GREAT LAKES BIOENERGY RESEARCH CENTER

Ecosystem service tradeoffs in grassland plant communities grown for biomass feedstock

Randy Jackson
Area 4 Co-lead
Associate Professor of Grassland Ecology
Agronomy Department, UW-Madison

U.S. DEPARTMENT OF ENERGY
DOE Bioenergy Research Centers

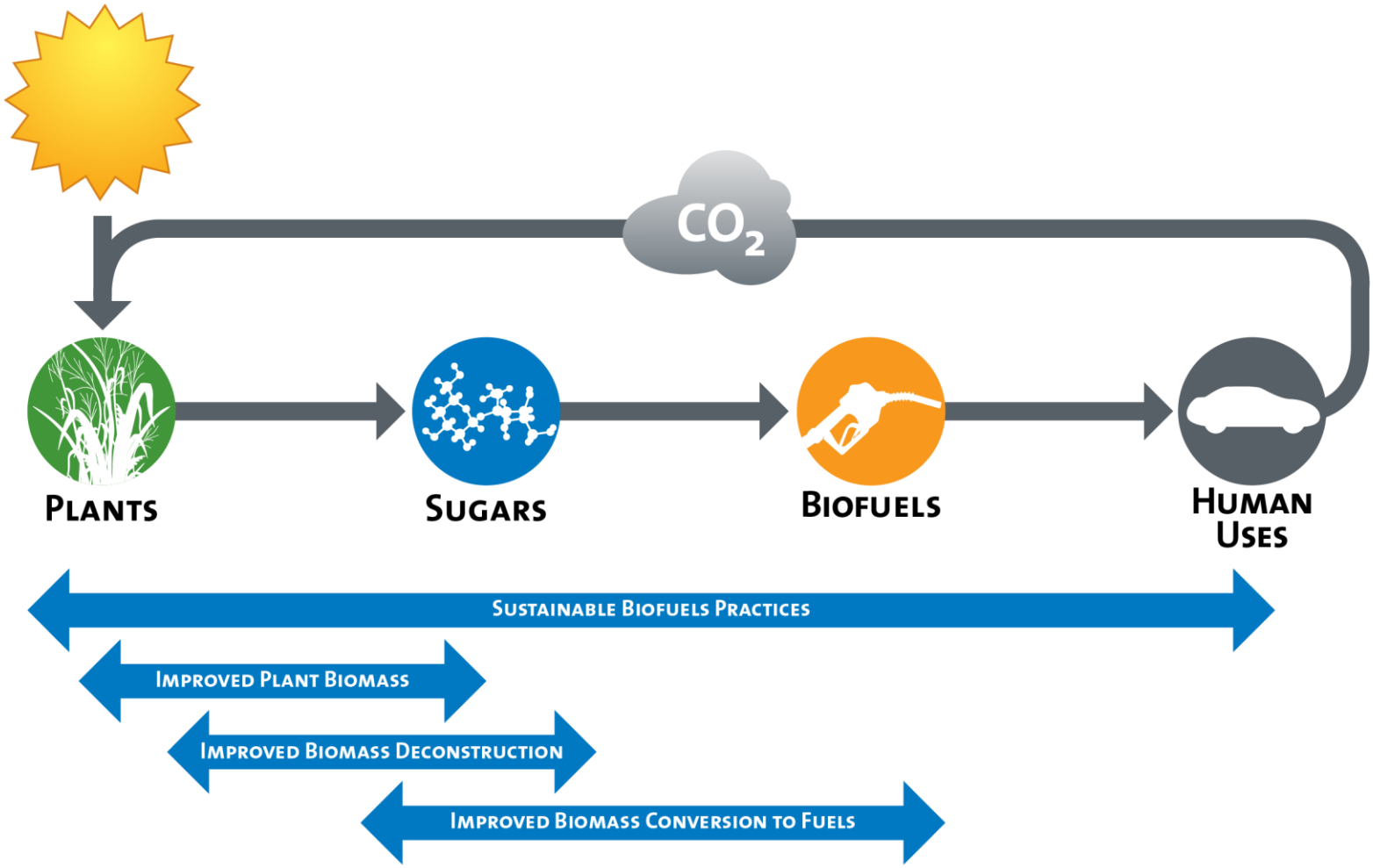
Co-authors

MSU		UW	
Phil Robertson	Rufus Isaacs	Laura Smith	Tim Meehan
Doug Landis	Ajay Bhardwaj	Josh Posner	Steve Bertjens
Kurt Thelen	Poonam Jasrotia	Teri Balser	Mark Renz
Jim Tiedje	Kevin Kahmark	Chris Kucharik	Matt Ruark
Steve Hamilton	Tom Schmidt	Gregg Sanford	Chao Liang
Ilya Gelfand	Kay Gross	Gary Oates	Jessica Miesel
Neville Millar	Julianna Tuell	Janet Hedtcke	Hannah Gaines
Kate Withers	Carol Baker	Claudio Gratton	
Ben Werling	Bruce Robertson		
Carol Baker	Tracy Teal		
Bruce Dale			

Roadmap for today's talk

- Overview of GLBRC
- Establishment-phase data

  Yield, Biogeochemistry, Biodiversity
- Perennial grassland management & composition effects on potential N retention


CO_2
Plants
Sugars
Biofuels
Human Uses
Sustainable Biofuels Practices
Improved Plant Biomass
Improved Biomass Deconstruction
Improved Biomass Conversion to Fuels

Potential feedstock supply bottlenecks

Agronomic

- Quantity of biomass per unit area → annual monocultures
- Planting, management, and harvesting logistics → annual monocultures
- Risk/Opportunity cost → annual monocultures

Socio-ecological

- Individual resistance to change → annual monocultures
- Institutional resistance to change
  - Food vs. Fuel → marginal lands, less productive
- Societal resistance
  - Environmental degradation → perennials, less productive
  - Anti GMO efforts → less productive
- Societal acceptance
  - Environmental improvement → perennial and diverse (wildlife habitat, water quality, C sequestration, …i.e. less productive)

GLBRC sustainability research – understanding tradeoffs among the 3 P's

Key biofuel crop attributes bundle ecosystem services

Productive

- Economically profitable
- Favorable energy return
- Land-conserving

Perennial

- Cost less to maintain
- Emit fewer greenhouse gases
- Less prone to soil erosion and water pollution

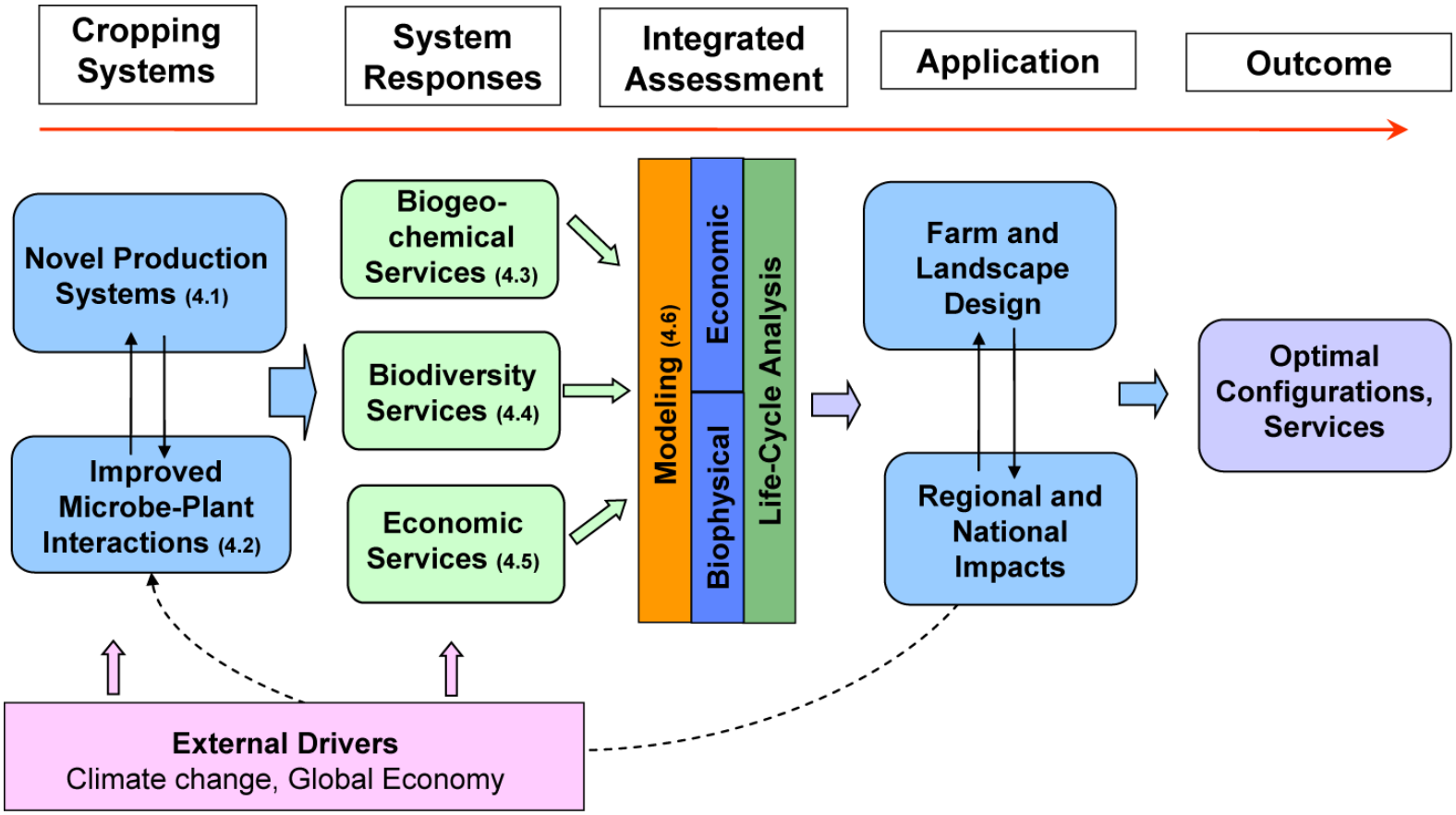
Polyculture-tolerant

- Pest and disease suppression
- Nitrogen fixation
- Nutrient and carbon retention
- Pollination services to surrounding crops

