% reduction
In dry years
little/no effect
In wet years
mean May-Sept
precipitation
control
warmed

Altered rainfall timing increased resin-collected NO_3-N by an average of 100%; no effect of warming





Williams (2007) assessed the long- and short-term effects of water stress on soil microbial communities using soils from the Irrigation Transect Experiment



- Sampled soils amended with water to minimize soil water deficits (11 yrs) vs control soils
- Used Phospholipid Fatty Acids (PLFA) to assess total community structure
- Used ^{13}C-labelled glucose + PLFA to assess active microbial community structure

Fatty Acid	Microbial Group
15:0i, 17:0i, 15:0a, etc.	Gram positive bacteria
cy17:0, cy19:0, 18:1Δ11c	Gram negative bacteria (also cy19:0 gm+)
10 Me18:0, 10 Me17:0, 10 Me16:0	Actinomycetes
18:2ω6,9, 18:1ω9c	Fungi
20:4 ω6	Protozoan
16:1 ω5	AM fungi
18:1ω8c	Methanotrophs

Results

- Microbial community structure affected more by long-term water stress (irrigation vs control) than by short-term drying-rewetting
- Fungal PLFAs decreased in response to water stress; consistent with increased fungal:bacterial ratios with long-term irrigation (Williams and Rice 2007)
- Suggests increased drought stress (e.g., climate change) will alter microbial community structure

Future Climate Change Studies

- Opportunities for additional studies of belowground microbial and consumer responses…
- Assessing root and belowground community responses to 10+ years of more extreme rainfall patterns and 15+ years of irrigation
- New research to assess changes in N cycling and potential N losses (isotopic approaches? trace gas fluxes?)
- New rainfall manipulation plots??

Changes in ecosystem C and N storage as a result of forest encroachment

Ecosystem Compartment	Grassland	Forest
Carbon Stocks (g m^{-2})		
Aboveground biomass	163 ± 35	6,065 ± 74
Soil		
O-horizon	0	1,540 ± 51
A-horizon (upper 10 cm)	3,443 ± 188	3,871 ± 119
Microbial biomass C	118 ± 8	129 ± 11
Total	**3,606**	**11,476**
Nitrogen Stocks (g m^{-2})		
Aboveground biomass	3.0 ± 0.6	48 ± 7
Soil		
O-horizon	0	56 ± 4
A-horizon (upper 10 cm)	298 ± 13	329 ± 9
Microbial biomass N	17 ± 2	16 ± 1
Extractable N	0.1-0.6	0.1-0.6
Total	**301**	**433**

Ecosystem consequences of C_4 grass invasion of a C_4 grassland

(Reed et al. 2005)

Compared to native *Andropogon gerardii*, the invasive *Bothriochloa bladhii* exhibited…

- greater plant biomass
- higher foliar and root tissue C:N ratio
- lower rates of decay and carbon cycling
- lower pools of total and available soil N
- greater spatial heterogeneity in C and N pools and fluxes

- Effects on soil communities? Plant-soil feedbacks?

