Benefits of Multi-Crop Rotation Systems

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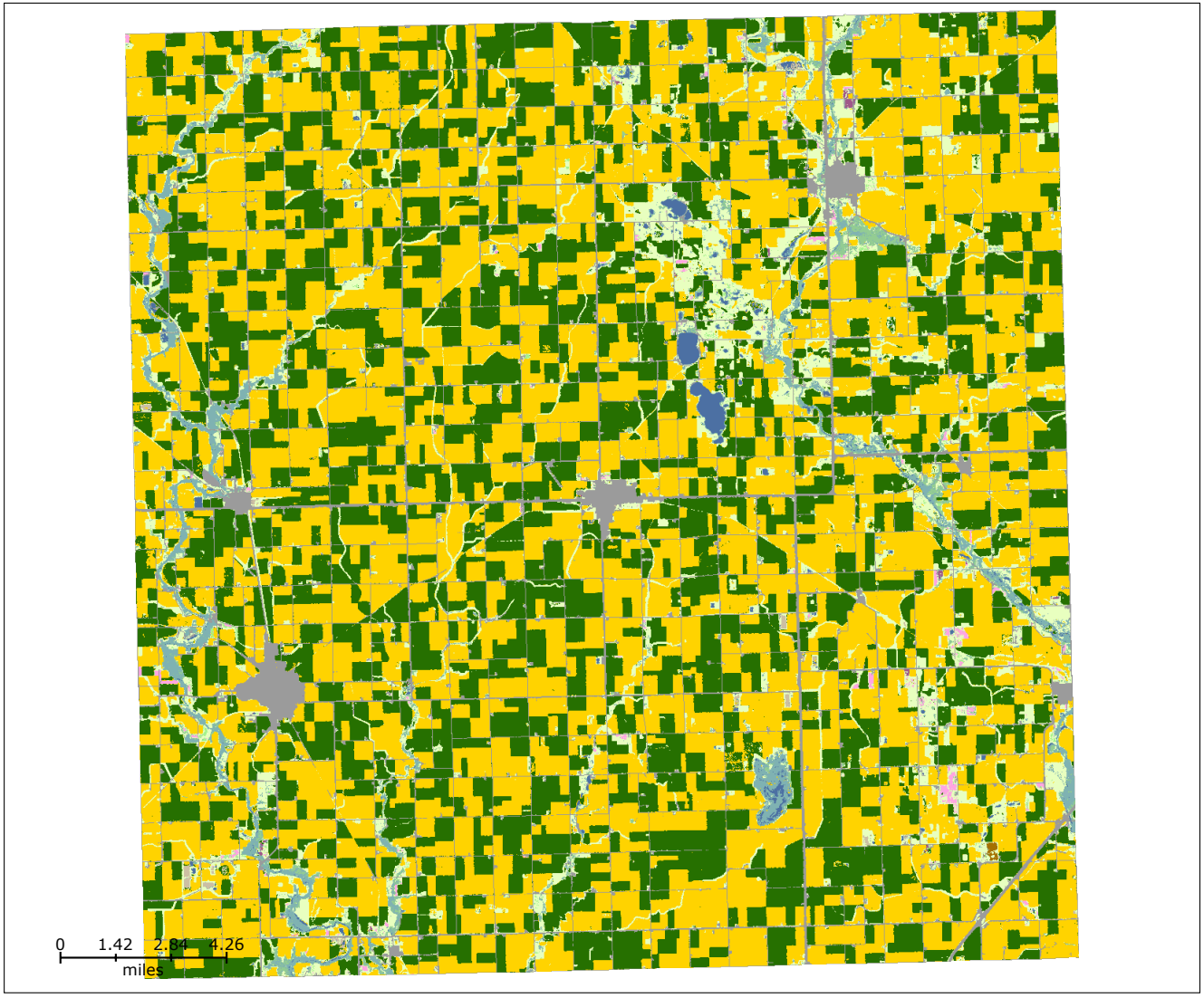
Iowa, 2014:

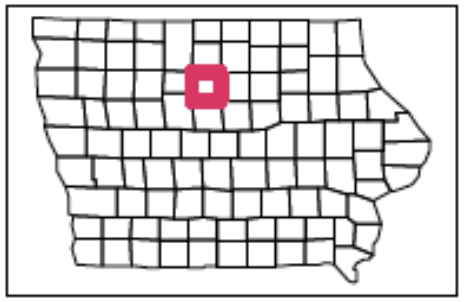
2.4 billion bushels of corn harvested
506 million bushels of soybean harvested
2.3 million cattle, 43.7 million hogs & pigs, 16.4 billion eggs marketed
3.9 billion gallons of ethanol produced
$30.8 billion of farm income from crops and livestock

http://www.nass.usda.gov/Statistics_by_State/Iowa/Publications/Annual_Statistical_Bulletin/2015/IA%20Bulletin%202015.pdf
http://iowarfa.org/resource-center/statistics/

