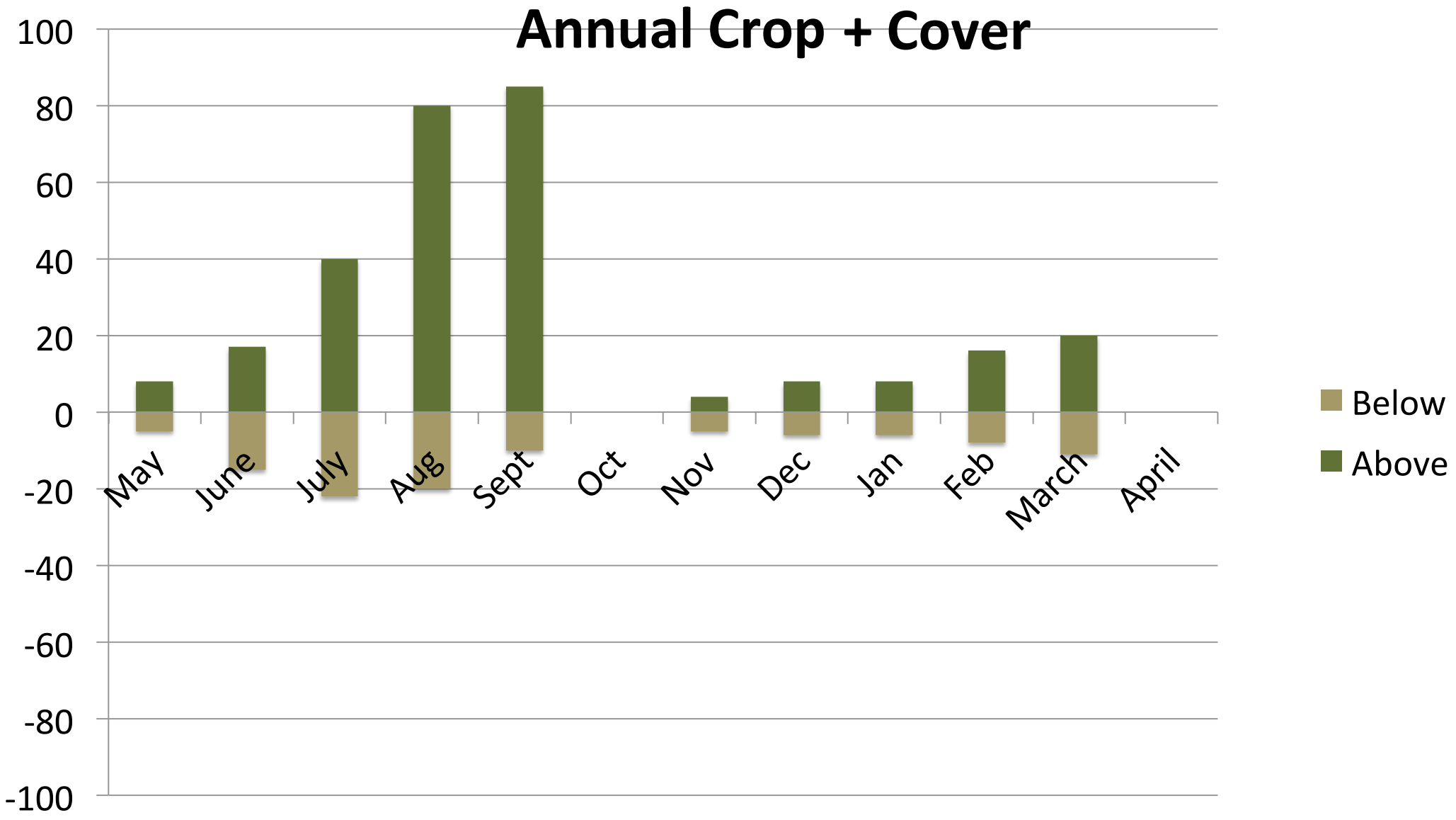
Soil health and water quality: Is perennial cover the critical ingredient?

Prof. Sieg Snapp, Michigan State University

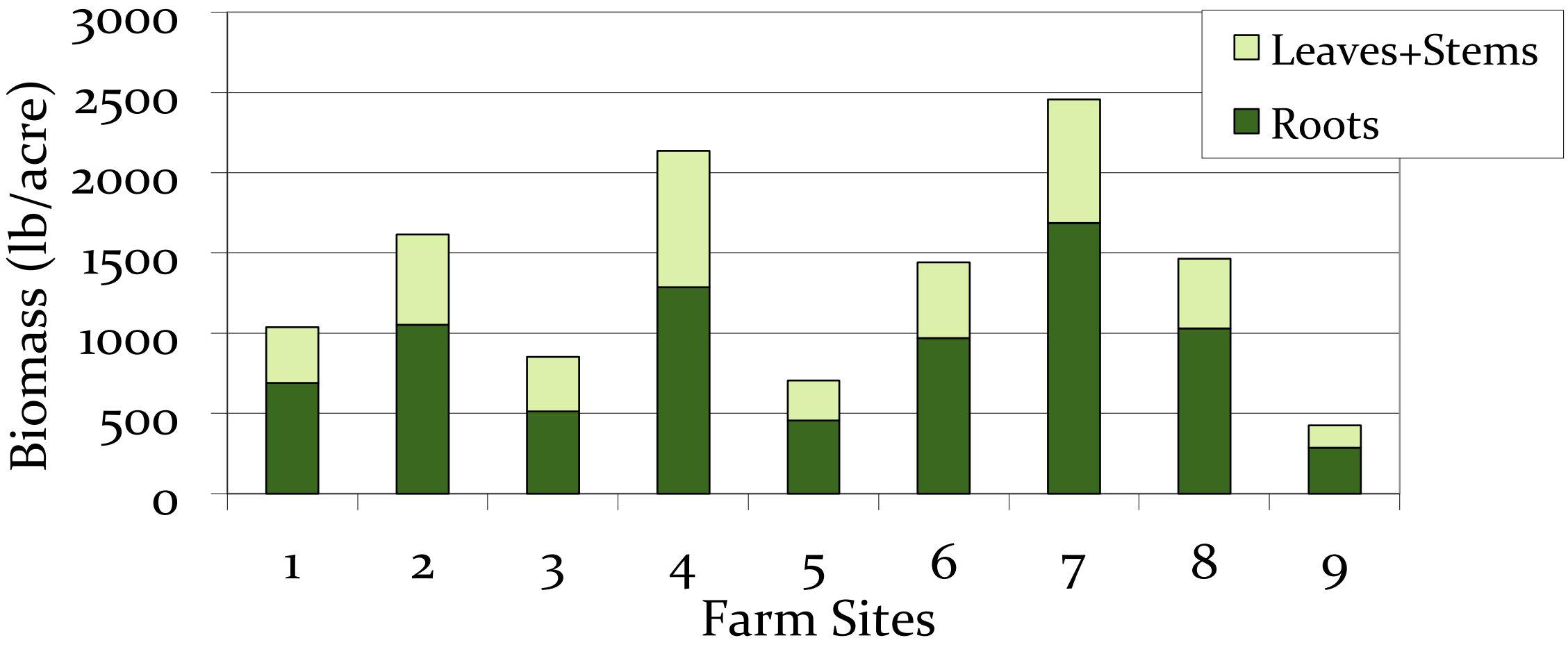
Enhancing Cropping System Performance under Increased Environmental Variability
University of Minnesota Symposium February 13, 2014

How to achieve continuous cover?

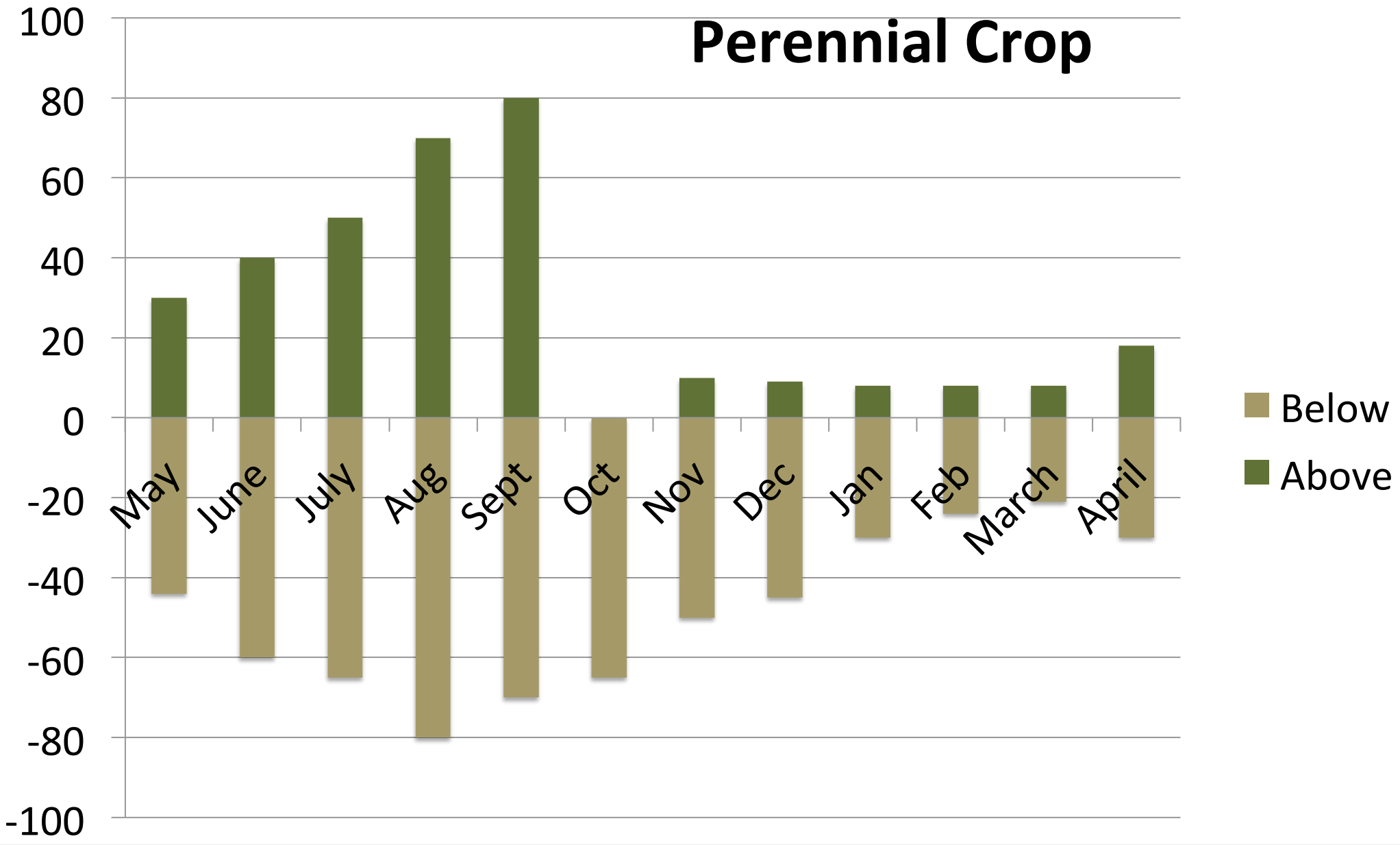
How to achieve continuous cover? Cover crops?


Annual Crop + Cover
100
80
60
40
20
0
-20
-40
-60
-80
-100
May
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
March
April
Below
Above