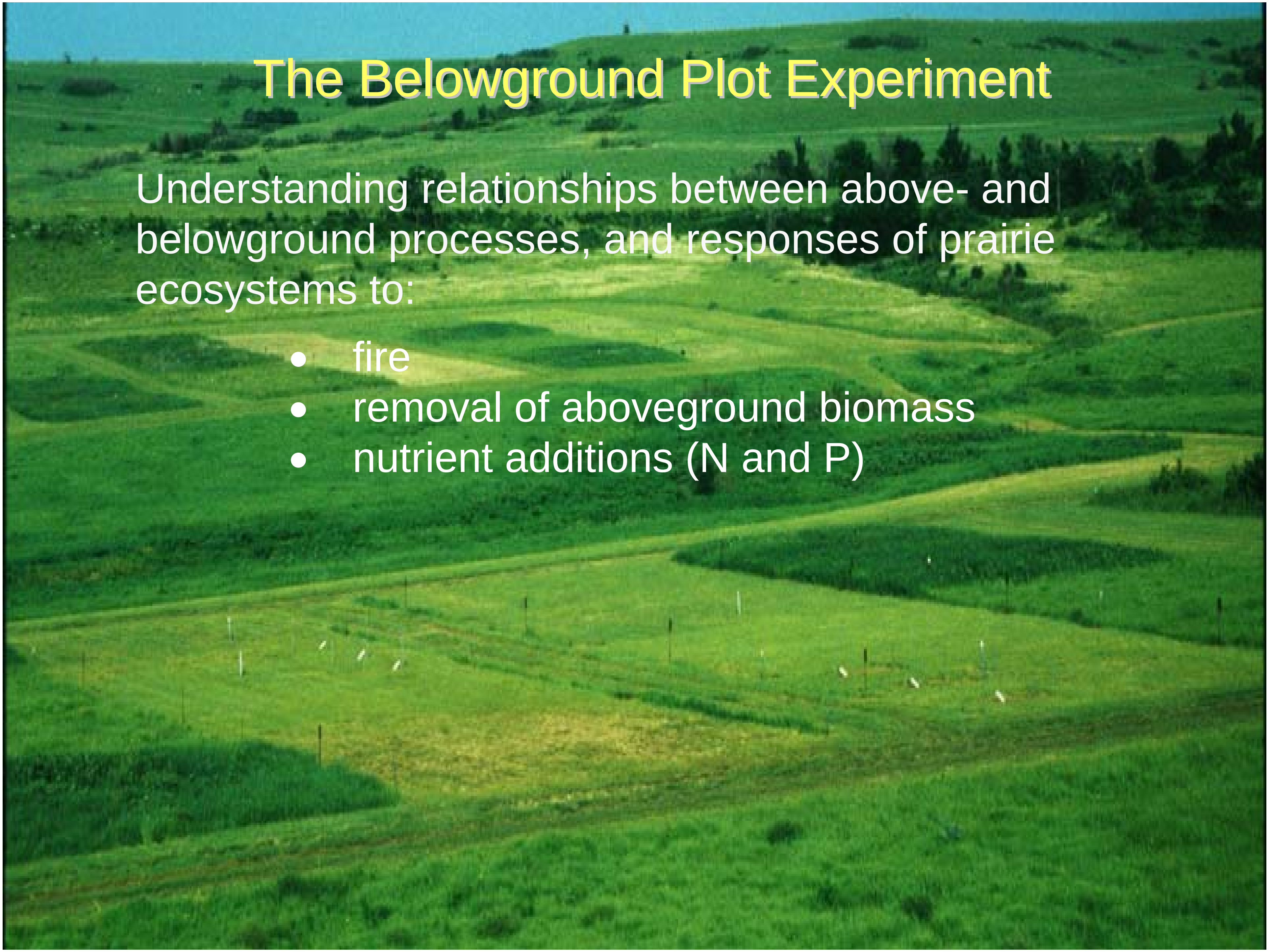
Future Land-Cover Change / Invasion Studies

- Effects of herbaceous plant species invasion on belowground biota and soil properties (potential new cross-site studies of *Bothriochloa bladhii* with Wilson, Hickman, et al.)
- Impact of expanded woody plant cover on soil food webs (new Belowground Plot Study)
- Impacts of increased woody plant cover on net ecosystem C exchange (new towers on 1D / 4B)

The Belowground Plot Experiment

Understanding relationships between above- and belowground processes, and responses of prairie ecosystems to:

- fire
- removal of aboveground biomass
- nutrient additions (N and P)



Future N Enrichment Studies

- Intensive sampling of the Belowground Plot Experiment for above- and belowground food web responses
- Impact of N enrichment on mycorrhizae, soil aggregate stability and C storage
- Links to new NSF Environmental Genomics project to assess the genetic basis of nematode responses to environmental change; molecular assessment of microbial community changes
- N enrichment study to assess responses to “pulsed” vs “press” (chronic) N additions
- Continuation of the P Plot Study (alteration of relative N and P limitation)
- Participation in Nutrient Network (NutNet)