Positioned appropriately

- Configuration of landscapes is key

GLBRC Sustainability Research Roadmap



Experimental infrastructure

Plot level → Landscape

Intensive sites

Plot
10^2 m^2

Scale-up

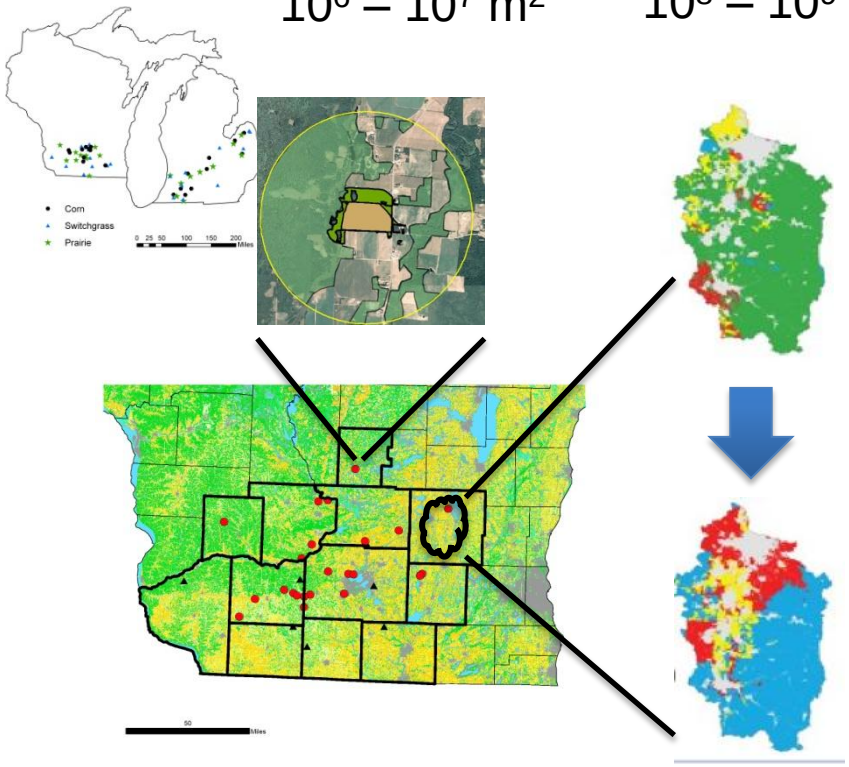
Field
10^5
m^2

Extensive sites

Neighborhood
10^6 – 10^7 m^2

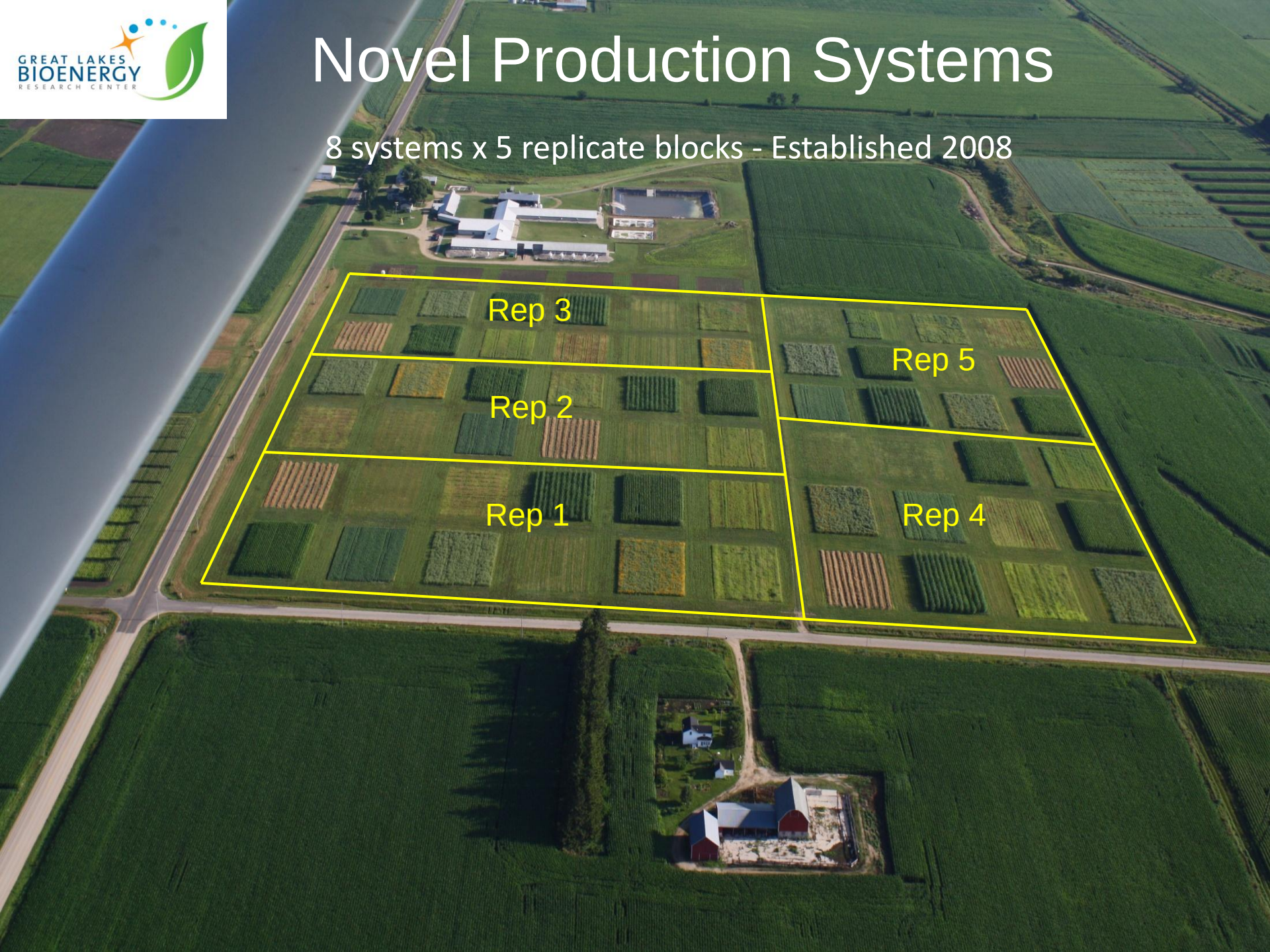
Land labs

Watershed
10^8 – 10^9 m^2

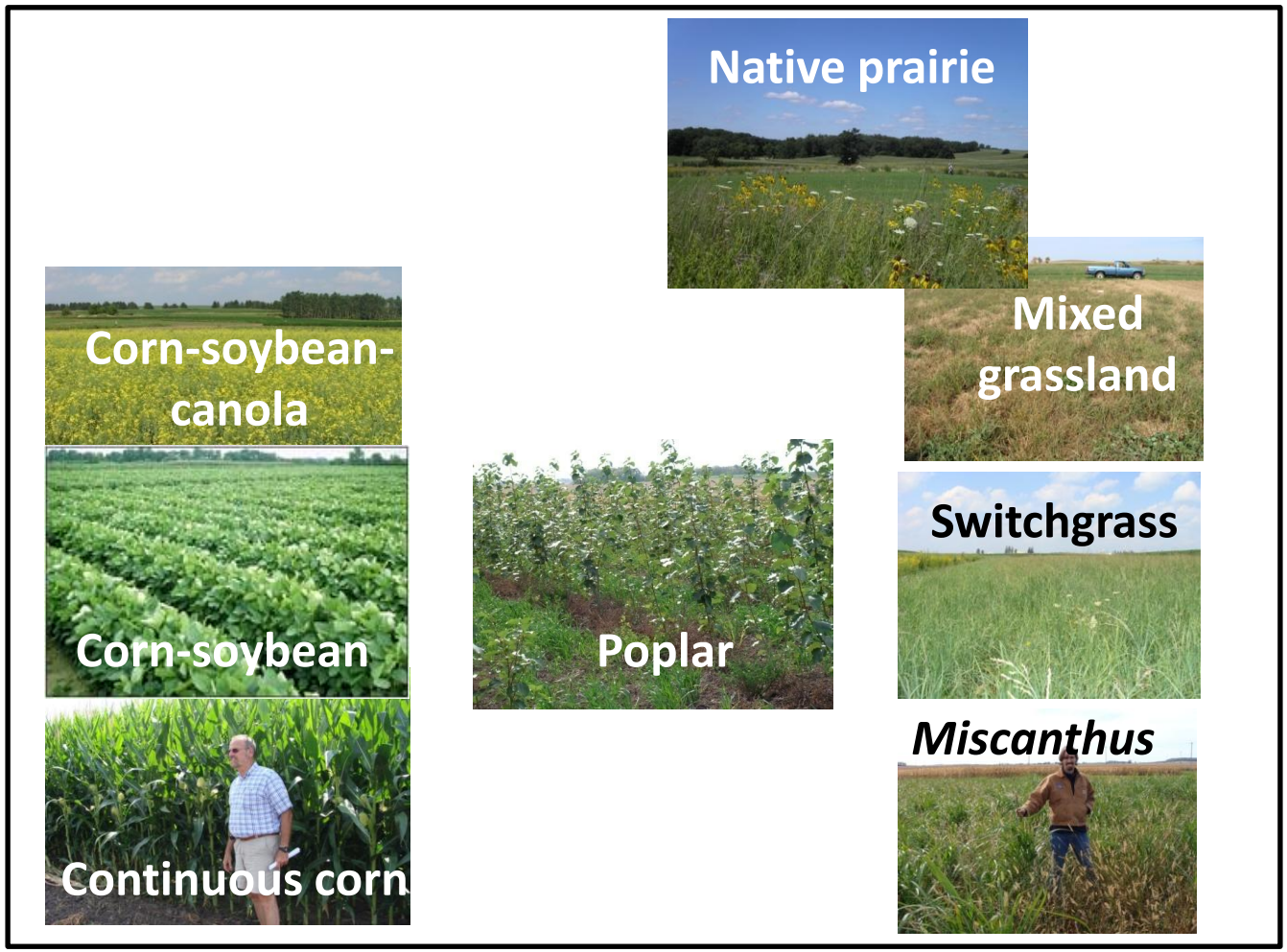


Novel Production Systems

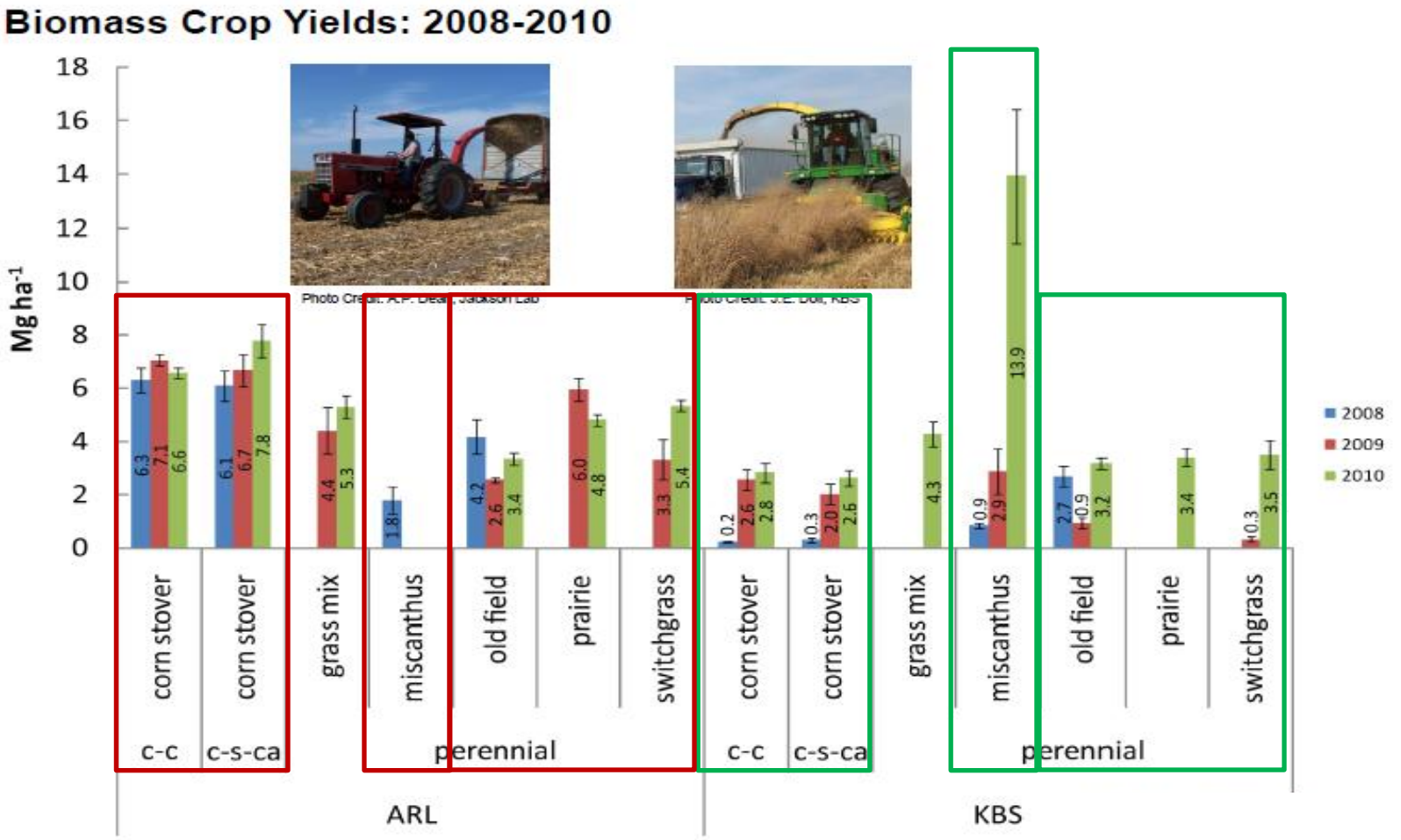
8 systems x 5 replicate blocks - Established 2008