Michigan potato farms in early April: Rye cover crop



Morrone and Snapp, 2011


Perennial Crop
100
80
60
40
20
0
-20
-40
-60
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-100
May
June
July
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Jan
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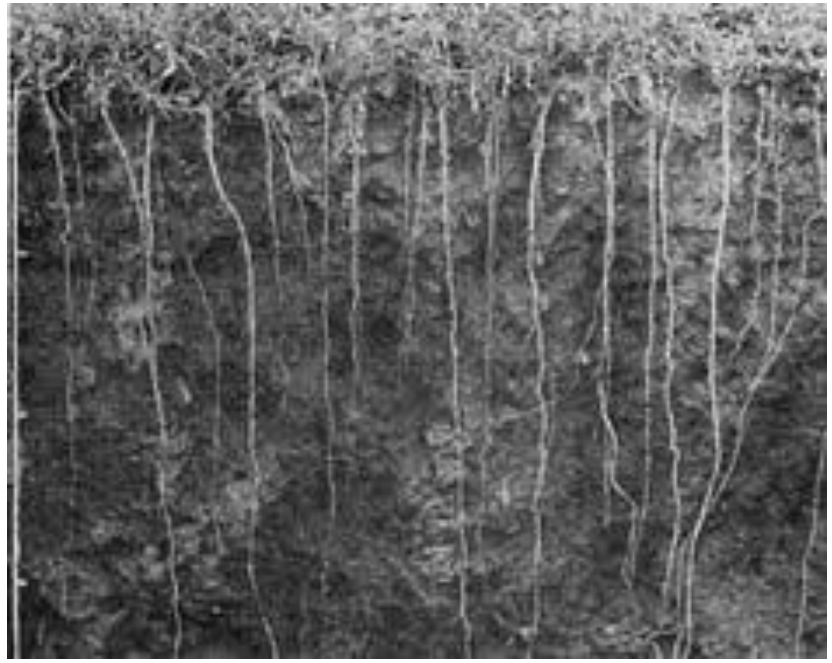
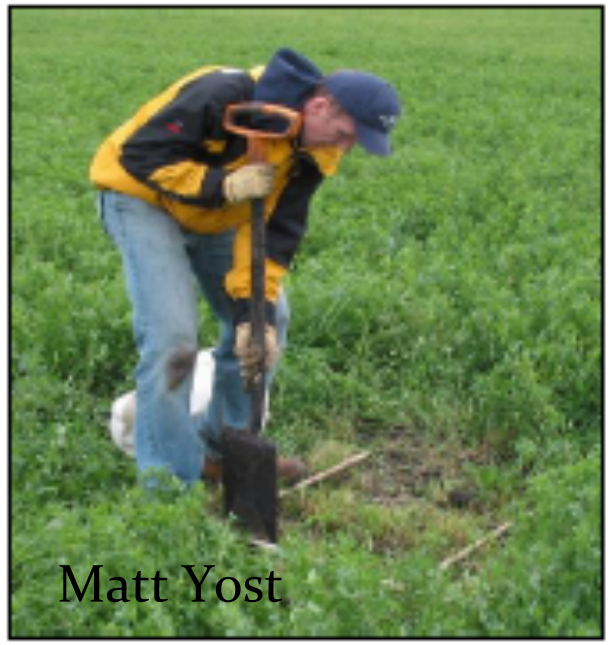
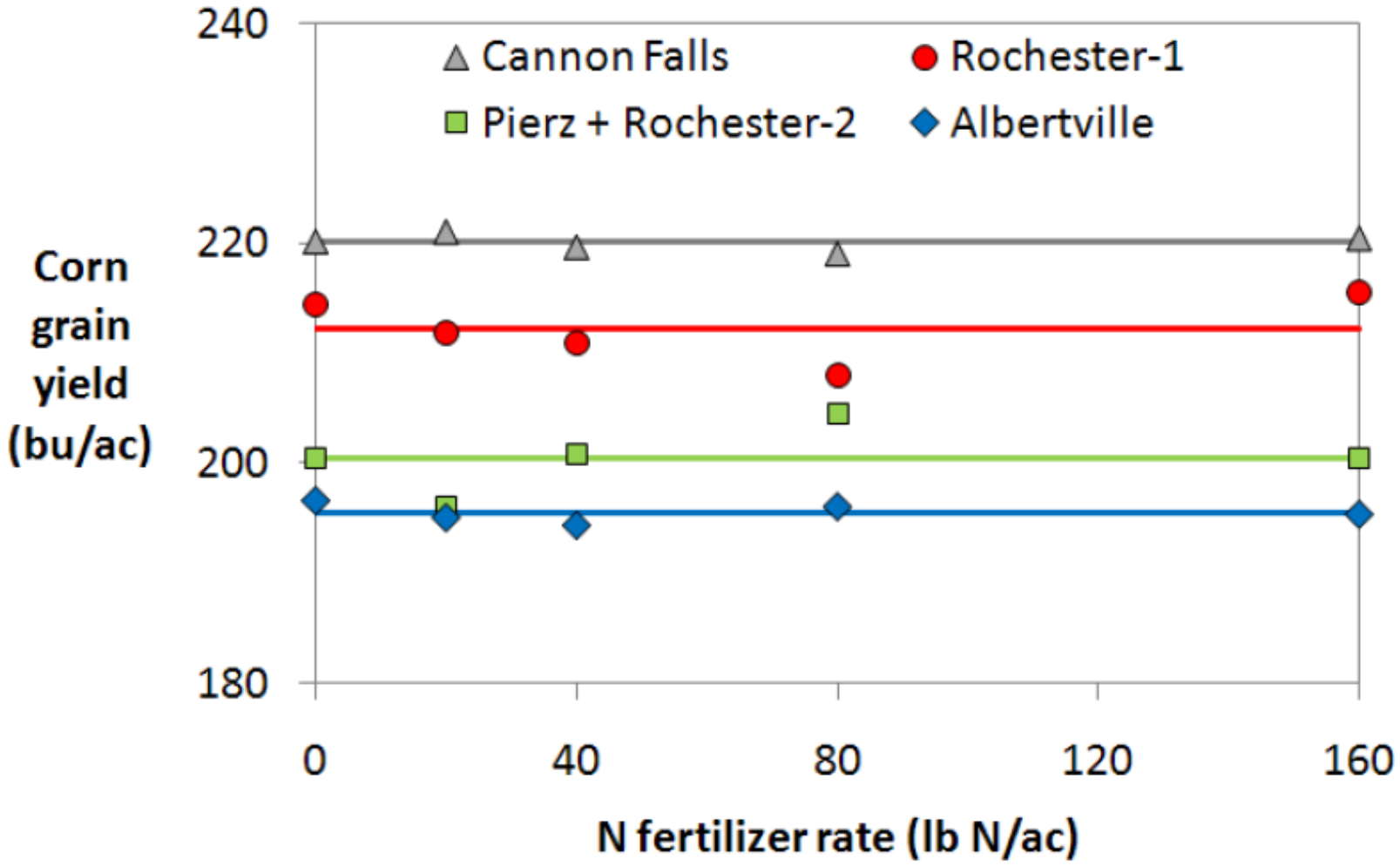
March
April
Below
Above

Queen Alfalfa





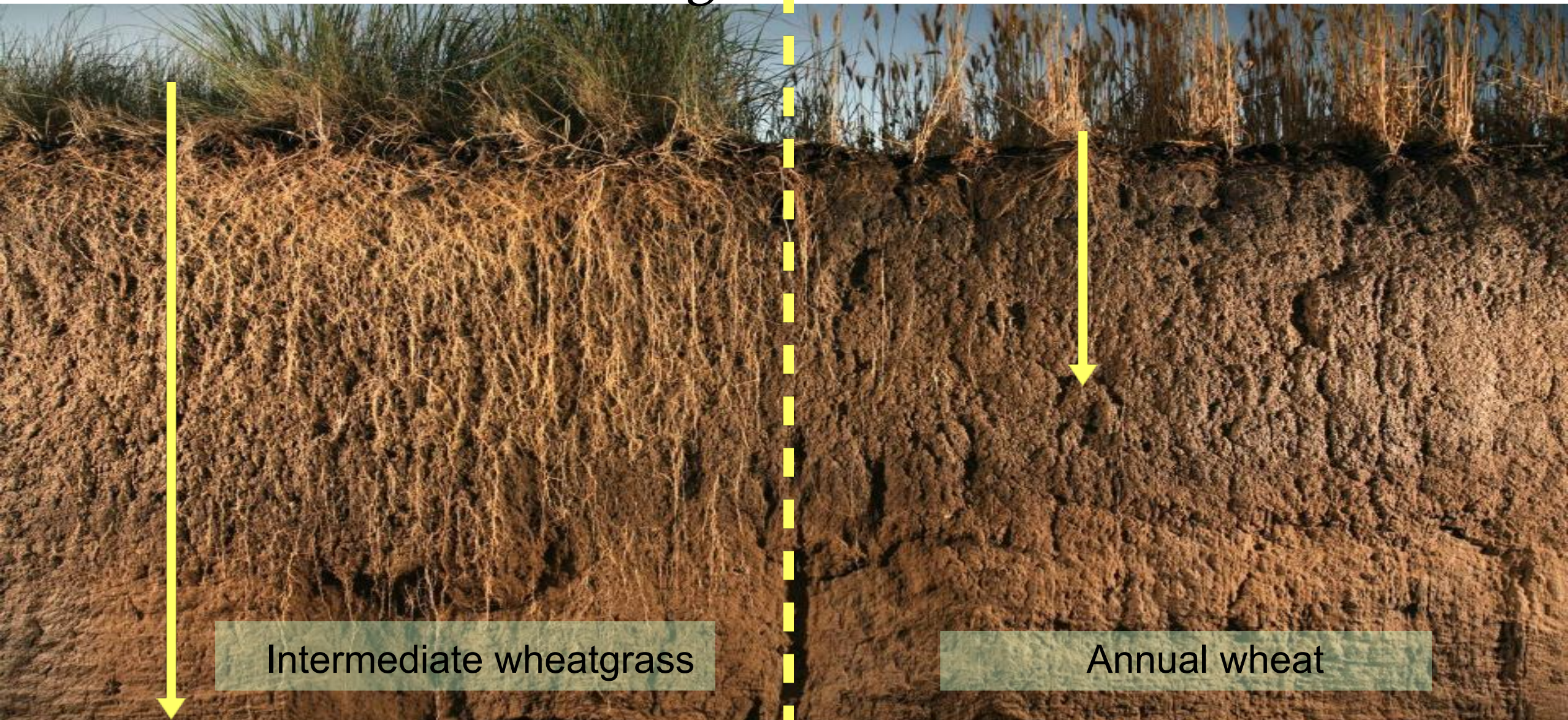
Alfalfa builds soil organic matter and nitrogen



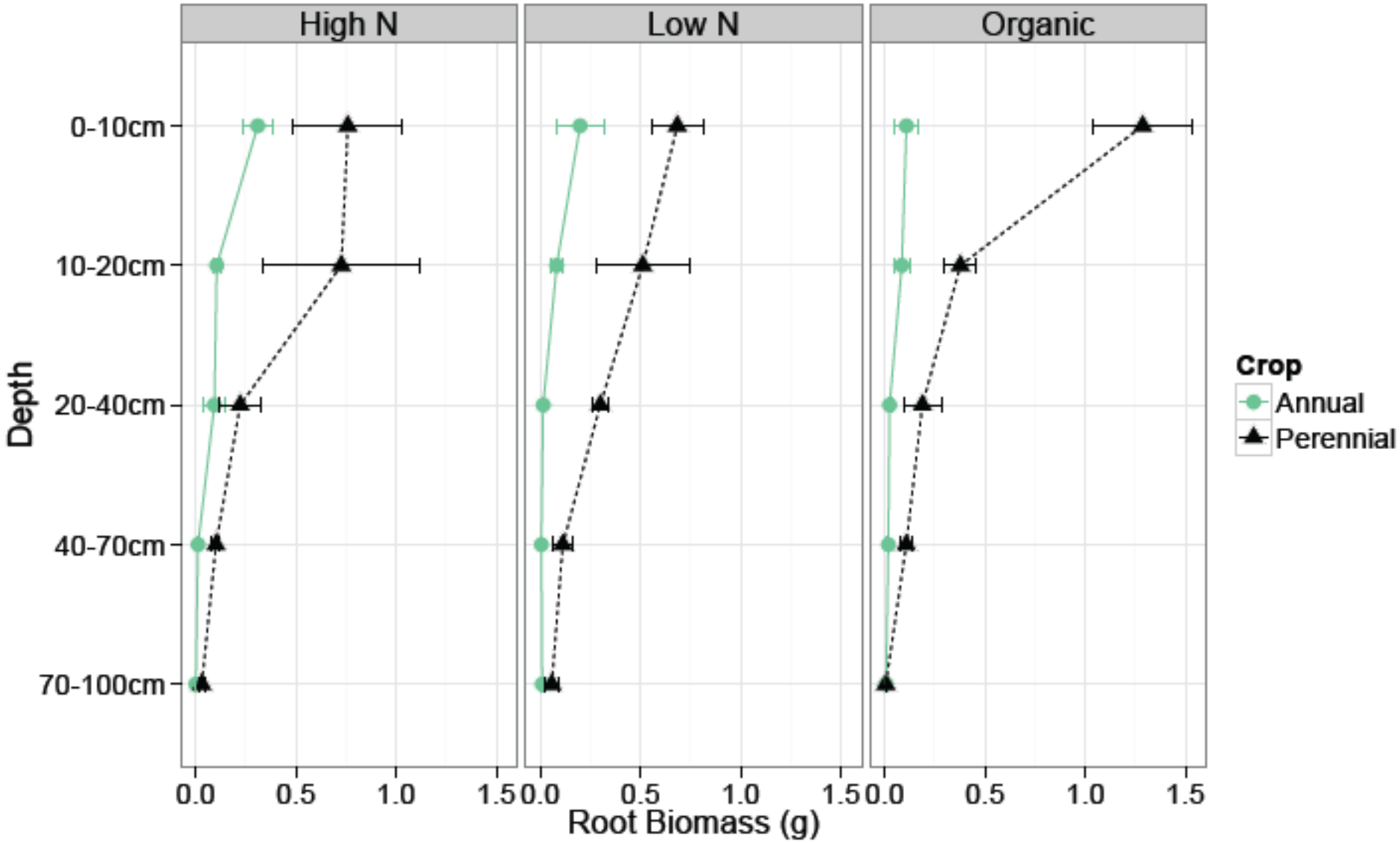
Coulter, Russelle, Yost and Sheaffer, 2010

Viewing roots of perennial grains in the field

Root Systems comparisons: Intermediate Wheatgrass & Annual Wheat



Coarse Root Biomass



Sprunger et al., 2013

Perennial Wheat?

David Van Tassel
Lee DeHaan

Th. intermedium
cv Luna

X

Triticum aestivum 280b

Perennial Wheat Research Timeline

1920's – 60's

1940s & 50' s

1970's -

1990's

2006 -

1900

1923 - 1935

1980's

1990's -

Montana

Perennial wheat regrowth: Washington State University

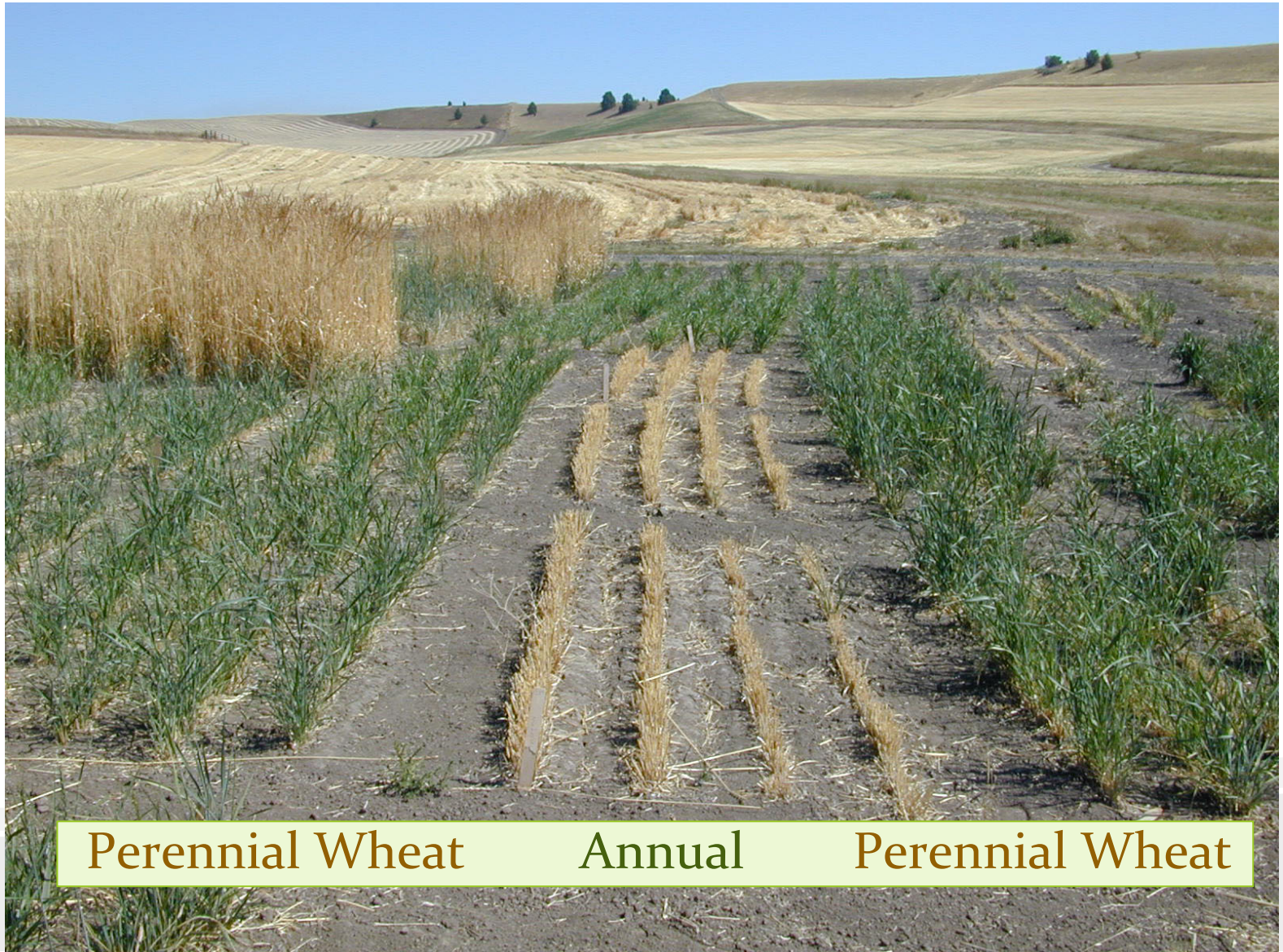
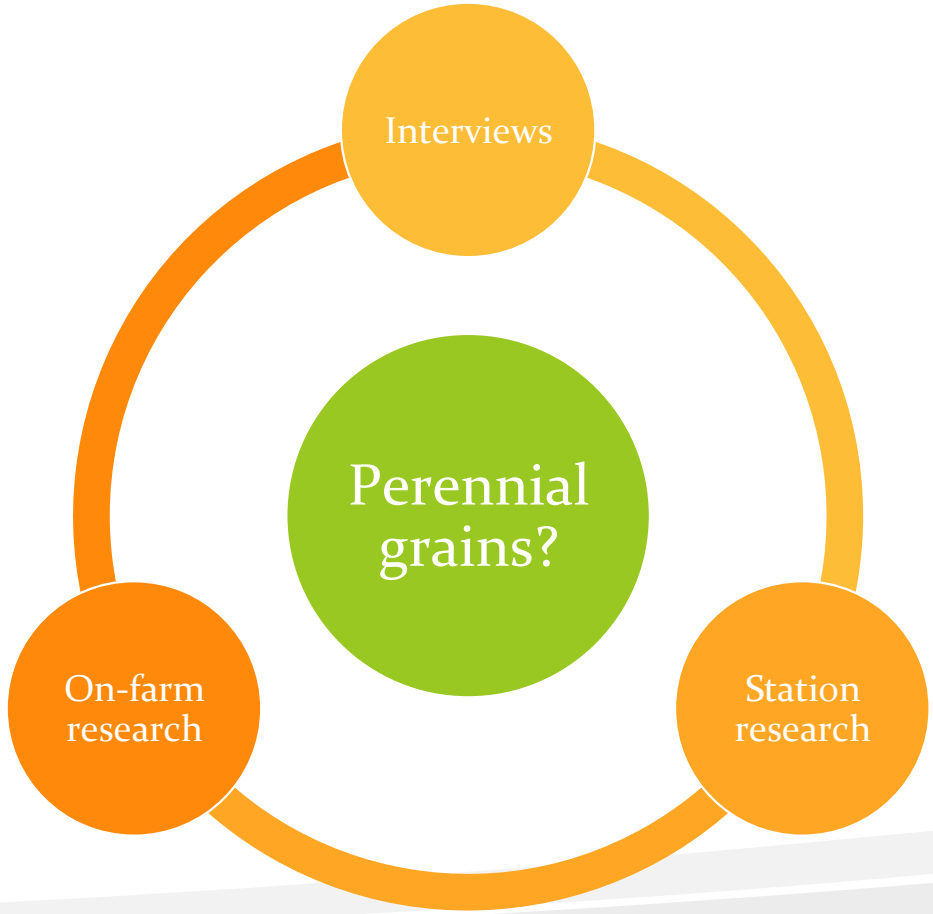


Photo by Steve Jones

Perennial grain research in Michigan

Assessing perennial grains as a cover option

- Farmer perspective
  - Interviews (12)
  - On-farm research (5)
- Research station
  - grain yield and dual use experiments
- Research station
  - Four year trial evaluating environmental services



Michigan farmer interviews and literature review

	Farm*	Society
Benefits	• Early spring growth • Lower production costs • Water quality • Conservation of marginal areas • Dual use grain & fodder	• Albedo cooling effect • Soil C sequestration • Water quality • Reduced soil erosion • Climate change resilience

*Spring 2012 interviews with 12 farmers interested in experimenting with perennial grains, unpublished data

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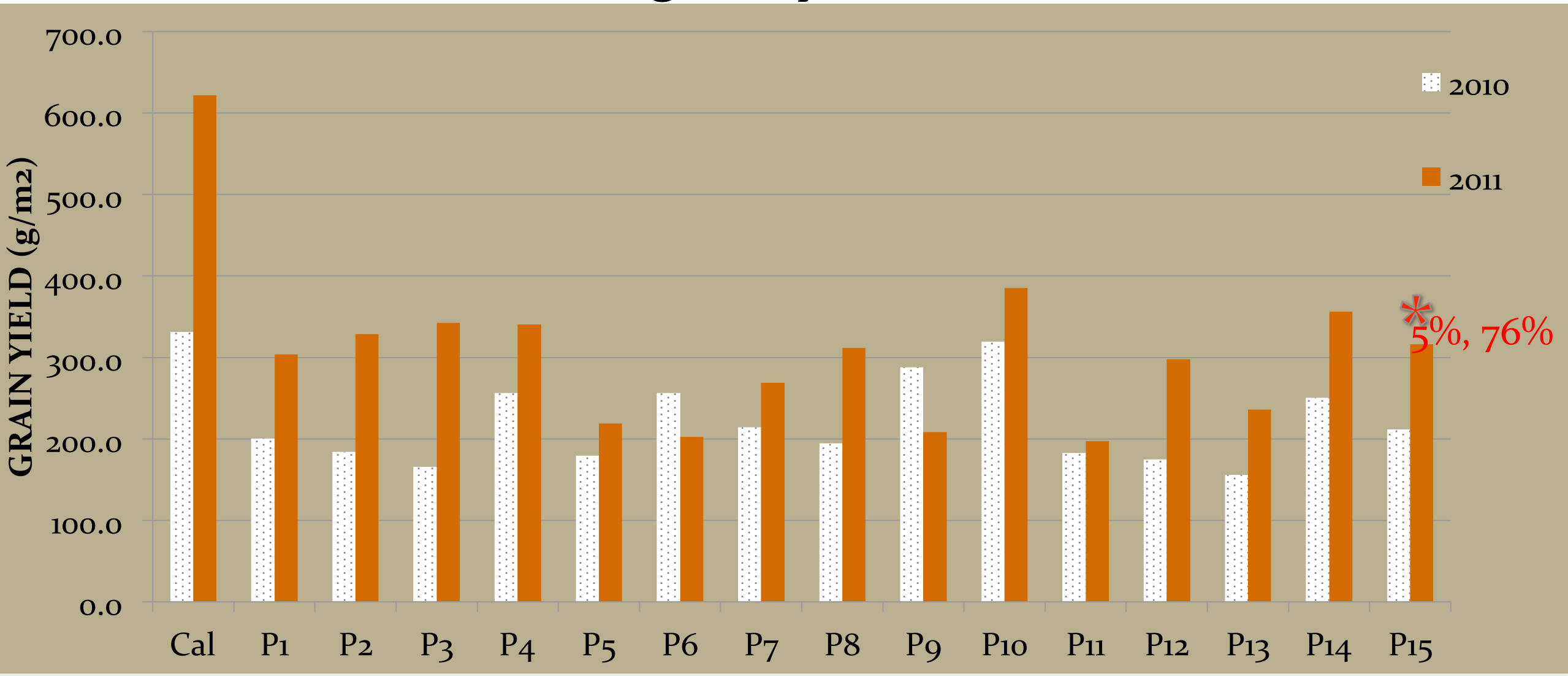
Michigan farmer interviews and literature review

	Farm*	Society
Costs	• Opportunity costs (compared to higher yielding crops) • Pest risk • Weed pressure	• Reduced food production • Disease reservoir • Reduced profitability (requires subsidies)

*Spring 2012 interviews with 12 farmers interested in experimenting with perennial grains, unpublished data

Annual and Perennial Grain Lines: field trial at KBS, SW Michigan since 2009

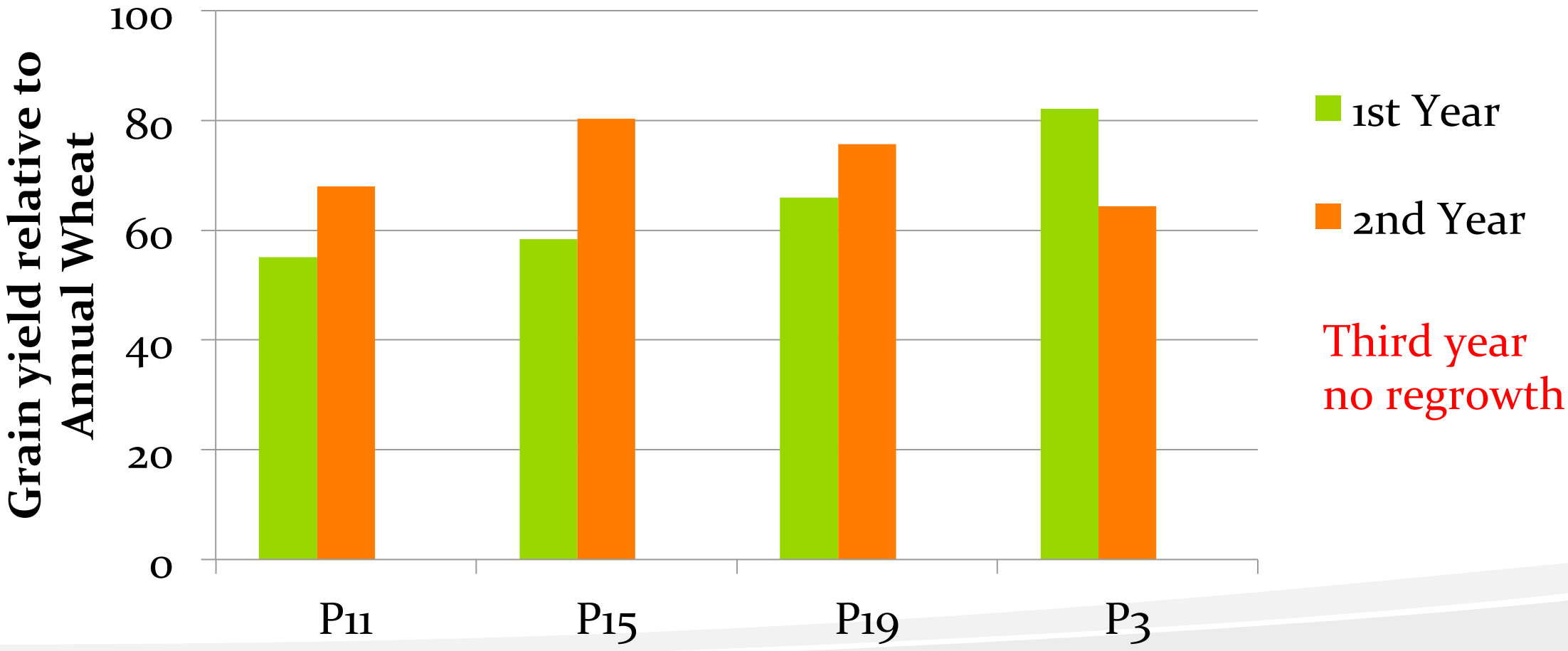
Perennial wheat WSU lines 2009 grain yield