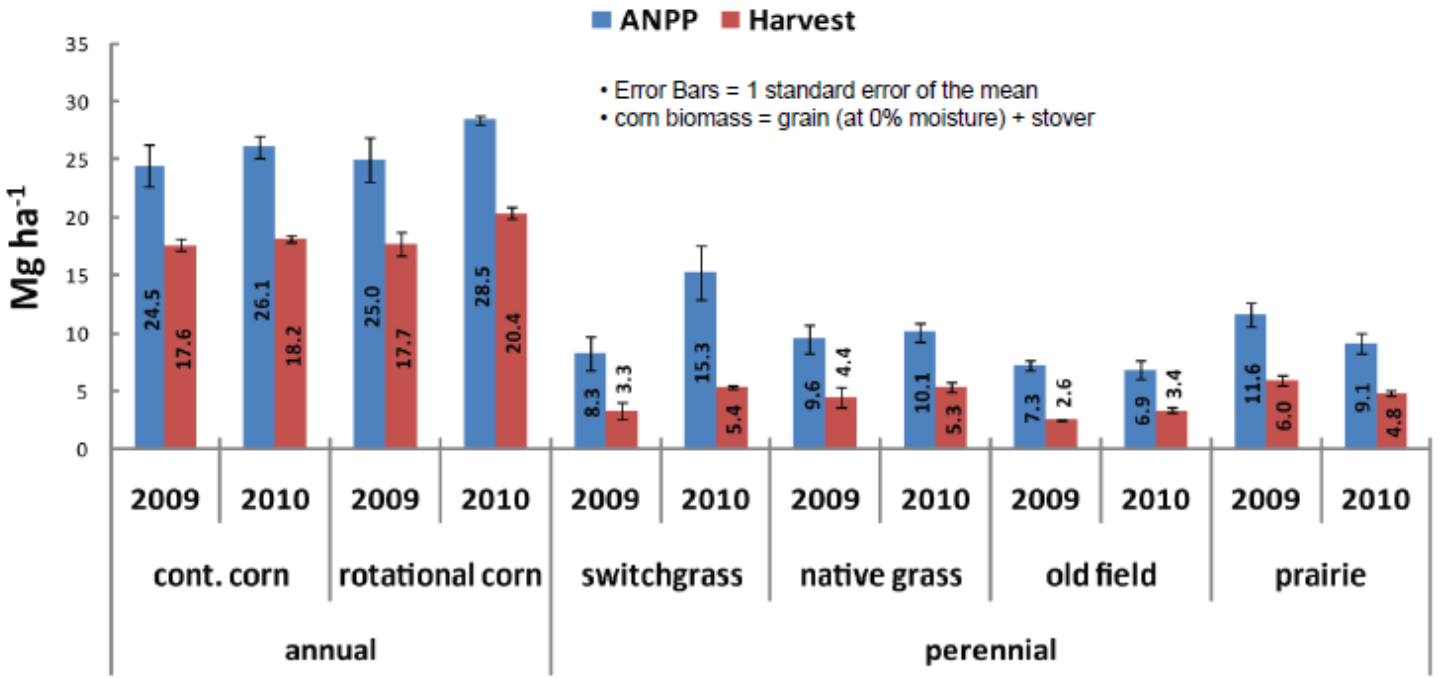
Dimensions of agronomic intensification



Novel production systems



Thelen, Simmons, Sanford et al., unpublished data



Harvest efficiency relative to peak standing biomass

	2009		2010	
	Harvest as %ANPP	% Discrepancy	Harvest as %ANPP	% Discrepancy
Corn	72%	28%	71%	29%
Switchgrass	40%	60%	35%	65%
Native Grass	46%	54%	53%	47%
Old Field	35%	65%	49%	51%
Prairie	51%	49%	53%	47%

Oates et al., unpublished data

What are the tradeoffs for higher production in corn?

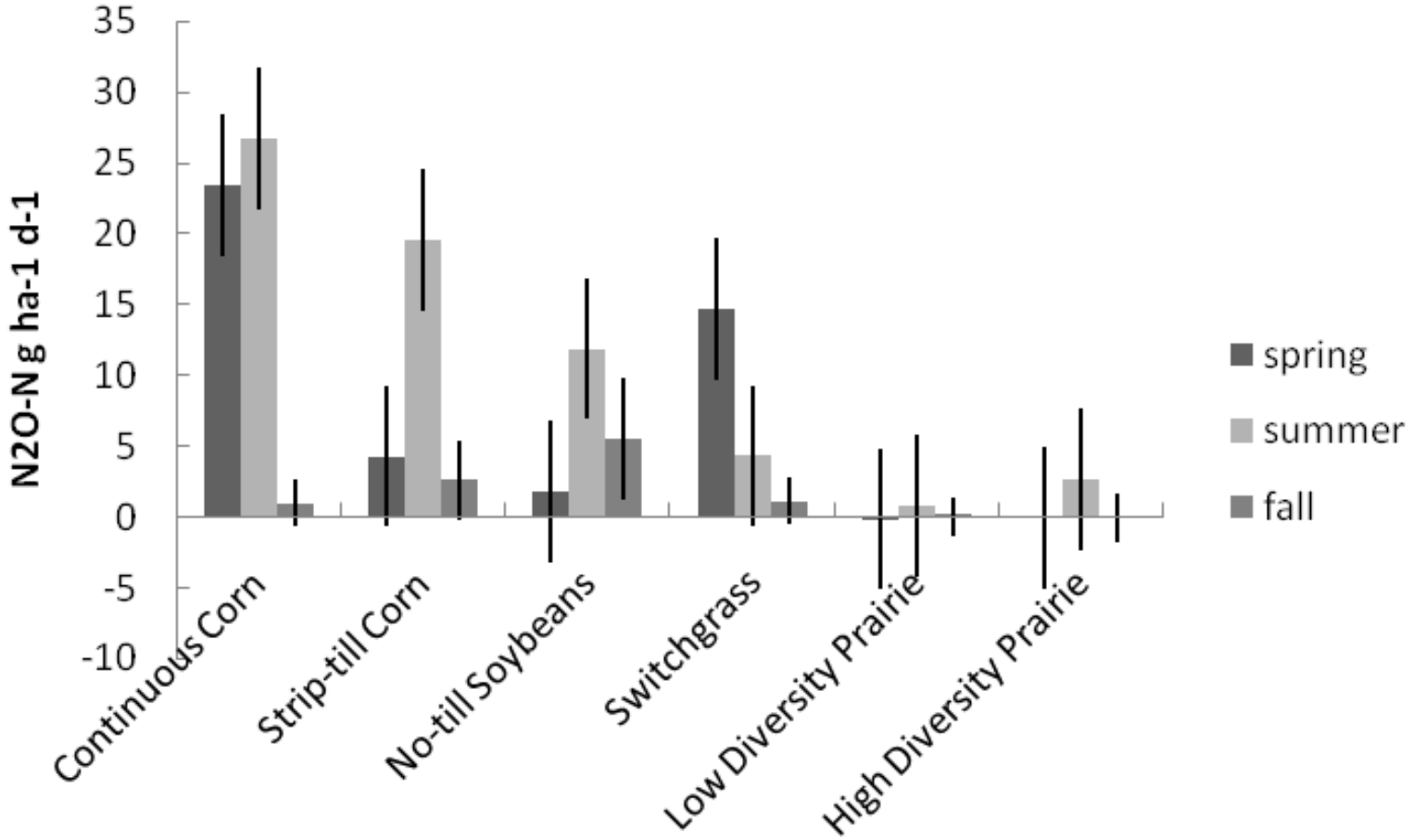
biogeochemical (data), biodiversity (data)

and *Miscanthus*?

biogeochemical?, biodiversity?, uncertainty (data)

Nitrous oxide fluxes

Wisconsin Integrated Cropping Systems Trial (2009)



Oates, Posner & Jackson, unpublished data

Soil Organic Carbon

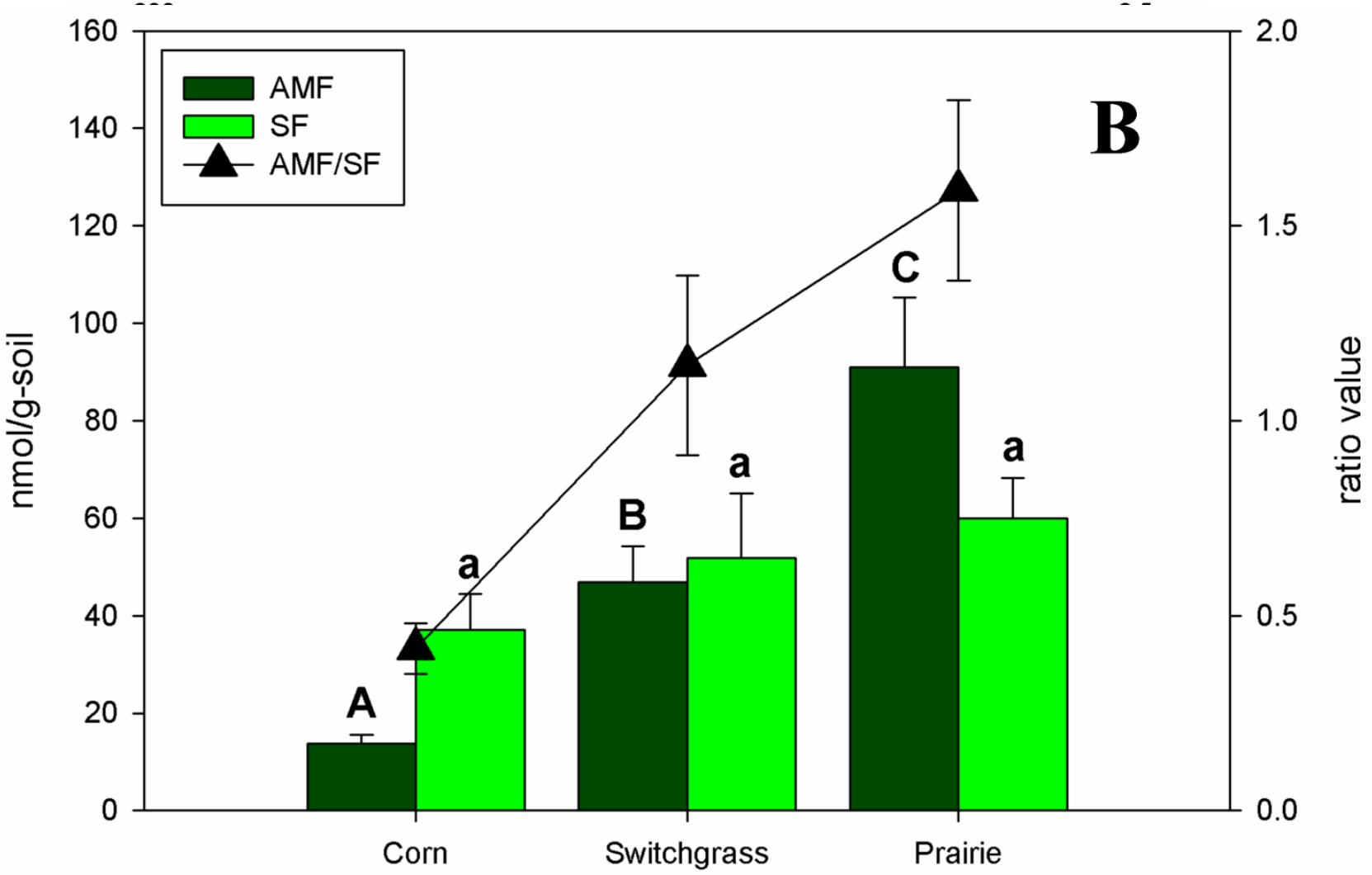
Wisconsin Integrated Cropping Systems Trial (1989 – 2007)