Wheat Grain Milling Quality

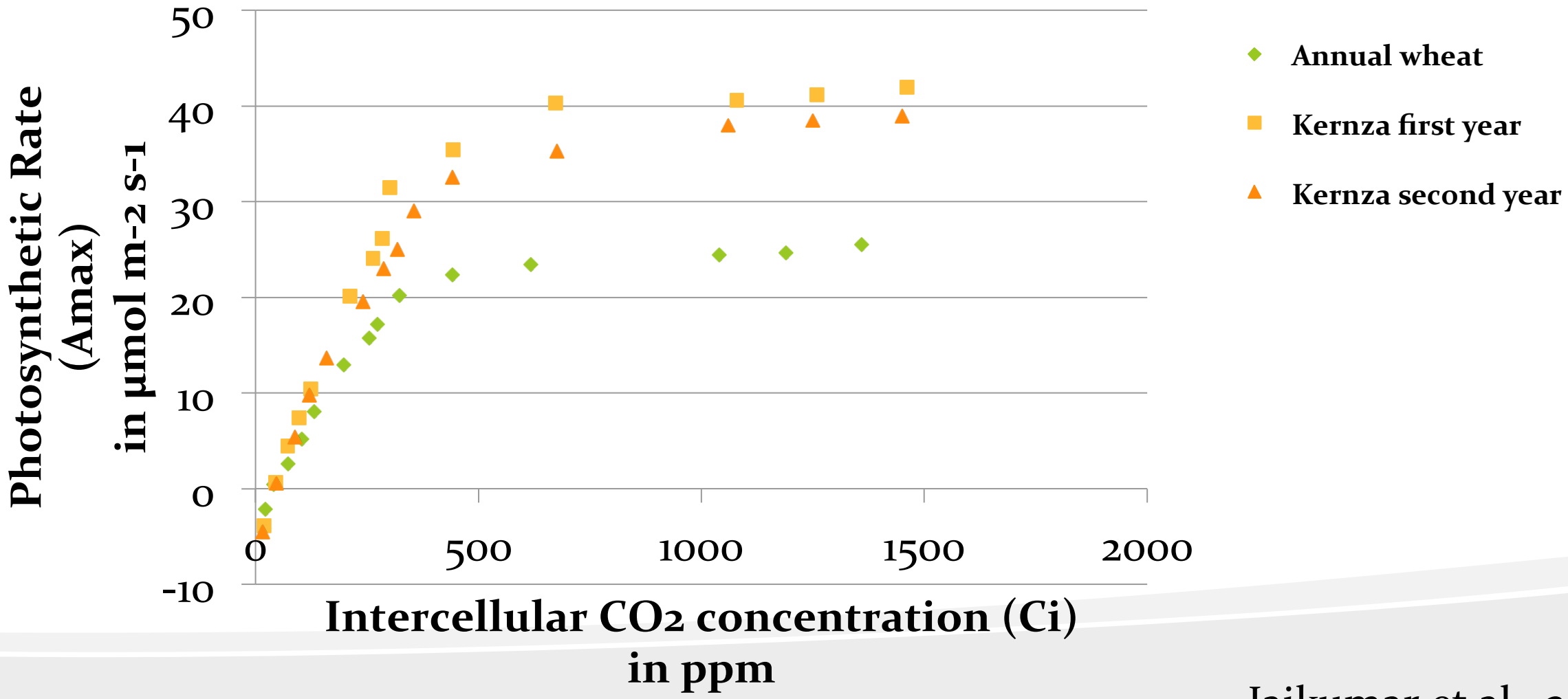
Wheat Line	Milling Quality Index
P10	61.4
P11	68.0
P12	59.4
P14	60.9
Caledonia	76.0
Frankenmuth	68.9
Hopewell	58.2
2005-P15	45.8
2005-P19	50.6

Yield of perennial wheat lines (2009-2010)



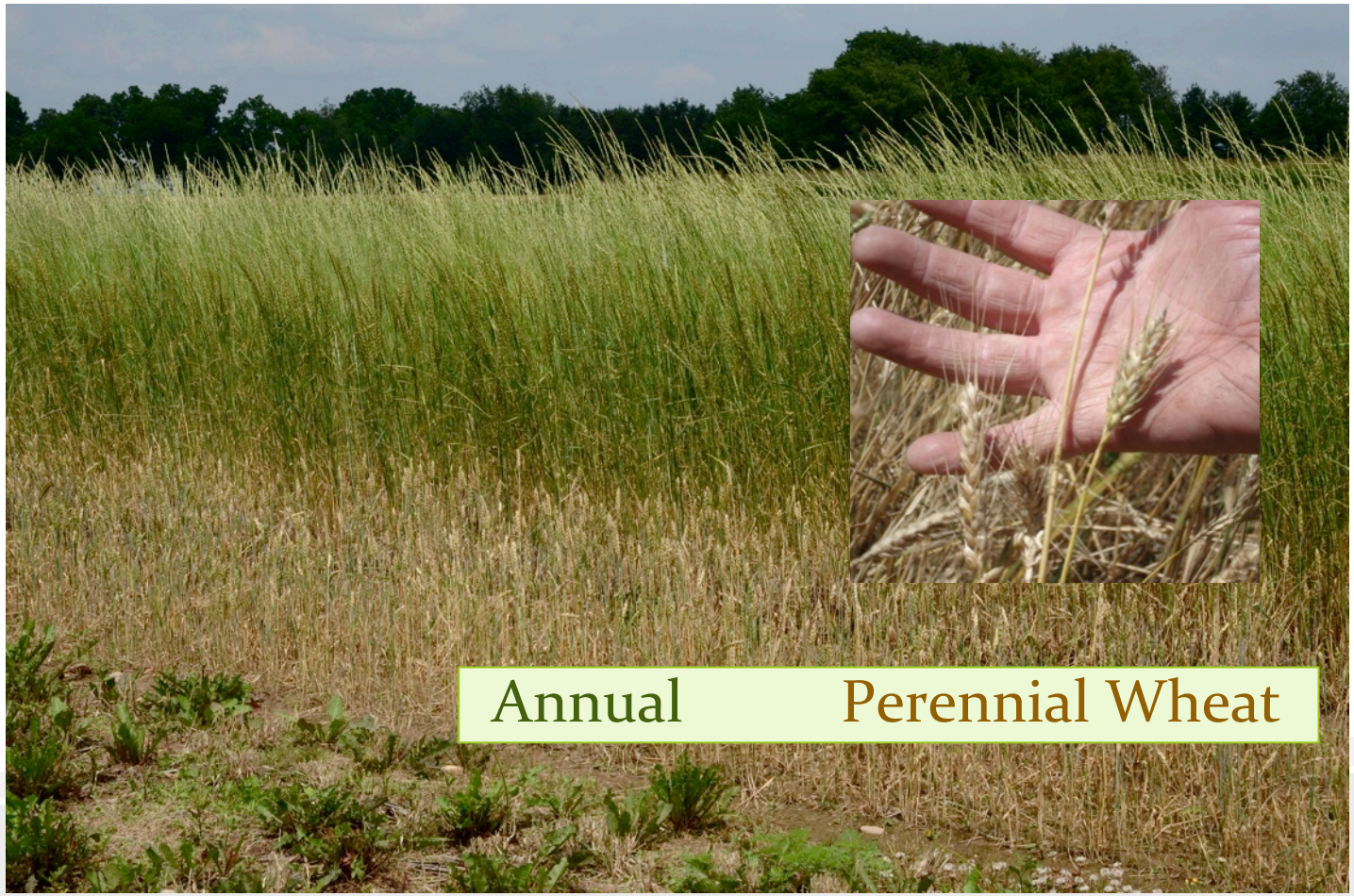
Jaikumar et al., Agronomy J 2012

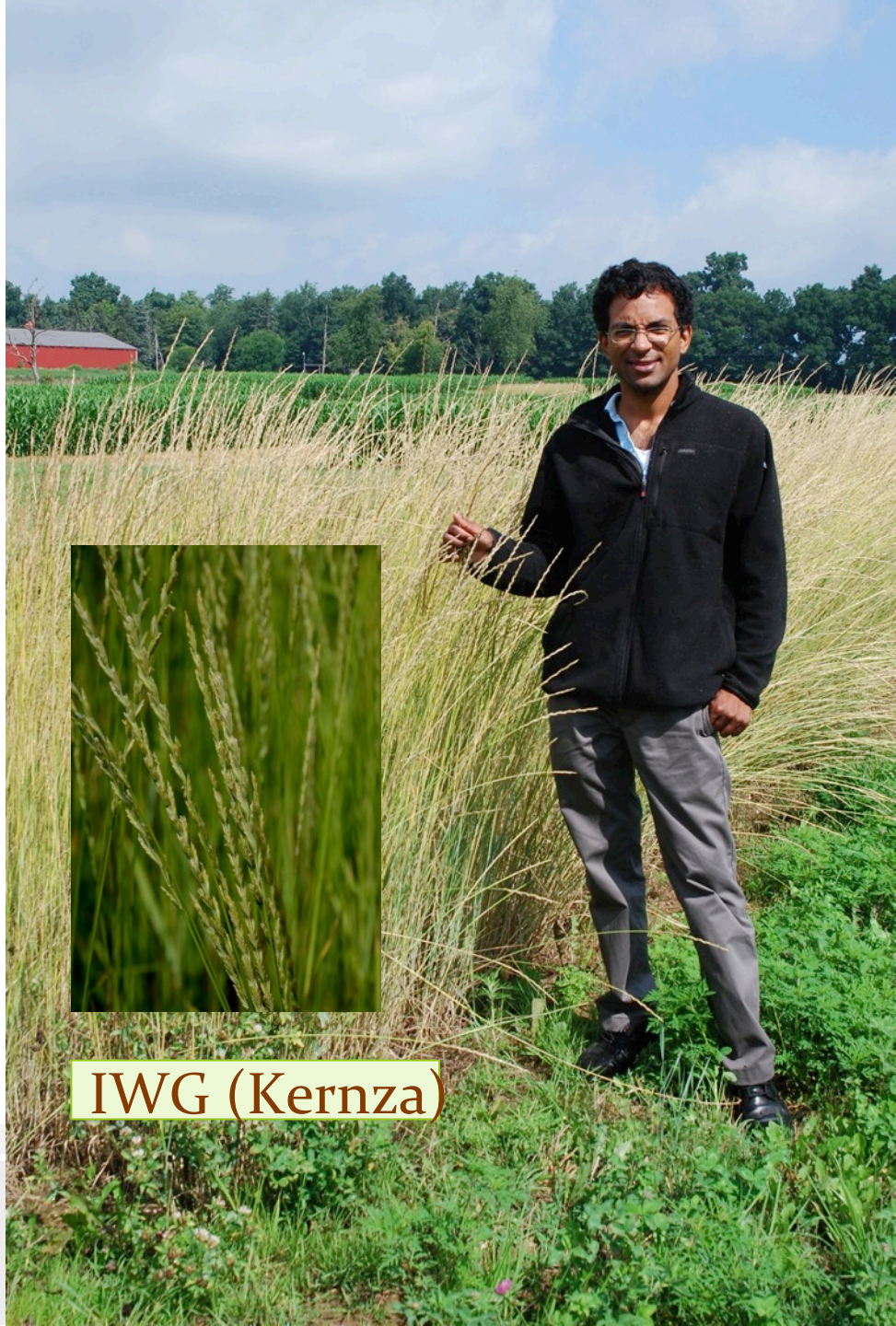
Photosynthetic rate



Jaikumar et al., 2014

Dual use: perennial grain and fodder in Michigan



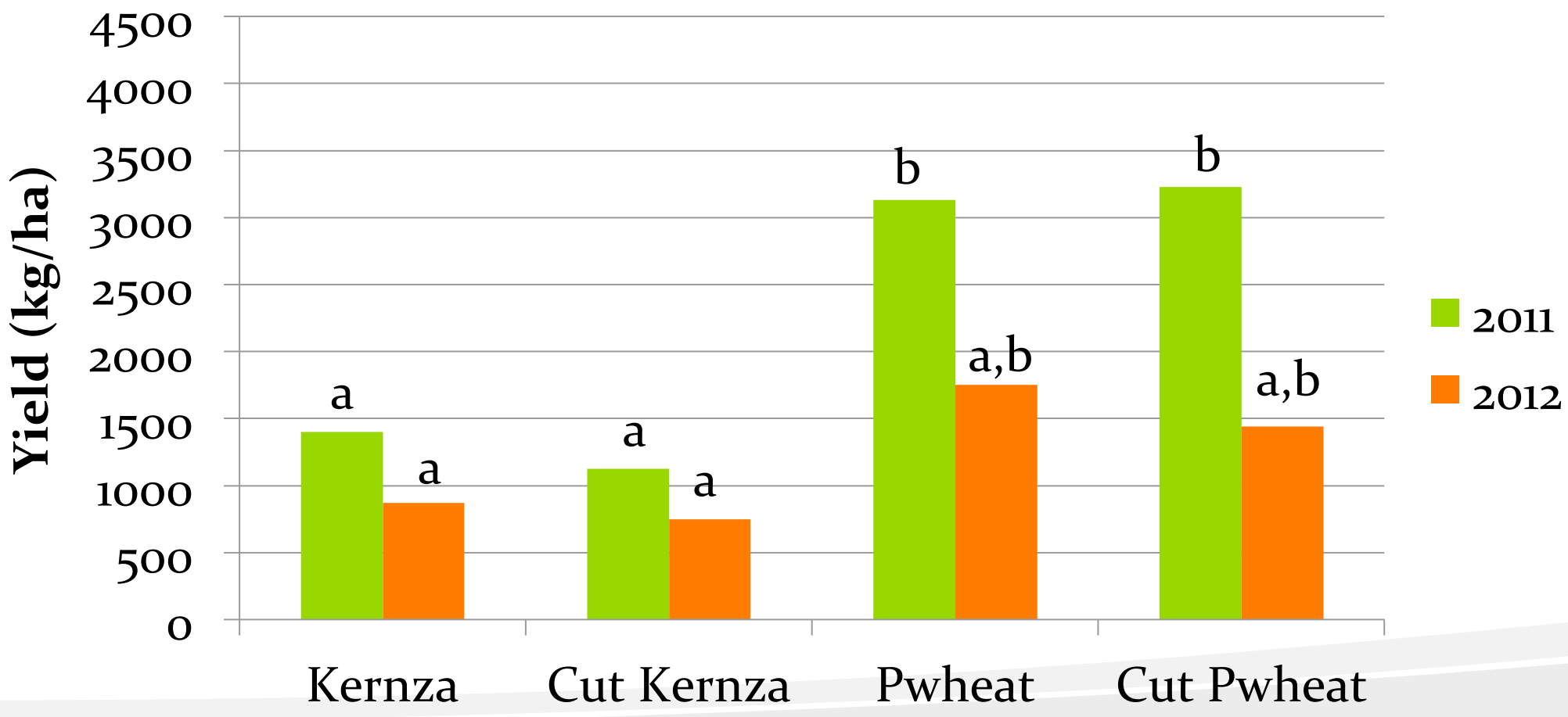


Perennial Wheat and Kernza: Dual use trial

- Experiment design
- RCB, 4 replications
- Factorial: *Species X management*
  - ***Species:*** **Perennial wheat** (2005 WSU lines, S. Jones and **Kernza** (2010 TLI, L. Dehaan)
  - ***Management:*** **Not Cut vs. Cut** for spring forage