System	Detail	n	SOC (%) 1989	SOC (%) 2007	Δ	Δ yr^{-1}	p-value
CS1	Conventional	12	2.92	2.77	-0.15	-0.0083	0.44
CS2	Conventional / No-till	12	2.63	2.58	-0.05	-0.0028	0.82
CS3	Organic	12	2.46	2.34	-0.12	-0.0067	0.51
CS4	Conventional	12	2.86	2.94	0.08	0.0044	0.69
CS5	Organic	12	2.66	2.68	0.02	0.0011	0.95
CS6	**MIRG**†	**12**	**2.96**	**3.30**	**0.34**	**0.0189**	**0.08**

System	Detail	n	SOC (%) 1998	SOC (%) 2007	Δ	Δ yr^{-1}	p-value
Low div	**Prairie**	**3**	**2.50**	**2.87**	**0.37**	**0.0411**	**0.05**
High div	**Prairie**	**3**	**2.31**	**2.69**	**0.38**	**0.0422**	**0.04**

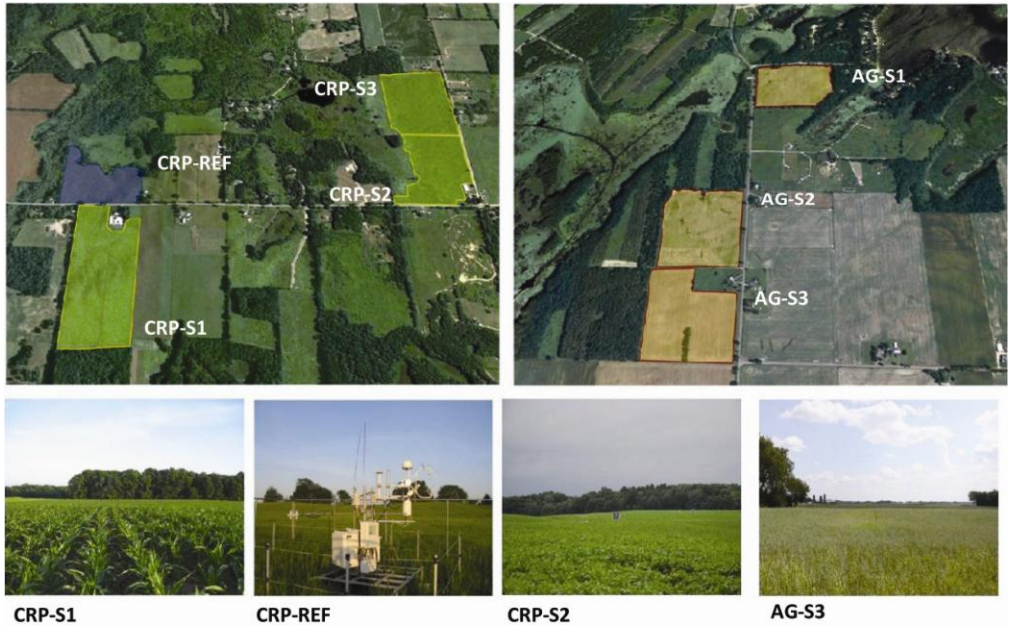
Sanford & Posner, unpublished data

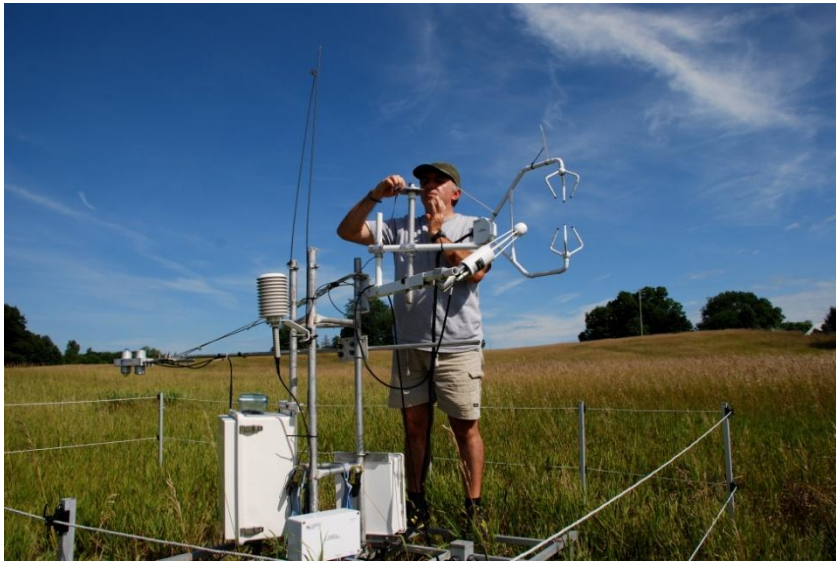
Improved plant-microbe interactions
(Microbial communities→ecosystem services)



Liang, Balser & Jackson, submitted

Soil C dynamics

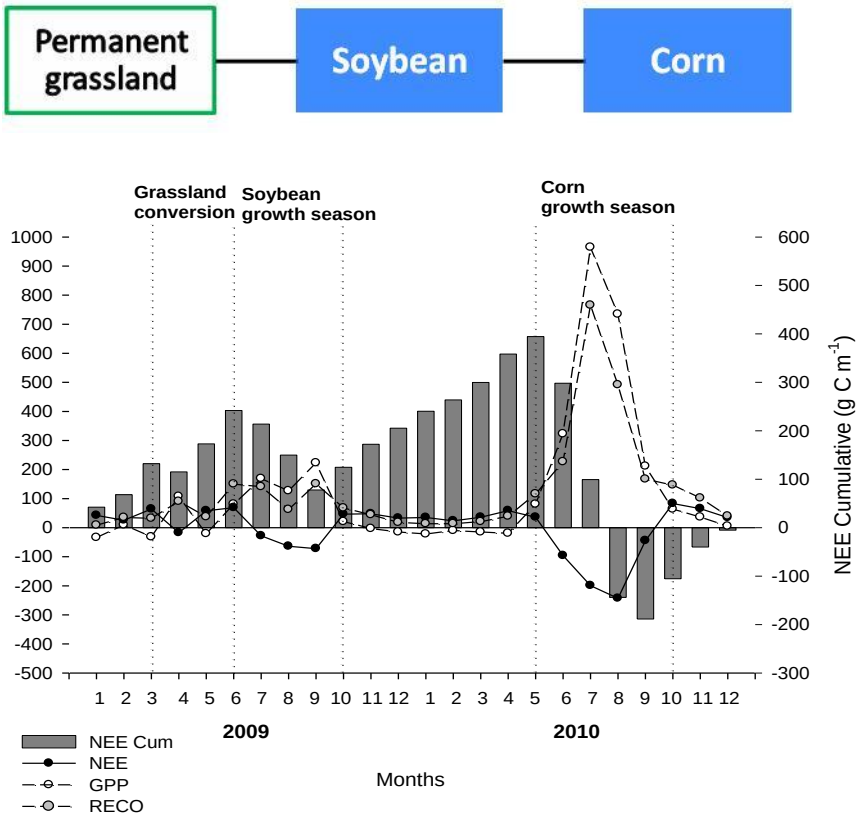


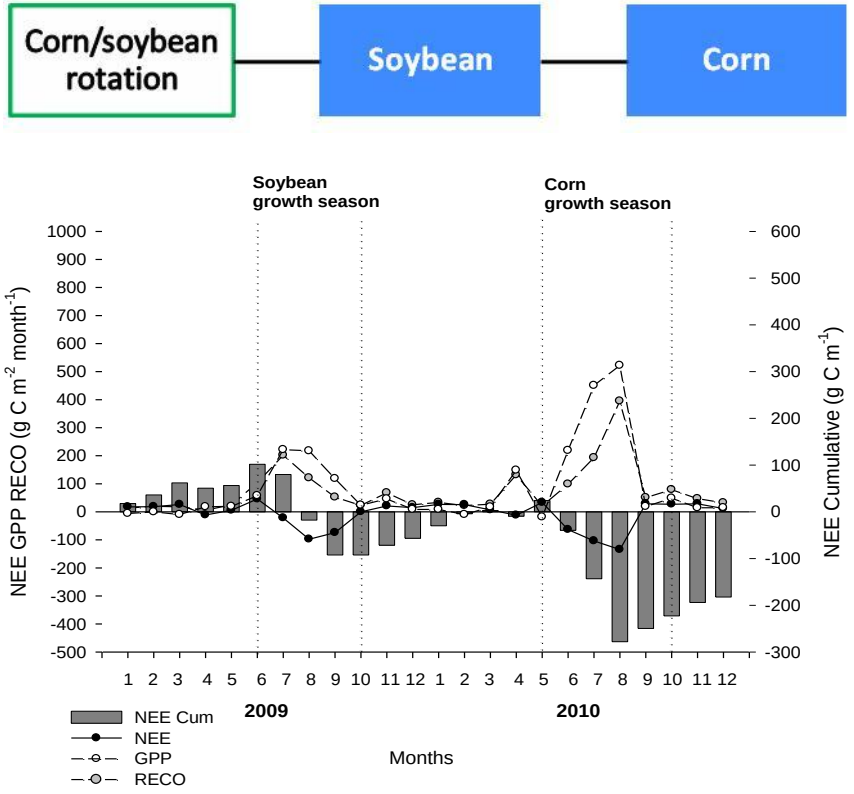


- Scale-up field sites
- Eddy covariance flux tower (1 of 6)

Soil C dynamics

Converting perennial grassland to corn resulted in loss of soil C

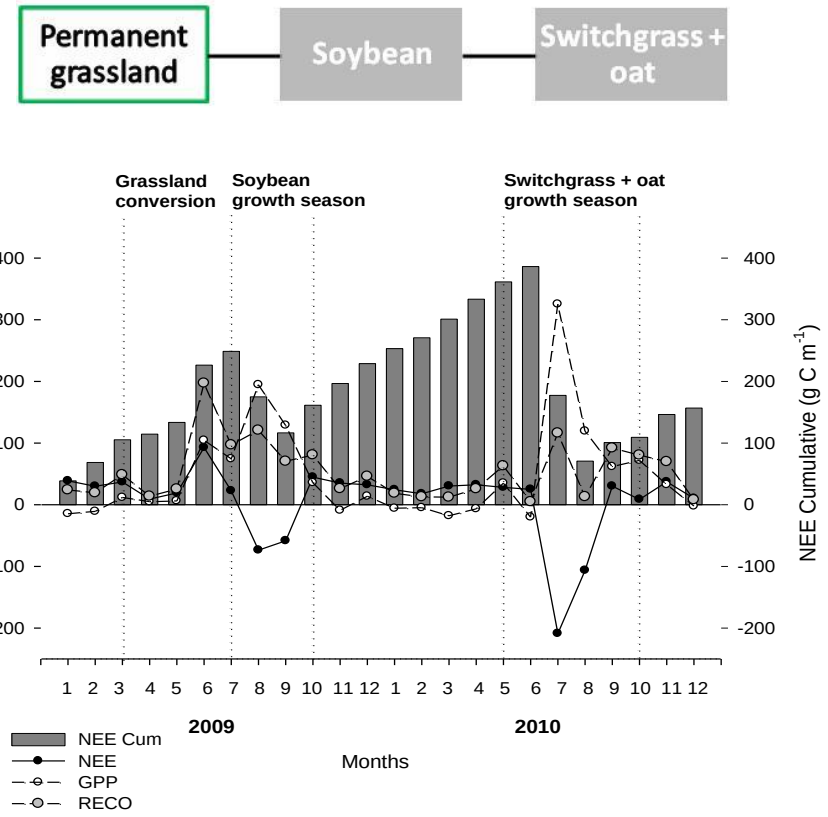


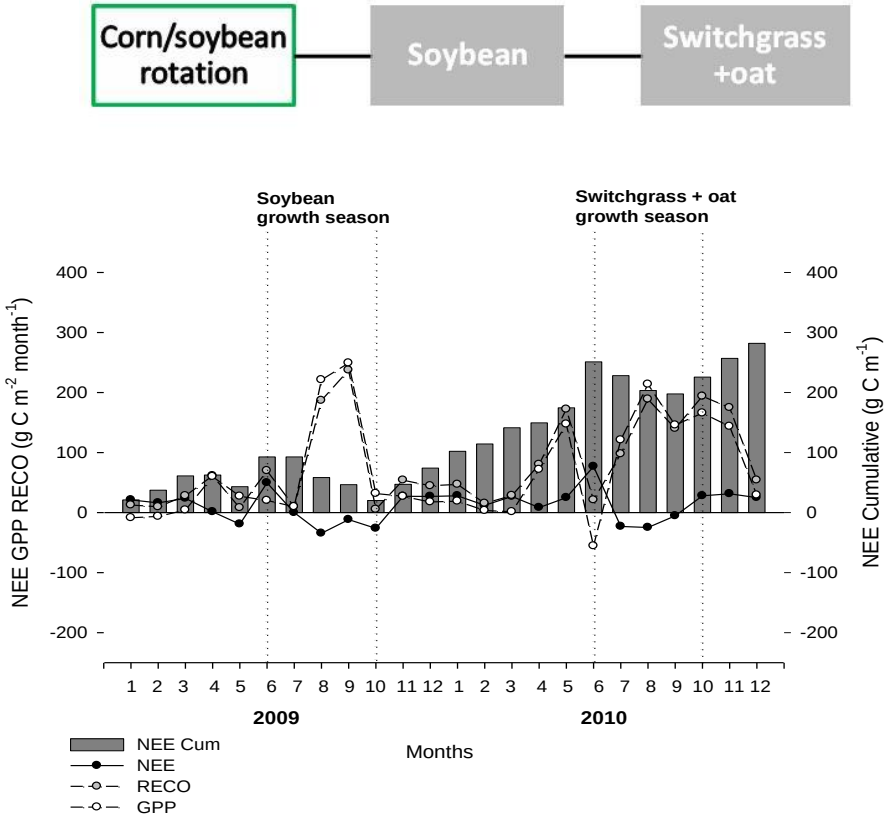


Zenone, Chen et al., unpublished data

Soil C dynamics

Converting to swtichgrass resulted in soil C gain, moreso when converting from annual cropping system

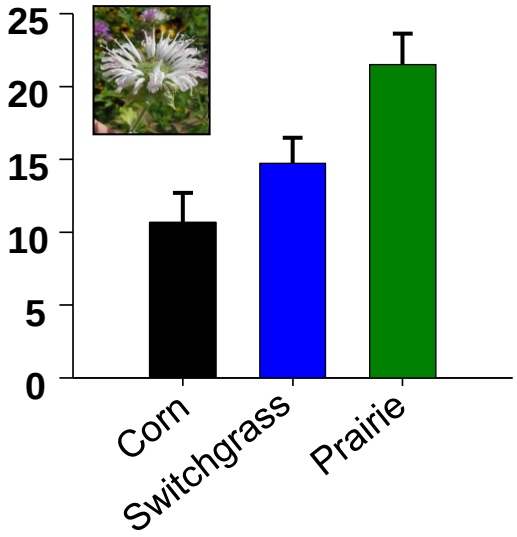




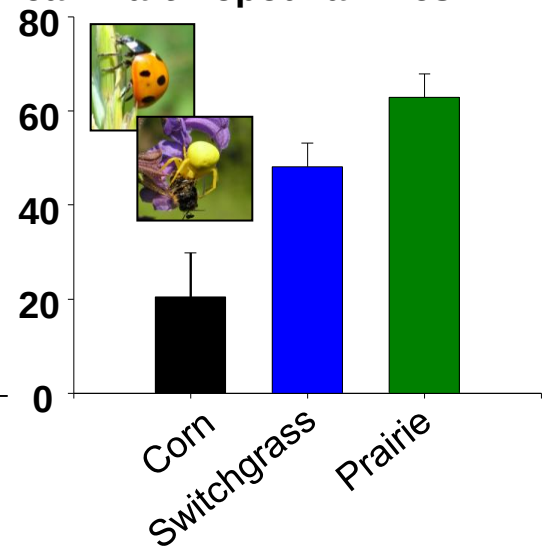
Zenone, Chen et al., unpublished data

Biodiversity responses

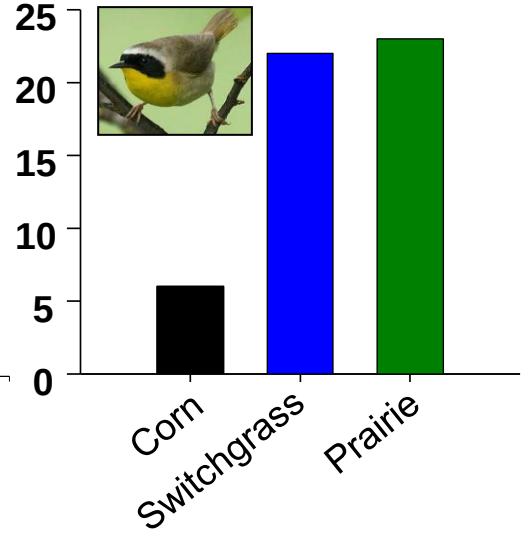
Mean # plant species



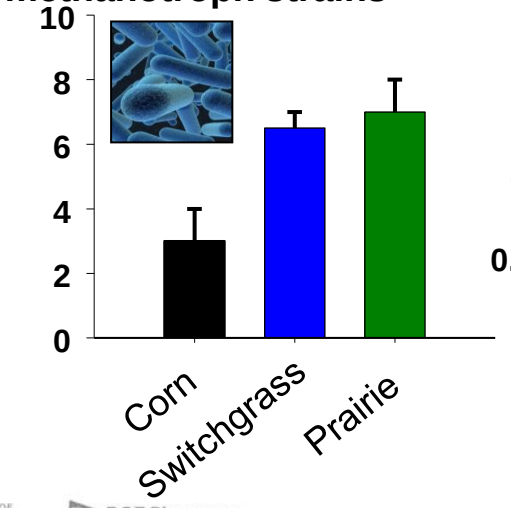
Mean # arthropod families



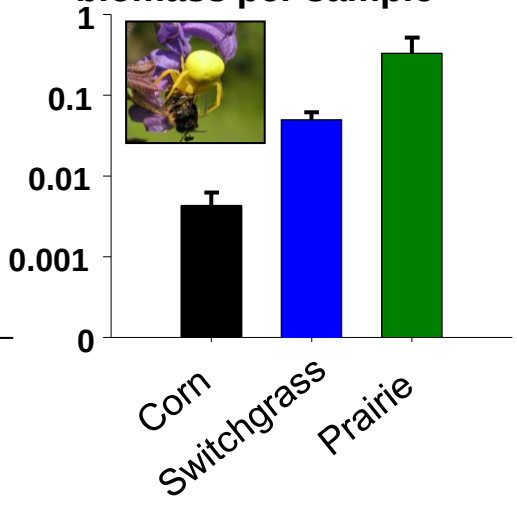
 # Breeding bird species



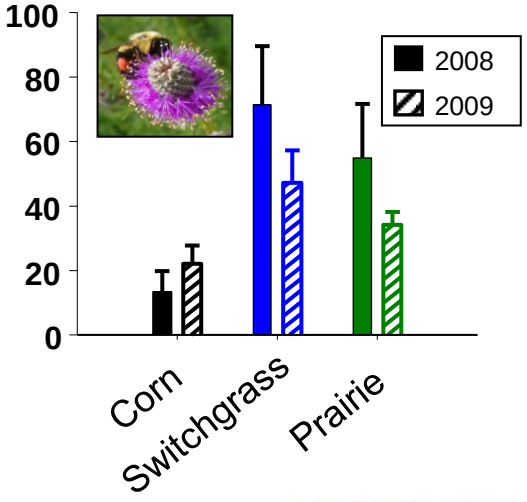
Mean # genetically distinct methanotroph strains