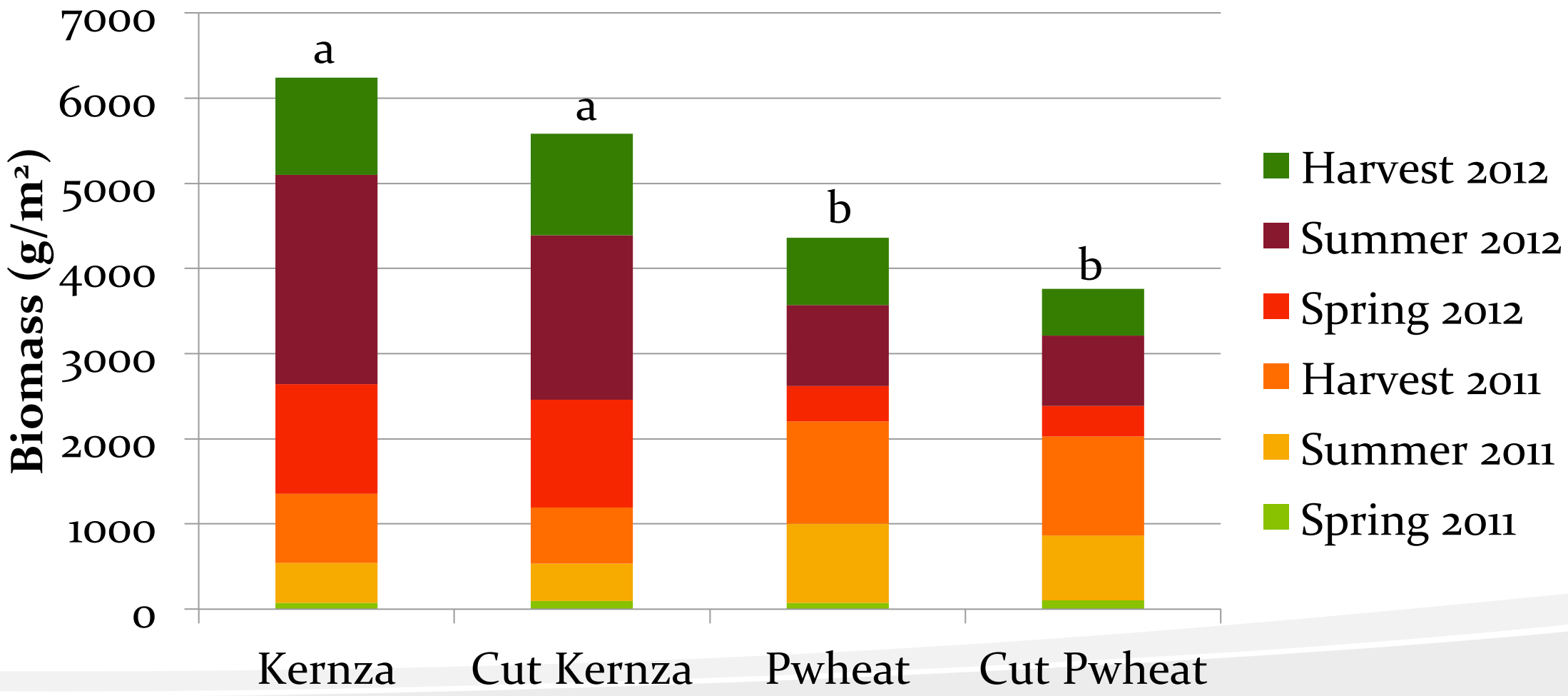
MS Thesis S. Tinsley, 2012

Grain Yield (2011-2012)



Kernza lines from Lee DeHaan TLI; Pwheat lines from Steve Jones WSU; MS Thesis S. Tinsley, 2012

Cumulative Fodder Biomass (2011-2012)



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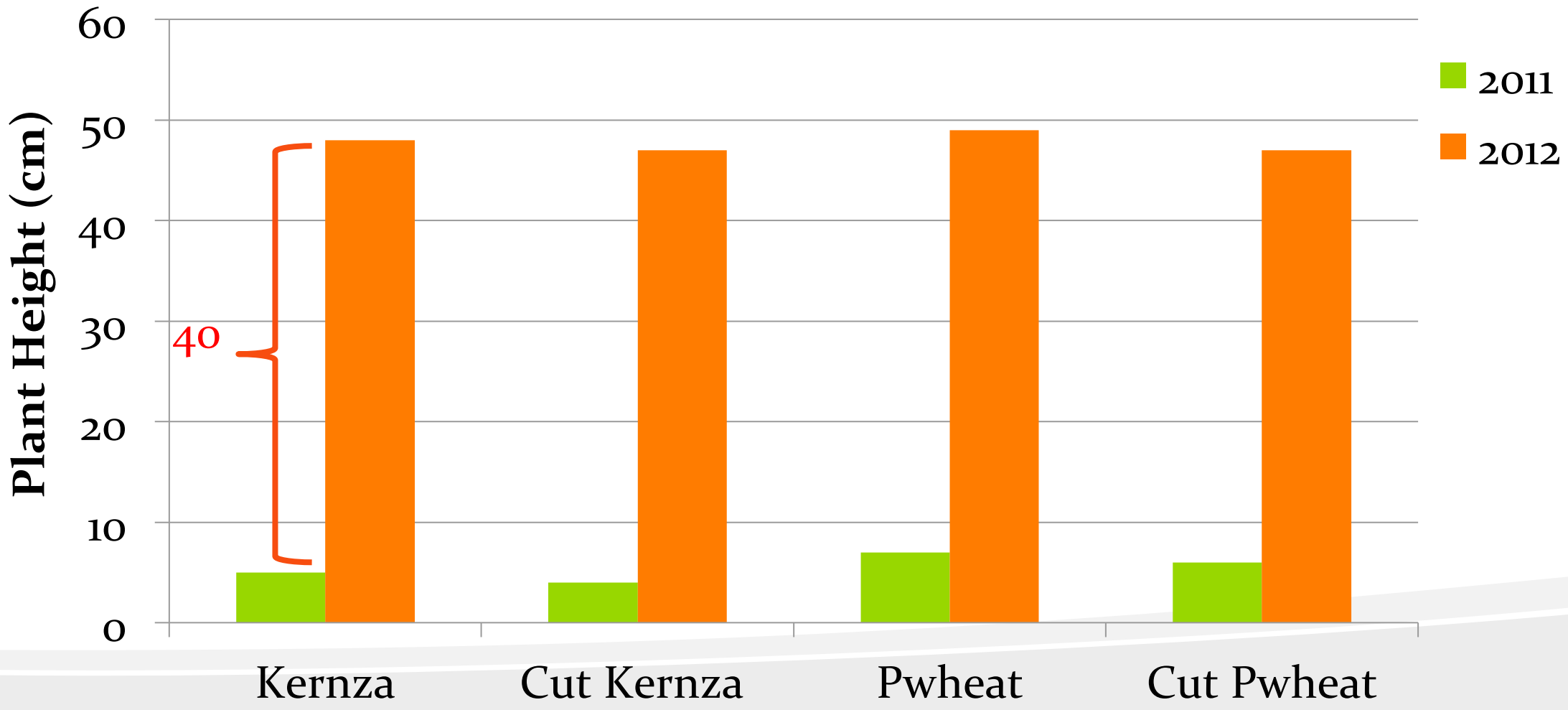
Vegetative regrowth mid-April



Kernza lines from Lee DeHaan TLI; Pwheat lines from Steve Jones WSU; MS Thesis S. Tinsley, 2012

Annual vs. Perennial Grains for Ecosystem services

Crossed with Management: High and Medium N Fertilizer, Organic

Nitrate leaching

Total Nitrate Leached by Year
(kg NO_3-N ha^{-1})

		2010	2011
High N	Annual	24.3	69.8
	Perennial	17.7	9.9
Med N	Annual	9.8	27.5
	Perennial	12.7	0.5
Organic	Annual	11.3	17.7
	Perennial	11.6	0.1

Culman et al., 2013

Conclusions

- Perennial wheat and Kernza are superior cover crops (water quality!), but inferior cereals
- Potential is high since grow early in spring, photosynthesize high rate and have deep roots
- Genetic improvement is urgently needed, particularly for regrowth

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Cover
Crops...
Protecting
the Bay
MARYLAND DEPARTMENT OF AGRICULTURE

Cereal rye in corn-soybean rotation

	fall	winter	spring	summer
Year 1	Corn Crop	Oct/Nov Harvest	Rye seeded / grows over winter	May/June Plant
Year 2	Soybean Crop	Oct/Nov Harvest	Rye seeded / grows over winter	May/June Plant

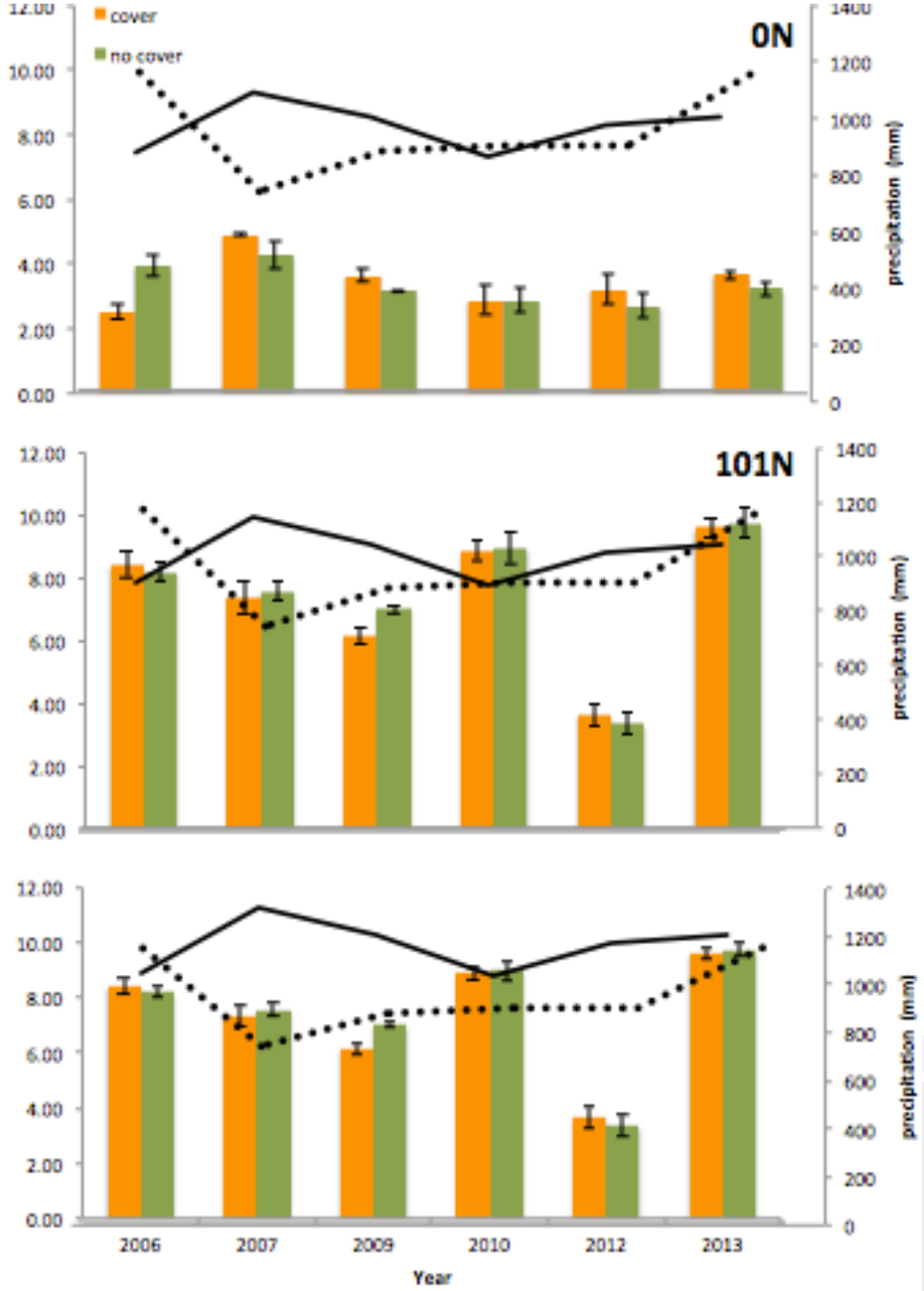
Rye cover crop vs winter fallow in SW Michigan

Field experiment started in fall of 2005 at the Kellogg Biological Station, MSU

Soybean and Corn no-till into rye

Corn Yield: Rye vs fallow

- Cereal rye vs winter fallow in a **corn-corn-soybean rotation**
- **Eight year trial** evaluating yield response to nitrogen fertilizer
- Rye cover crop did not reduce corn yield at 0, 101 or 200 lb of N fertilizer per acre