Mean grams predator biomass per sample

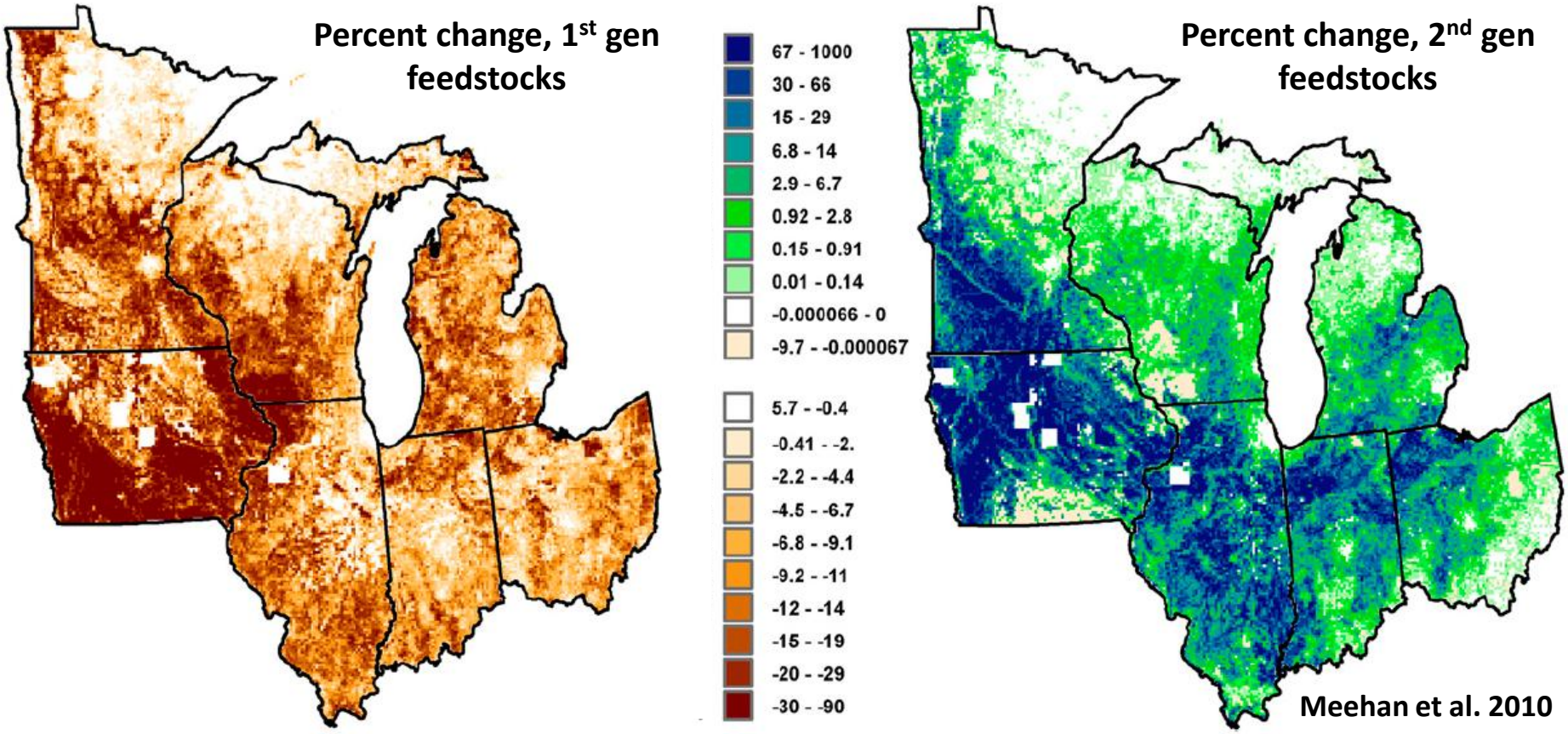


Total bees captures per site



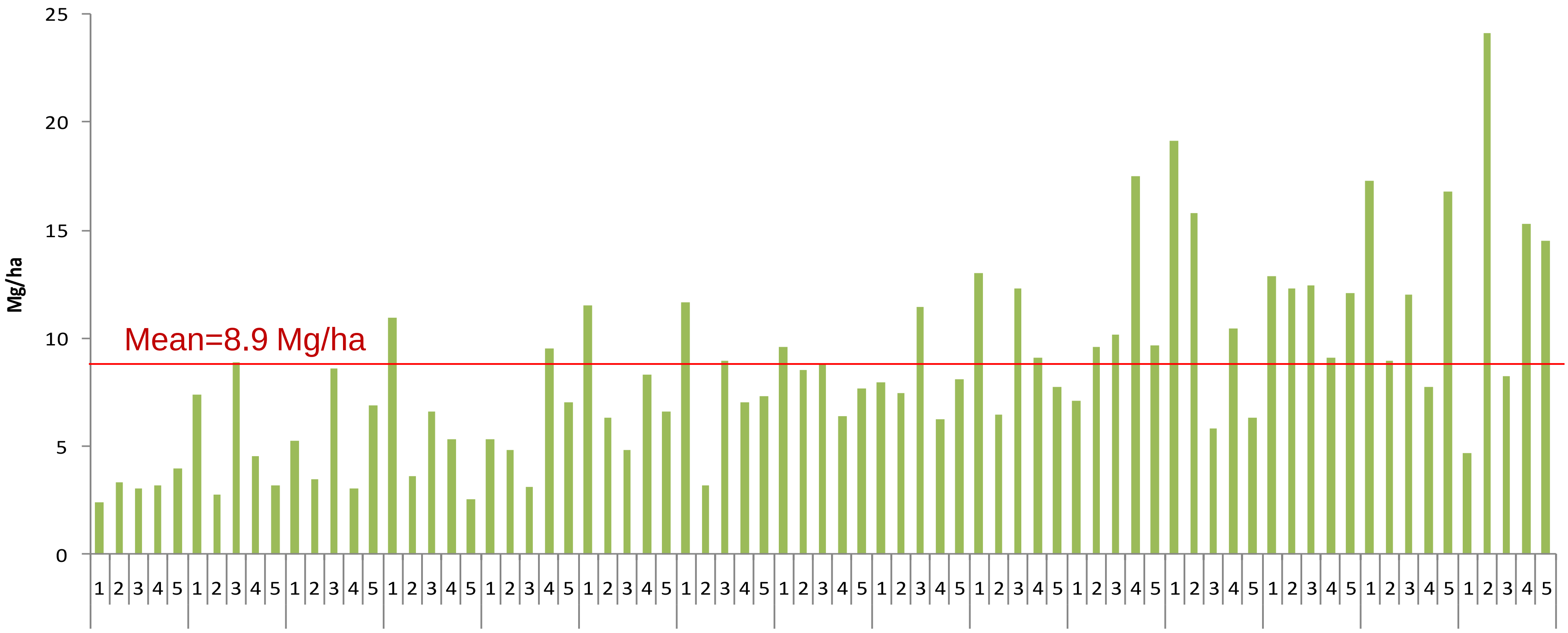
Rare Bird Diversity

Predict diversity from landscape characteristics for current landscapes, and 1st and 2nd generation feedstock scenarios

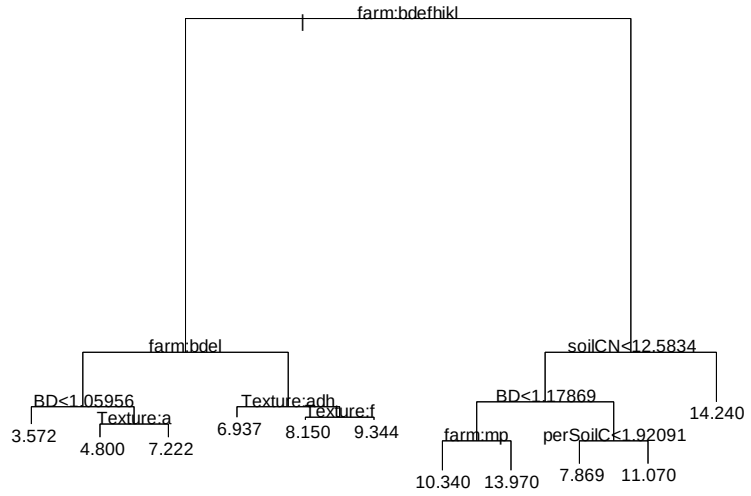


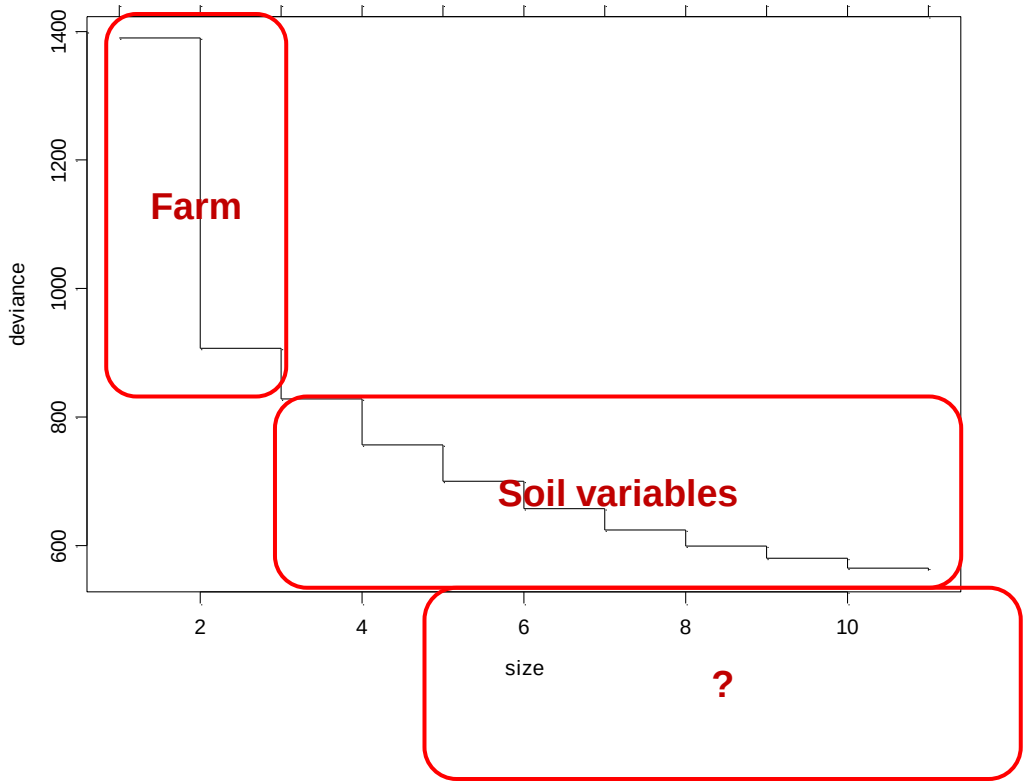
CRP yields
(southern WI)

Switchgrass biomass harvested from 20x50-cm quadrats on CRP in southern WI



Regression tree predicting yield (Mg/ha) of warm-season grasses in southern Wisconsin CRP





Bertjens & Jackson, unpublished data

Perennial polycultures will be less productive and more variable than annual monocultures

→ Agronomic intensification likely

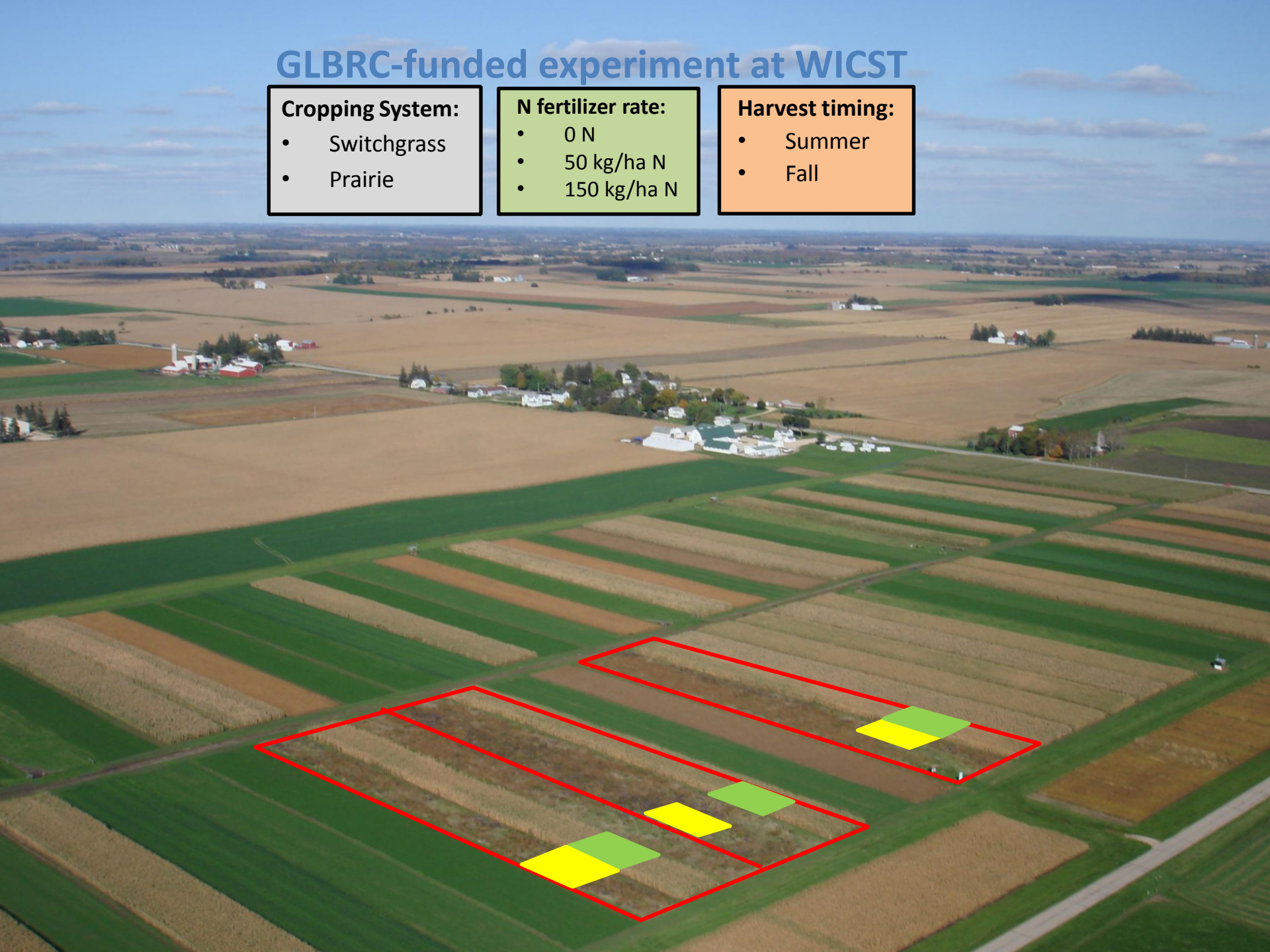
What are the ramifications?

GLBRC-funded experiment at WICST

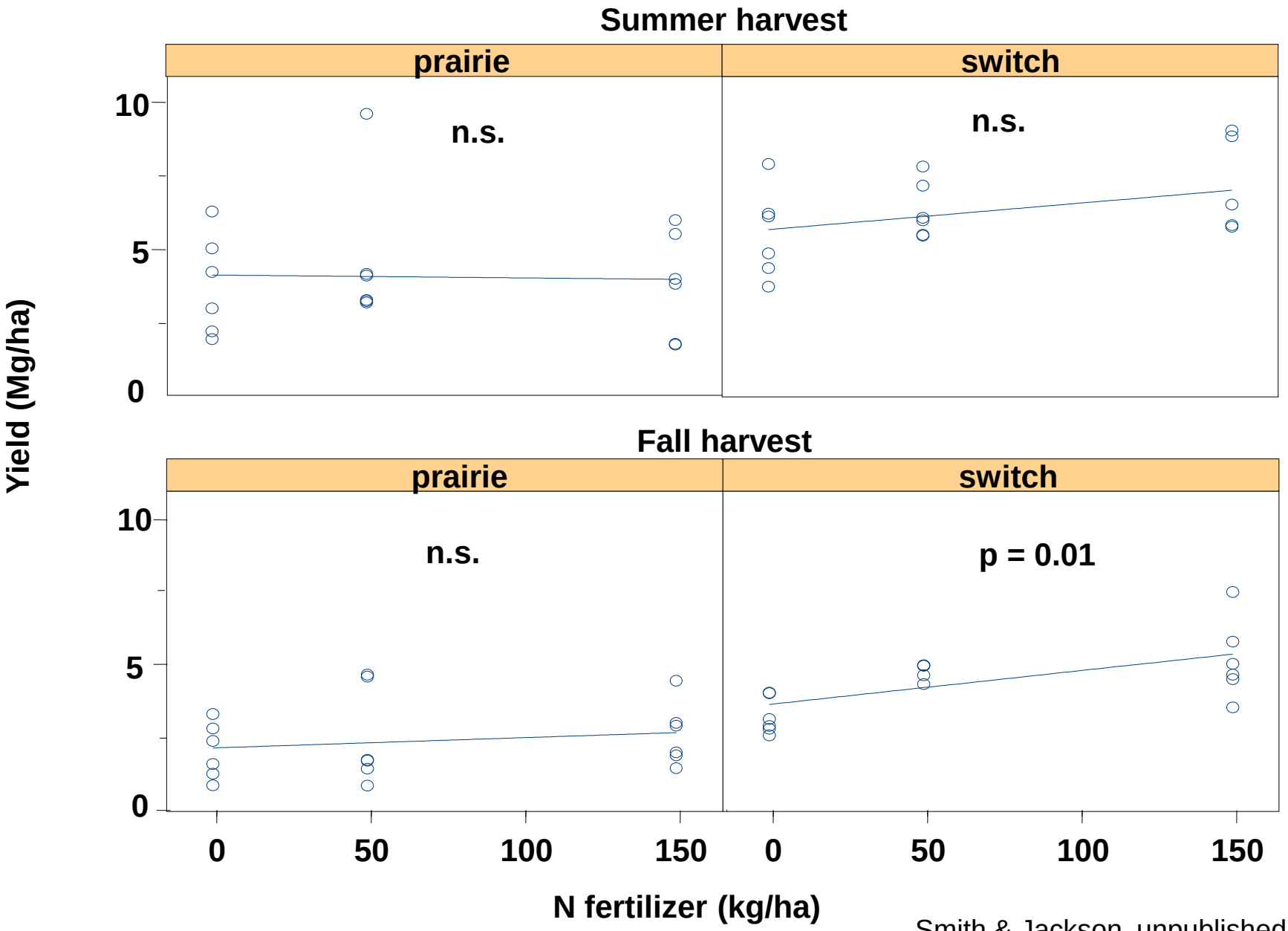
Cropping System:
- Switchgrass
- Prairie

N fertilizer rate:
- 0 N
- 50 kg/ha N
- 150 kg/ha N

Harvest timing:
- Summer
- Fall

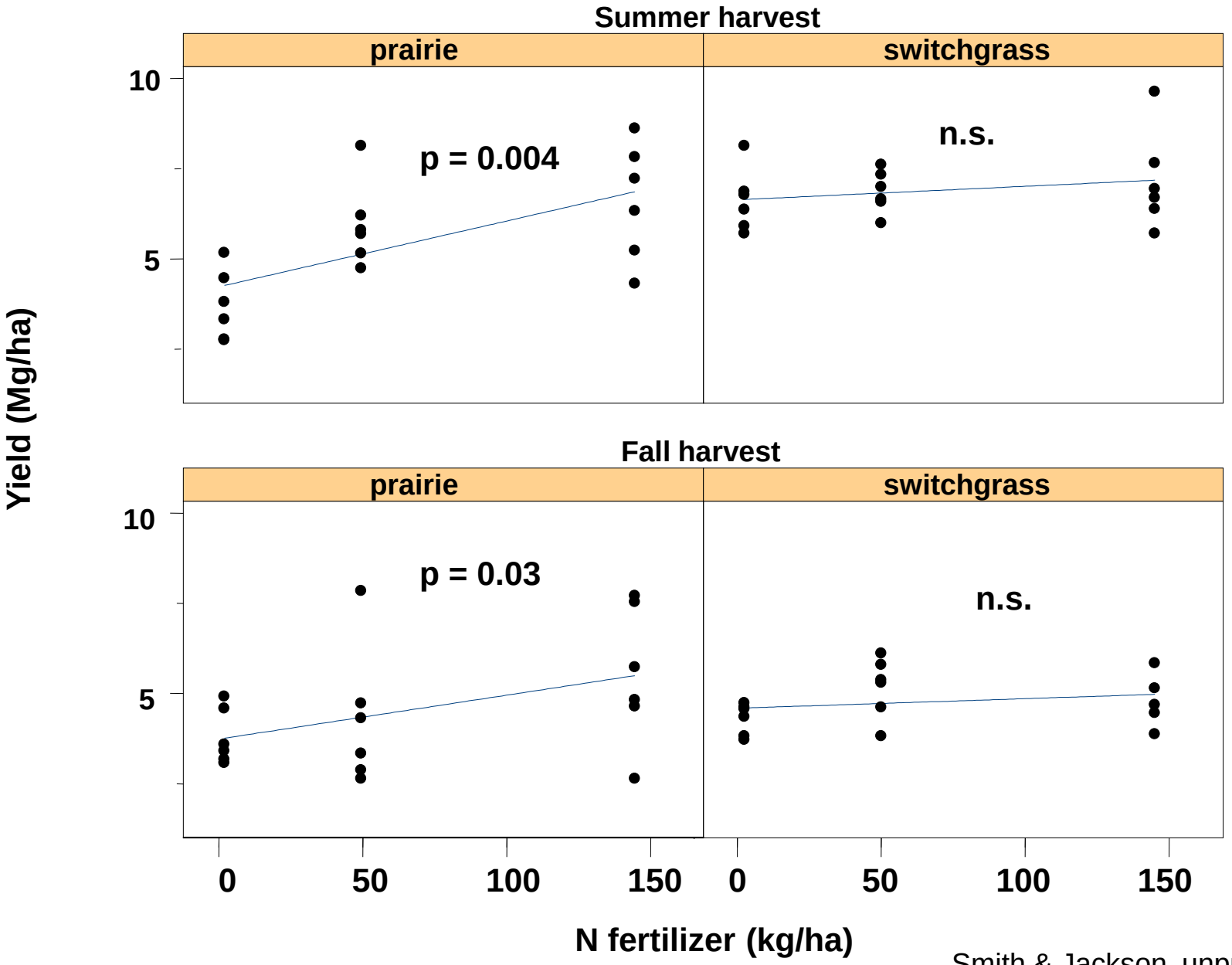


2009 Yield Response to N treatment



Smith & Jackson, unpublished data

2010 Yield Response to N treatment



Smith & Jackson, unpublished data

P105 T9
Sp/150

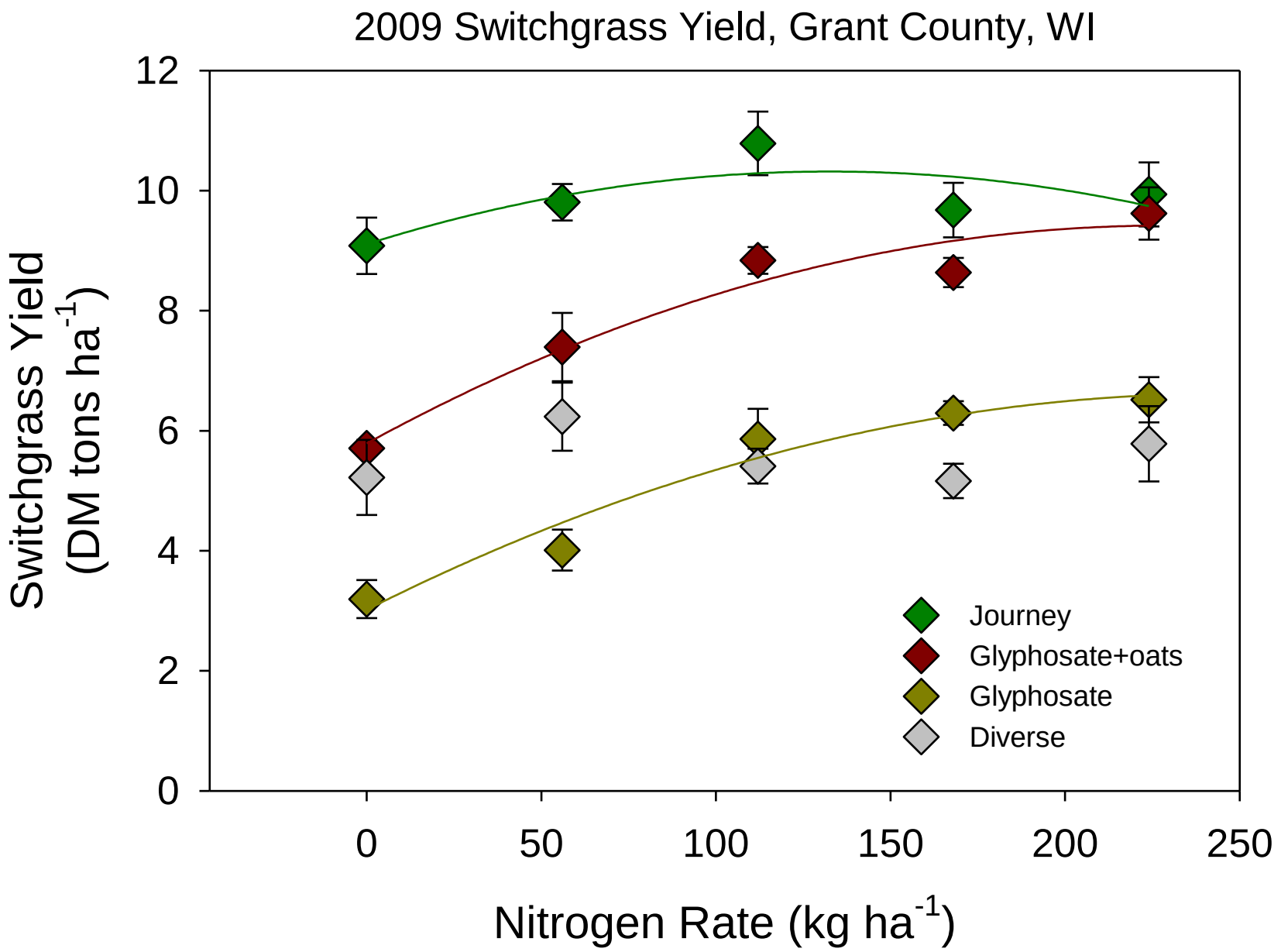
P106 T10
Cont.