Snapp and Sowmya, unpublished data 2014

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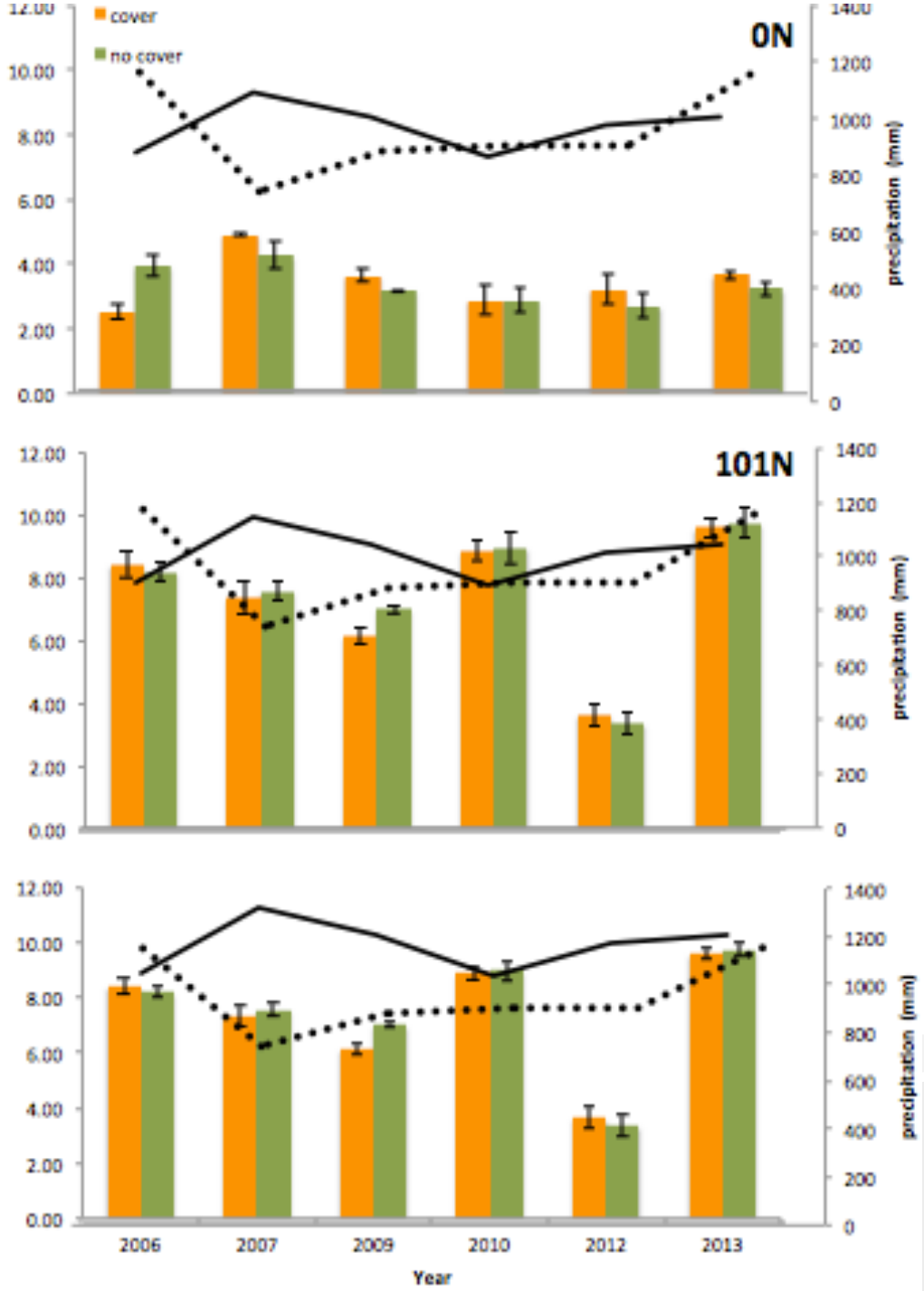
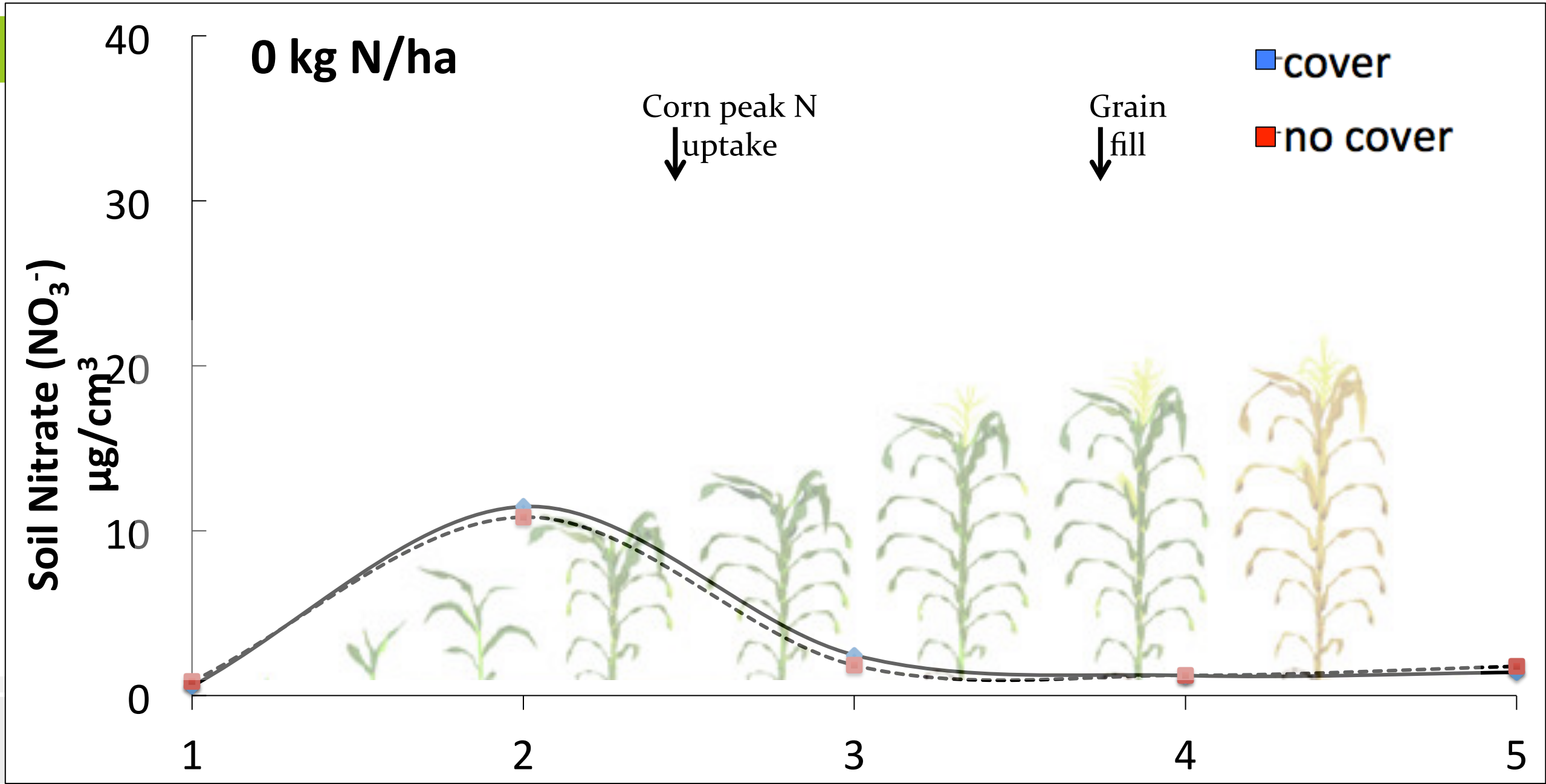


Snapp and Sowmya, unpublished data 2014

Soil nitrate monitored five times over the 2013 season



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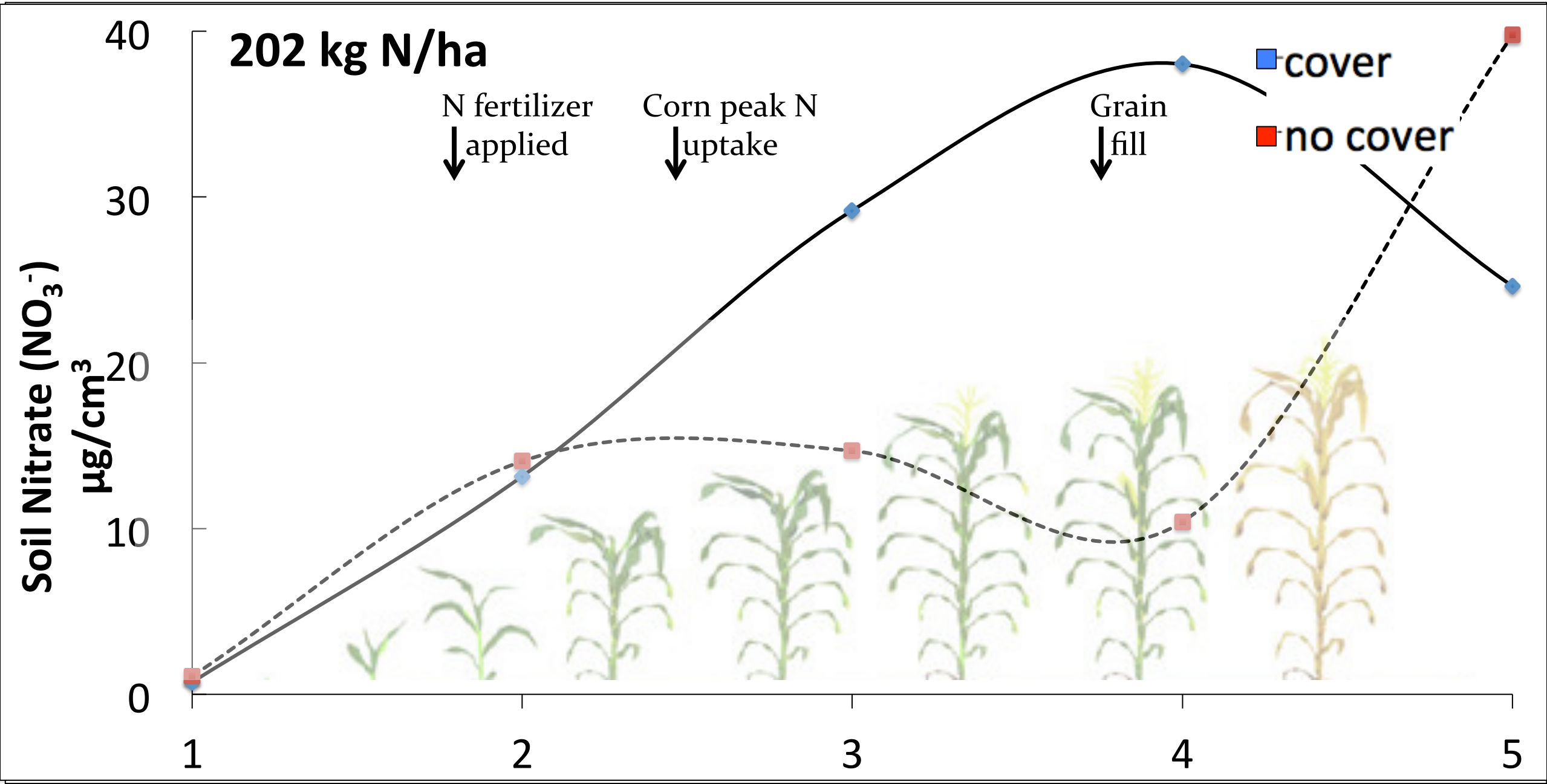


Red clover in wheat production

	fall	winter	spring	summer
Year 1	Sept plant		Wheat Growth Red clover interseeded	July Harvest
Year 2	Red clover		May: plant corn (use less N?)	

Diversify wheat by frost-seeding red clover seed

Red clover frost seeded into wheat (6 up to 12 lb seed/acre)

Also works for white clover - Why these species? What plant traits?

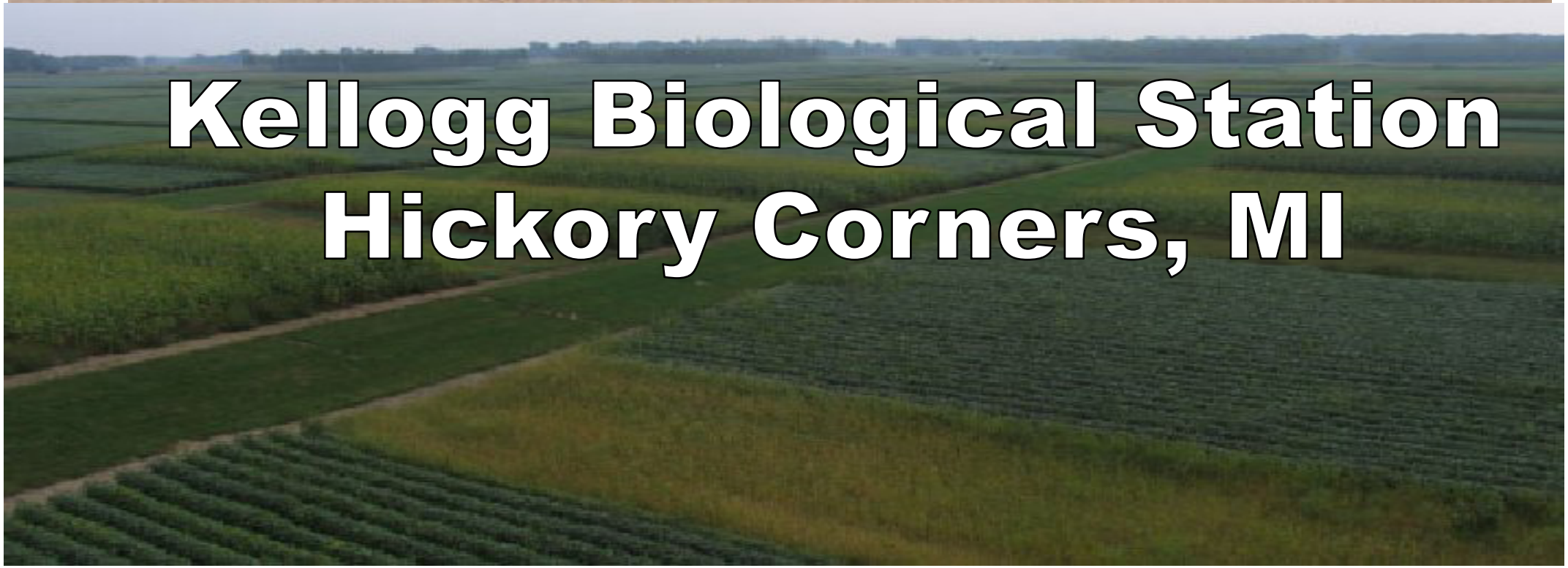
Rye or Red clover seed can be mixed with or seeded after fall manure application

Rector et al., 2009

Fertilizer N-credit for Corn after Red Clover

- Red clover biomass ~ 100 lb of N/acre
- 50% available = 50 lb of N/acre (30 to 100 lb of N/acre)
- Corn crop in a Wheat-Corn rotation N fertilizer recommendation is 100 to 150 lb N/acre
- "Credit" is 50 lb of N, so reduced fertilizer requirement by 33 to 50%