Switchgrass & prairie establishment – southwest WI

Year-1 treatments (2008)

1. Switchgrass + **Glyphosate + 2,4-D**
2. Switchgrass + **Glyphosate**
3. Switchgrass + **Journey**
4. Diverse mix + **Journey**
    1. Switchgrass (1 lb a^{-1})
    2. Sideoats grama (1.5 lb a^{-1})
    3. Indian grass (2 lb a^{-1})
    4. Big bluestem (2 lb a^{-1})
    5. Little bluestem (2.5 lb a^{-1})
    6. IL bundle flower (4 oz a^{-1})
    7. Yellow coneflower (2 oz a^{-1})
    8. Partridge pea (8 oz a^{-1})
    9. Canada milk vetch (8 oz a^{-1})

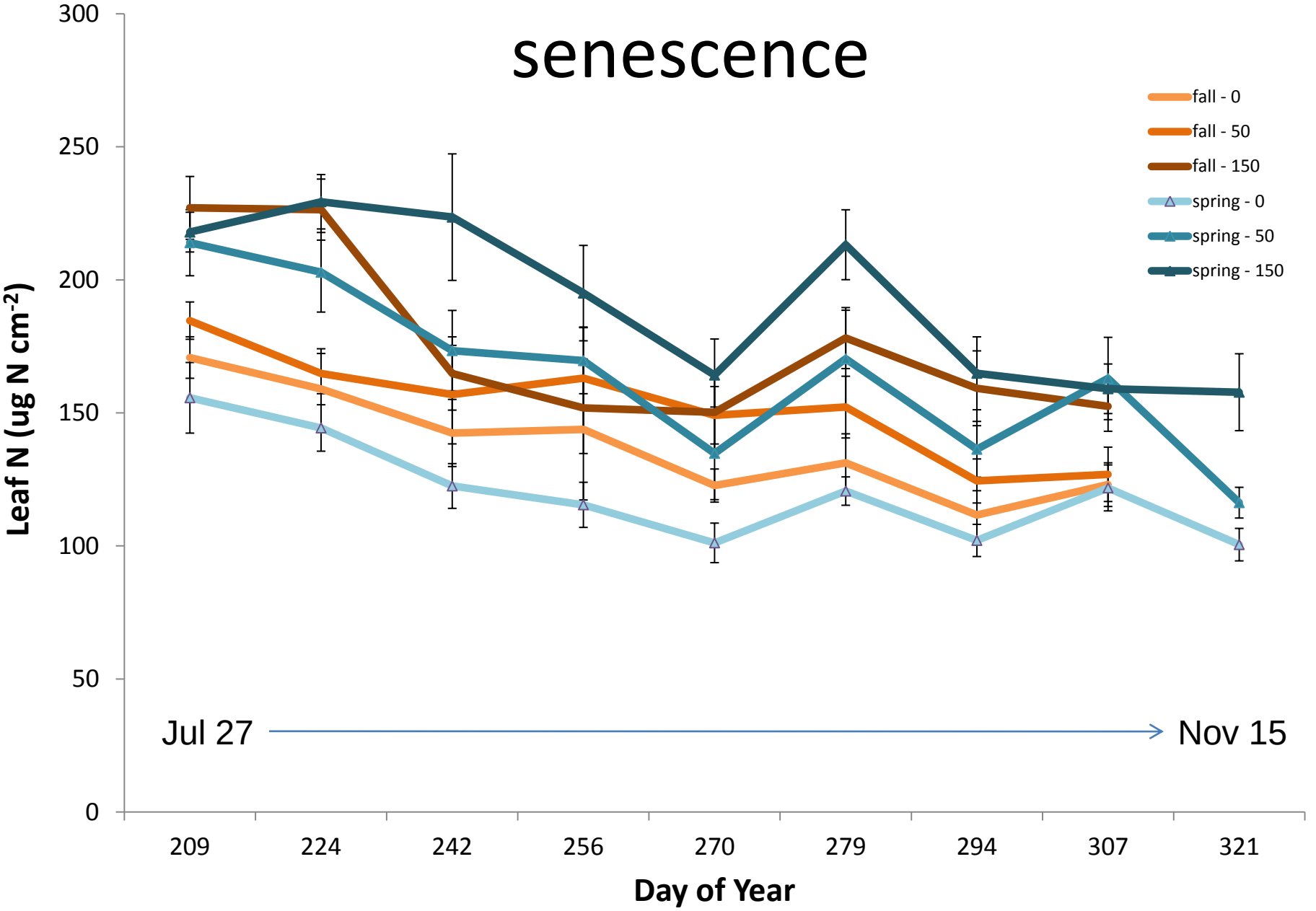
Year-2 switchgrass & prairie yields



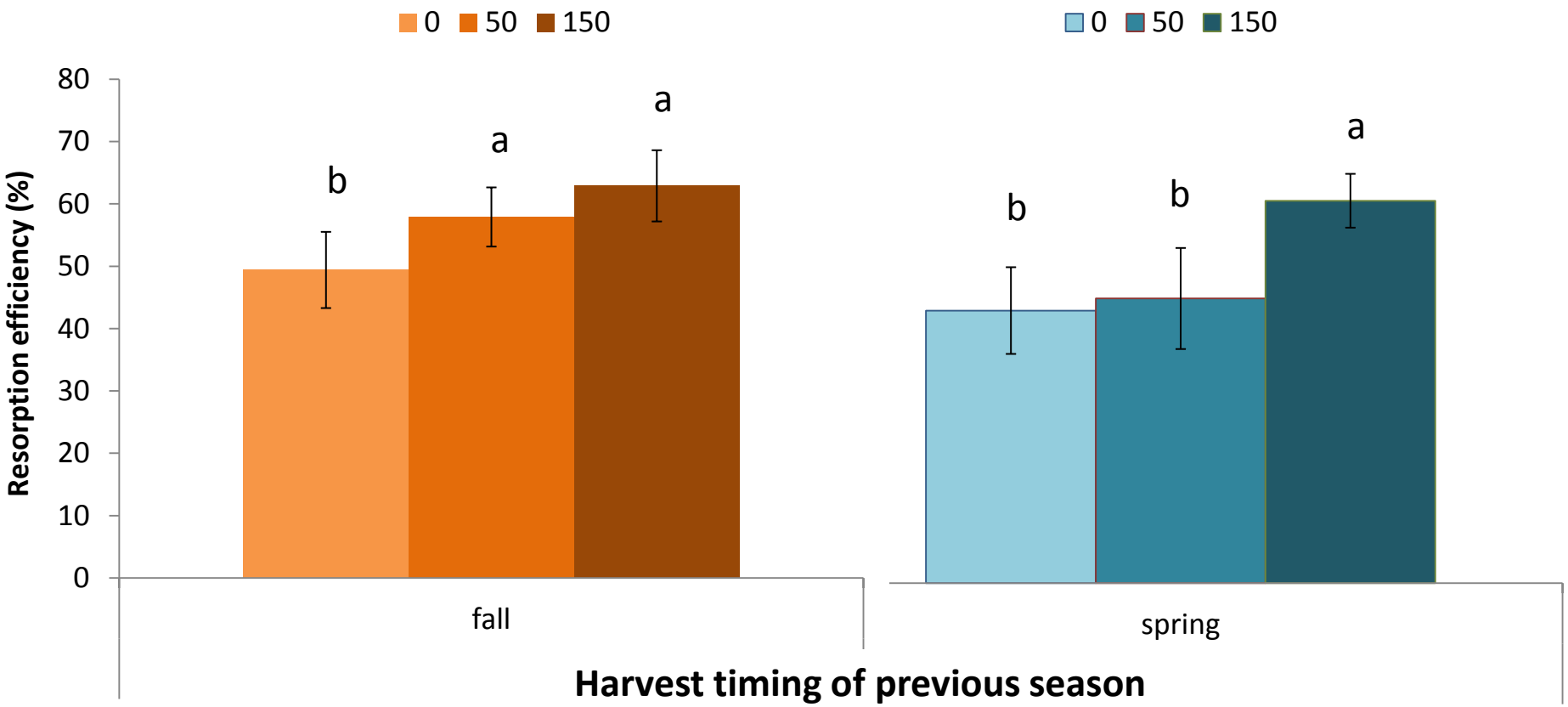
Ruark, Renz, & Jackson, unpublished data

Switchgrass and prairie response to N weak, highly variable, and dependent on establishment method

Switchgrass Leaf N through senescence

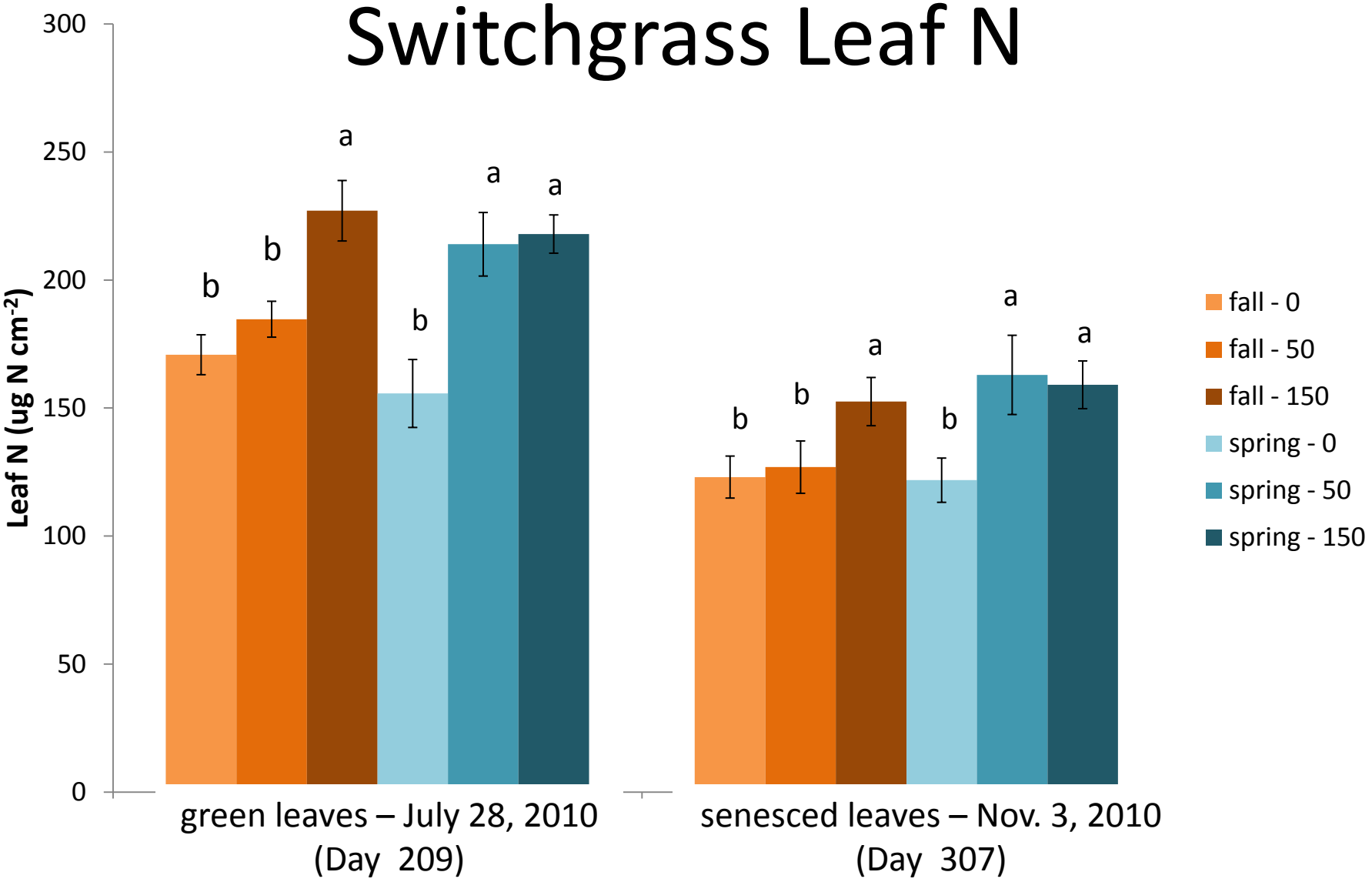


Switchgrass N resorption: end of season



(Samples collected November 3, 2010)
Error bars are +/- 1SE; n=6

Switchgrass Leaf N



Error bars are +/- 1SE; n=6

Summary

1. Perennial polycultures → lower & more variable productivity feedstocks
2. Agronomic intensification of perennial grasses likely, which will compromise ecosystem service gains
3. Should look for gains in NUE, NRE, and NRP in perennial grasses
4. Must find ways to pay farmers for providing ecosystem services