Mutch, et al., 2006



Long-term field crop trials at Michigan State University

Living Field Laboratory (LFL) Trial @ KBS

Main plot: Conventional vs. Organic Management

Sub-plots: Cropping system diversity

C-C and C-C-S-W

C^r-C^r and C^r-S-W^{rc}

r=rye winter cover
rc=red clover cover

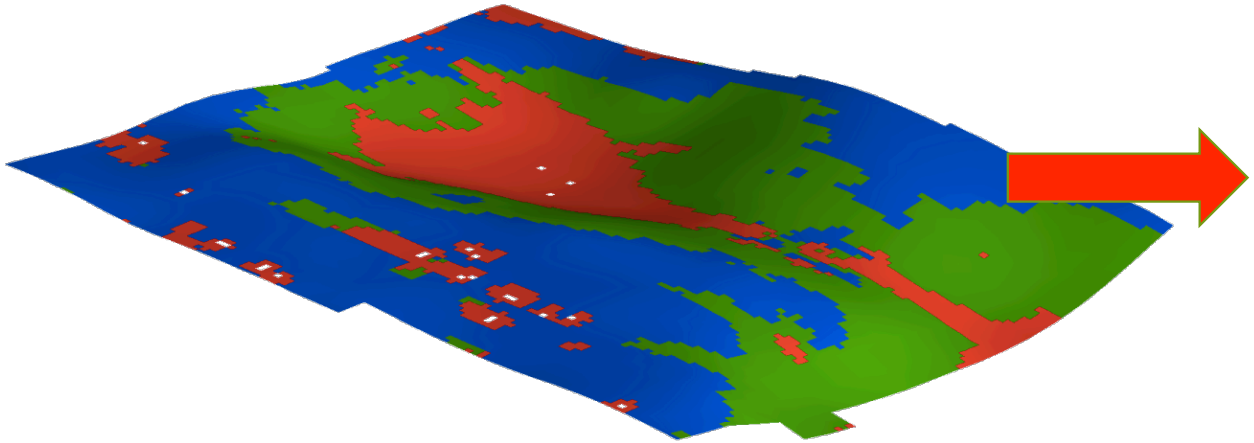
LFL management

- Conventional management: *best practice, adjust N-fertilizer based on N-credit (with and without cover crops)*
- Organic management: *best practice, carbon-nitrogen sources (compost, covers), disturbance for weed control (with and without cover crops)*

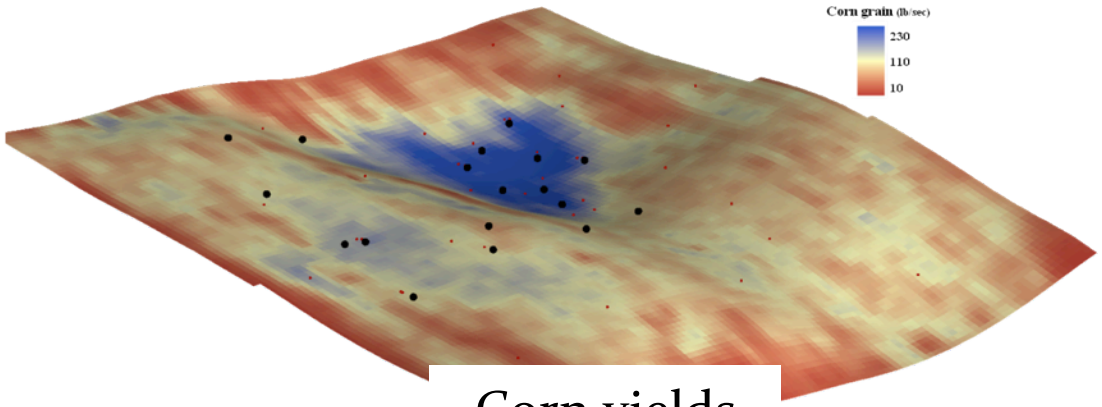
Red clover cover crop

4 Mg/ha compost

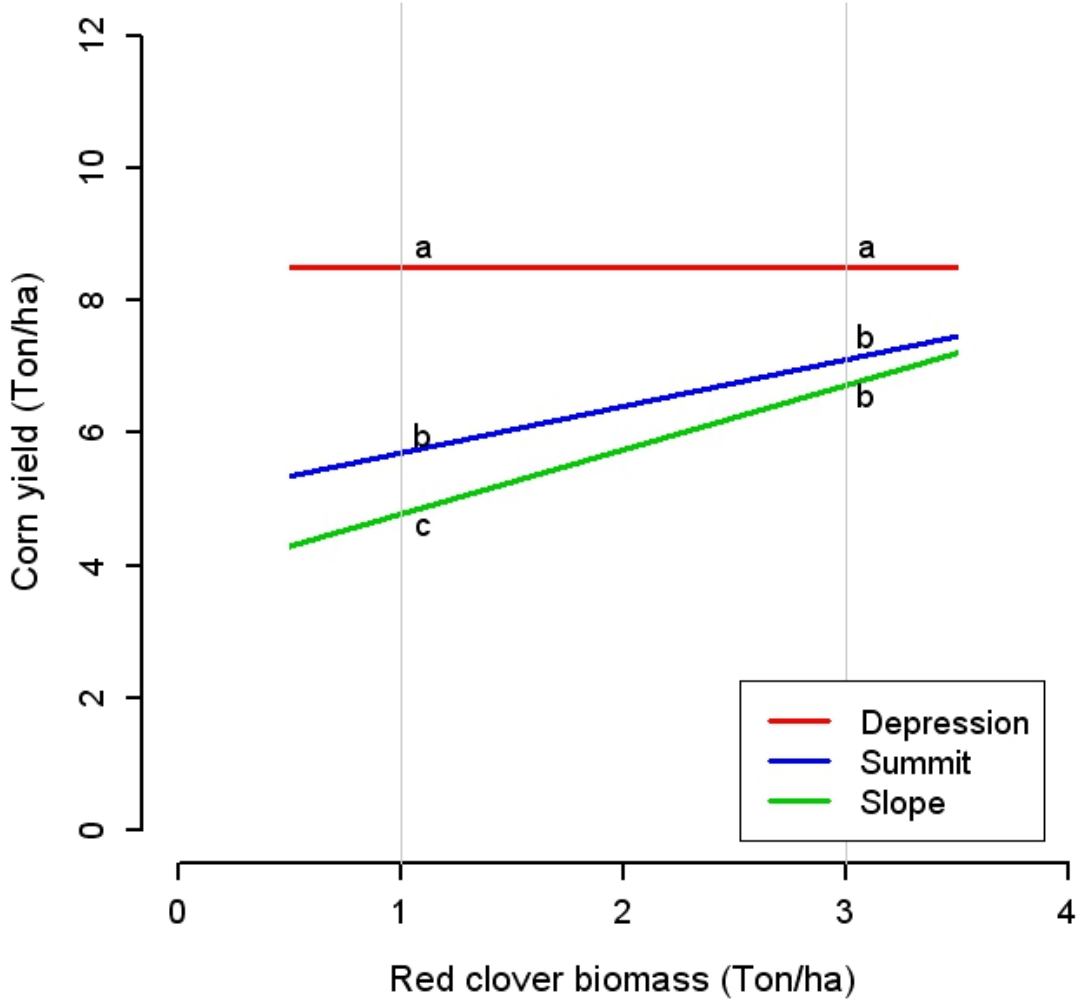
VARIABLE OVER SPACE: Red clover field



Landscape positions



Corn yields



3D map with topographical positions: Summit (Blue), Slope (Green), and Depression (Red); along with the map of corn yields (LEFT). The effect of red clover biomass on corn yields at each topographical position (RIGHT); Munoz, Kravchenko, Snapp et al.

Living Field Laboratory Trial: Cover Crop Nitrogen Credit

		2007	2008	
	Int. Fert.	46.3	56.2	**N lb/Acre**
	Compost	50.1	38.4	
	Organic	53.1	46.8	
Red Clover	**Average**	**49.9**	**47.1**	**48.5**
	Int. Fert.	NA	7.1	
	Compost	NA	-7.6	
	Organic	NA	-2.6	
Cereal Rye	**Average**	**NA**	**-1.0**	**-1.0**

Gentry & Snapp, 2009

Cover Crops Build More than Nitrogen

Extension Bulletin E-3137 • New • January 2011

Advanced Soil Organic Matter Management

MICHIGAN STATE UNIVERSITY | Extension

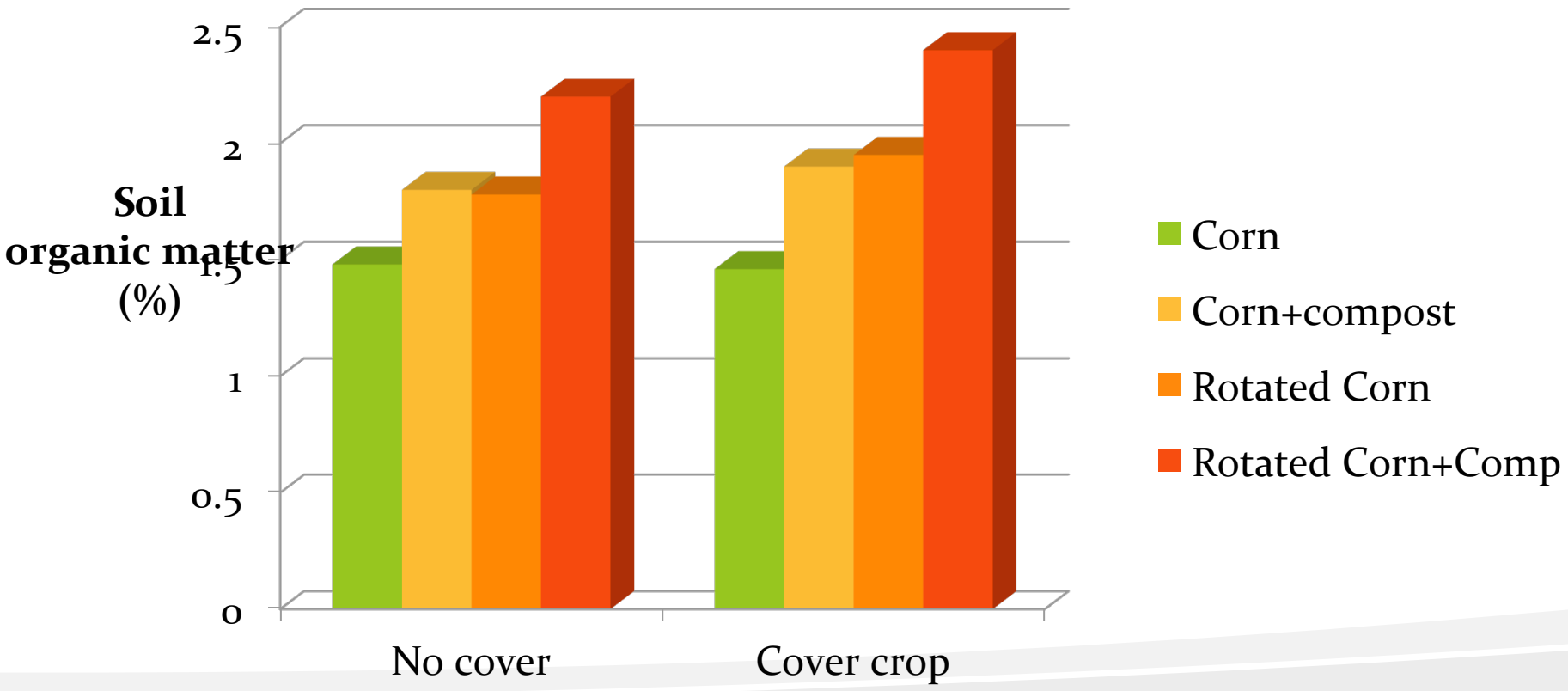
Managing Soils

Soil organic matter (SOM) is the foundation for productive soil. It promotes healthy crops, supplies resources for microbes and other soil organisms, and regulates the supply of water, air and nutrients to plants. SOM can deliver over half of the nitrogen and a quarter of the

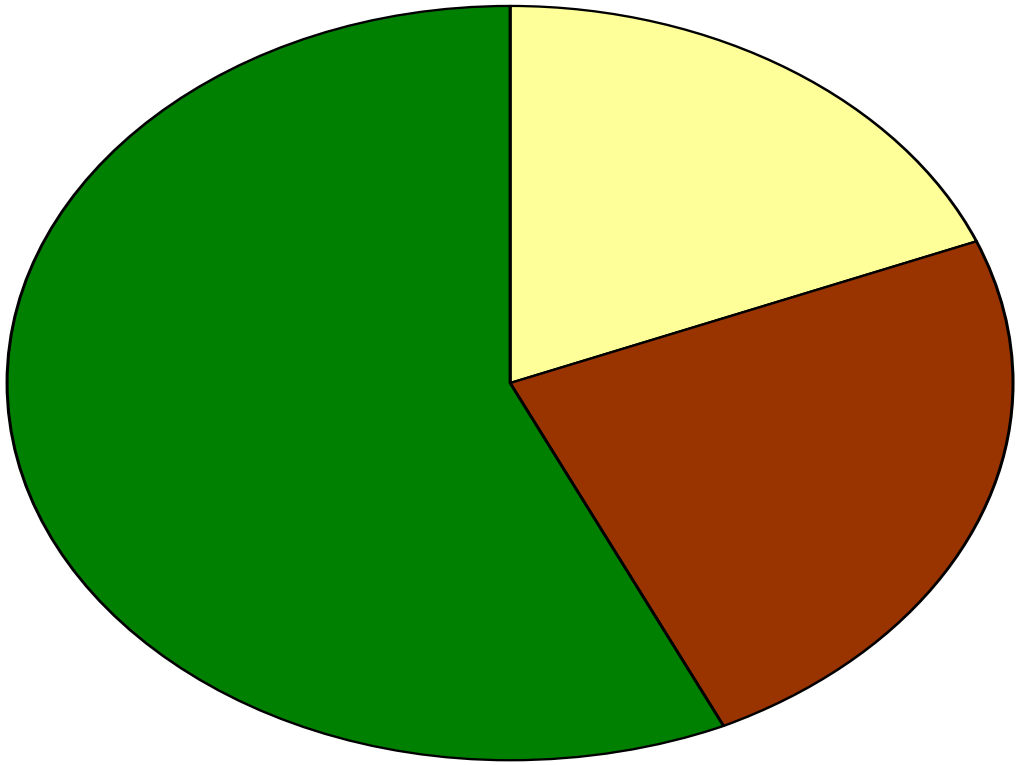
Practices that influence SOM include crop rotation, tillage, residue management, cover crops and targeted use of manure or compost (see Fig. 1). A wide range of management tools exist to reduce soil disturbance and promote living plant cover, both of which conserve SOM and protect against erosion.

Soils with sufficient SOM typically have an increased

Soil organic matter in Living Field Lab (LFL) Trial



Soil Organic Matter Pools



- ACTIVE: Recent OM inputs and soil organisms
- SLOW: Organic compounds derived from active pool, protected
- STABLE: Physically protected humus, extremely recalcitrant

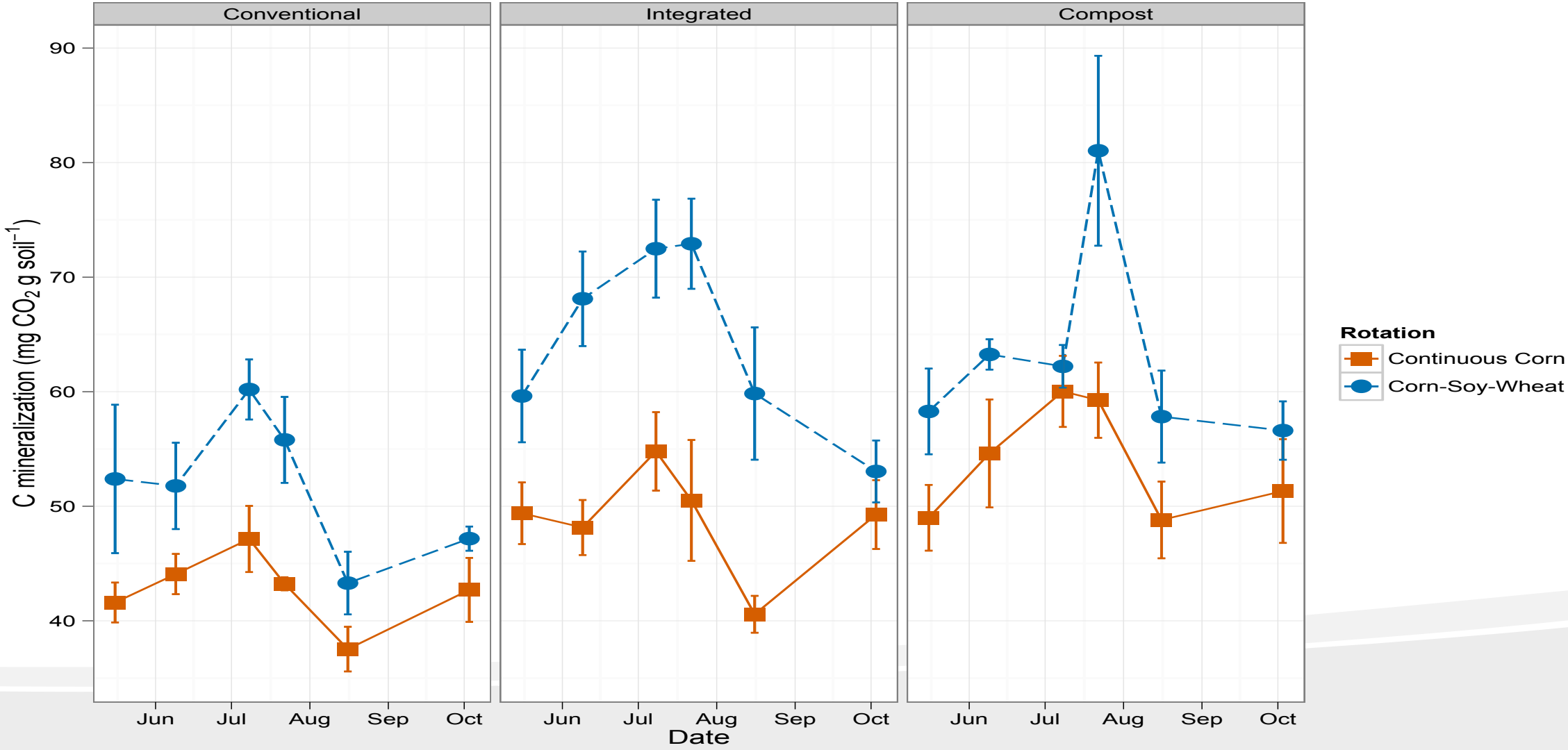
Active Carbon: mineralization test

Soil samples are incubated in a jar and the carbon dioxide that is mineralized is measured, this provides a measure of soil activity (respiration of carbon dioxide)

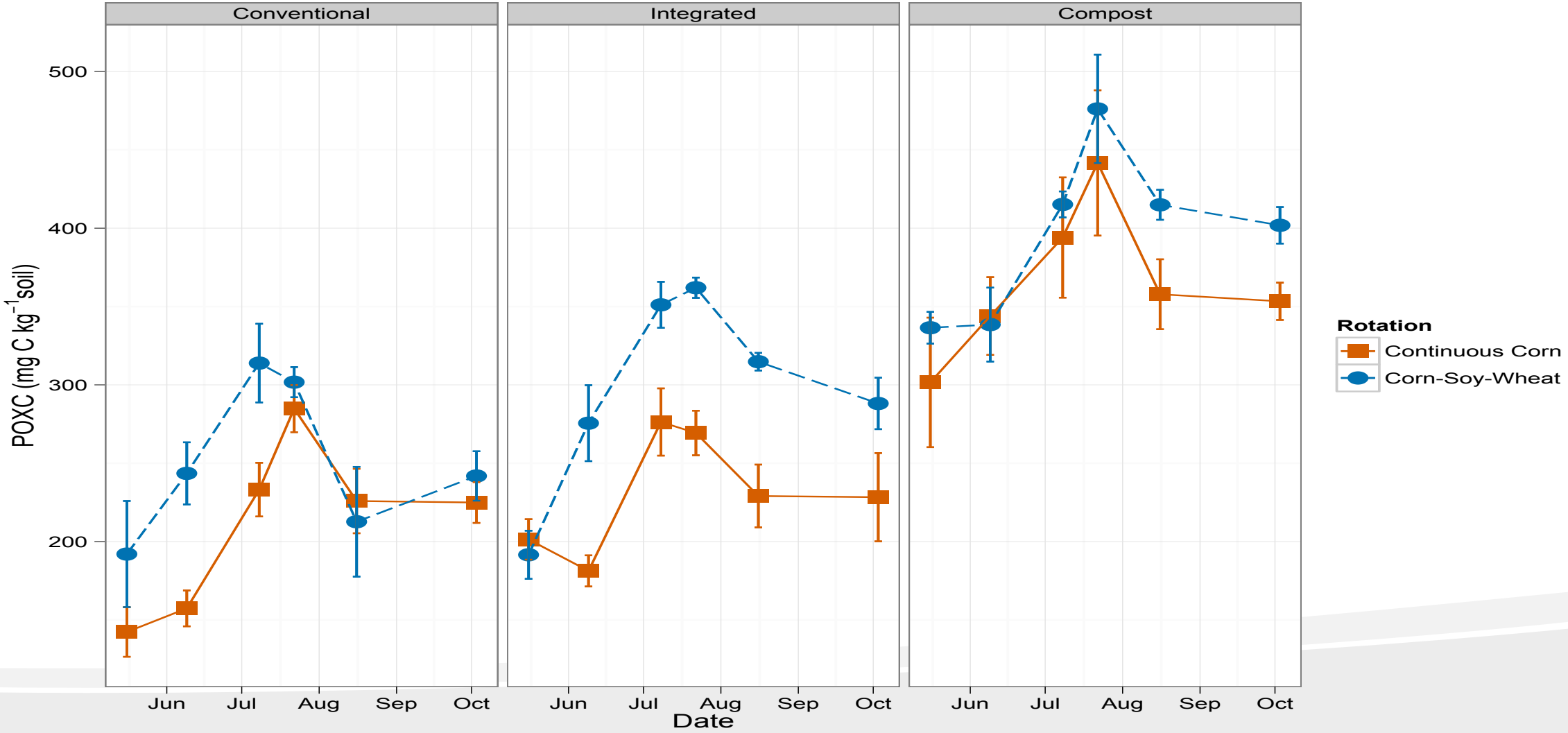
Active Carbon POXC test

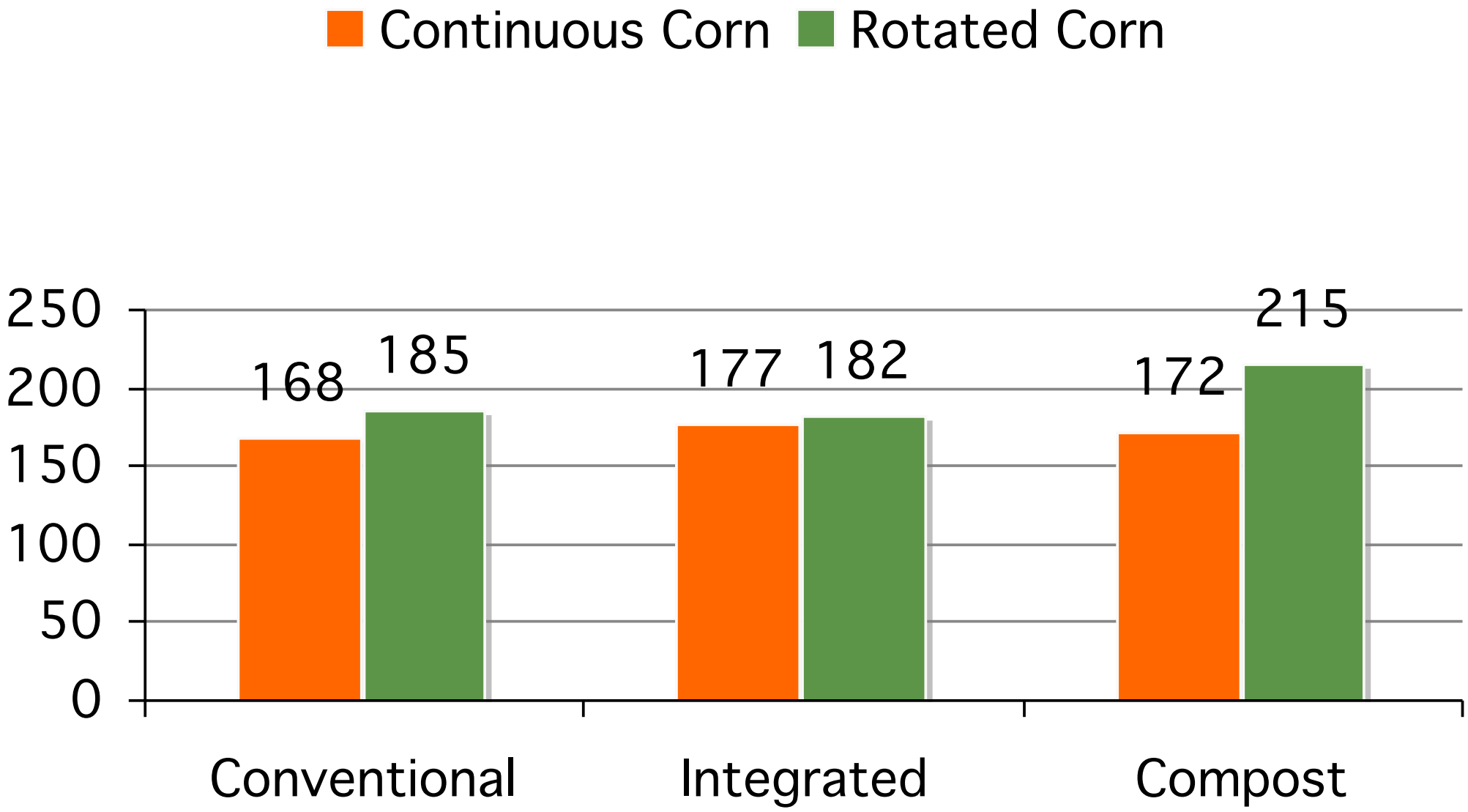
The test tubes shown here are laboratory standards for the POXC measurement, showing the range of values possible with permanganate oxidizable carbon (POXC). The lighter color is where more active carbon was oxidized, from a soil with more active carbon.

Active carbon: CO_2 mineralization in LFL 2011



Active carbon: POXC color in LFL 2011





Corn grain yields (bushels/acre) in LFL 2011

Correlation Coefficients: Corn Yield and Soil Properties

Stage/Measure	Grain Yield	Significance
V5		
POX-C	0.25	NS
C-Mineralization	0.64	$P < 0.001$
NO_3-N	0.41	$P < 0.05$
N-Mineralization	0.21	NS
V10		
POX-C	0.35	NS
C-Mineralization	0.61	$P < 0.001$
NO_3-N	0.57	$P < 0.01$
N-Mineralization	0.53	$P < 0.01$

Culman et al., 2013

Overall take home

- Red clover and cereal rye are proven cover crop options for field crop production

- Cover crop growth is variable over a field and benefits are on **summit** and **slopes**
- Cover crops improve soil **nitrogen** and **carbon** status
  - Red clover provides ~ 50 lb N/acre fertilizer credit
- Soil Nitrate and C-Mineralization are strong indicators of grain yield

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- **Cover crops improve soil nitrogen and carbon status**
  - **Red clover provides ~ 50 lb N/acre fertilizer credit**
- Soil Nitrate and C-Mineralization are good indicators of active soil organic matter and grain yield

Thank YOU!

National Science Foundation
WHERE DISCOVERIES BEGIN

THE LAND INSTITUTE

MICHIGAN STATE UNIVERSITY Founded 1855

KBS LTER
Kellogg Biological Station
Long-term Ecological Research

USDA ORGANIC

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Questions?

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