A SIMPLIFIED, HOMOGENEOUS LANDSCAPE

Corn and soybean in Iowa: 63% of total land area, 82% of cropland



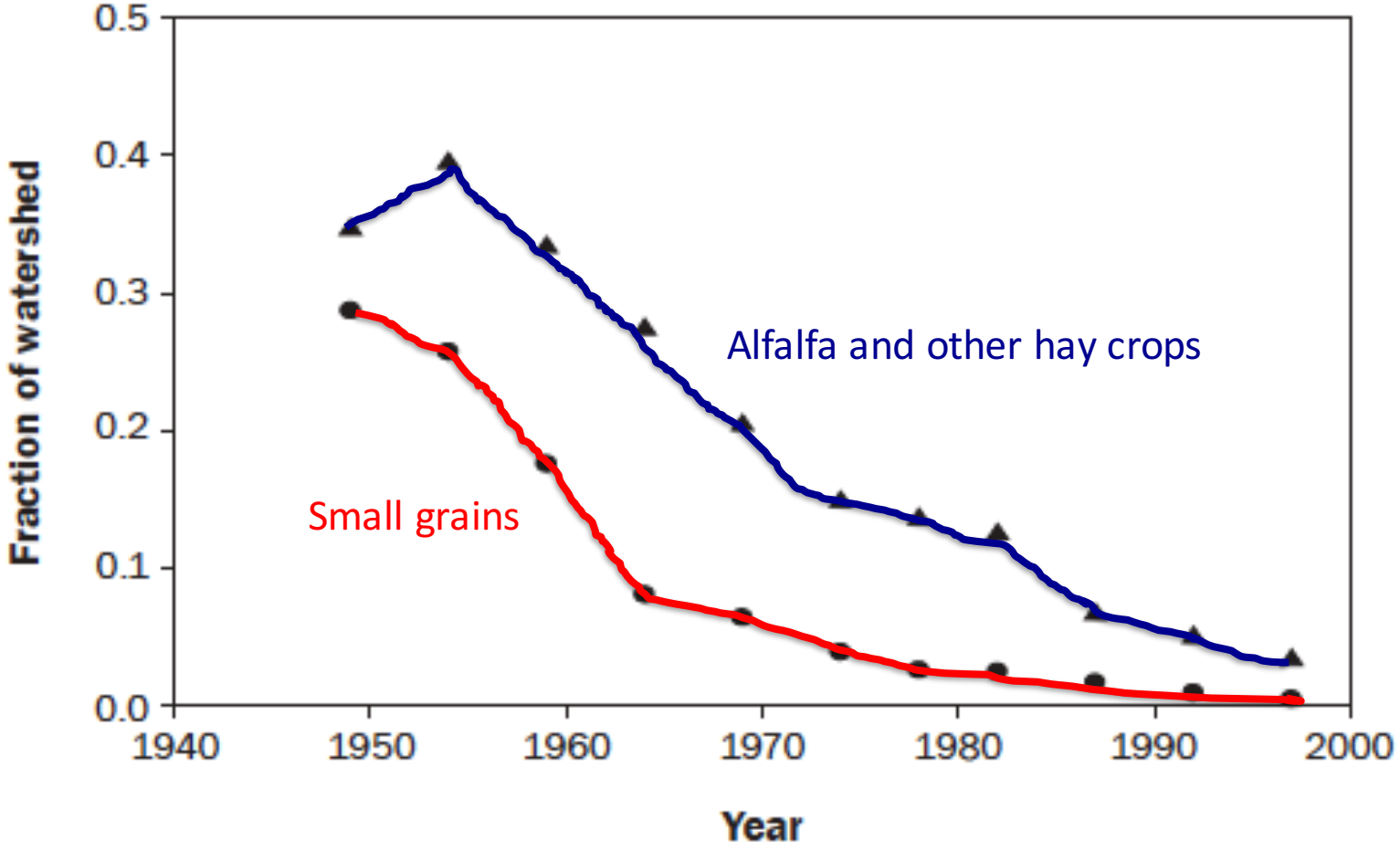


Wright County, 2011
583 sq. miles
(1,509 sq. km.)

Yellow = corn
Green = soybean

USDA-NASS Cropland Data Layer

Large reduction in area planted to small grains and alfalfa and hay crops within the Raccoon River Basin from 1949 through 1997.



Hatfield et al., 2009, JSWC

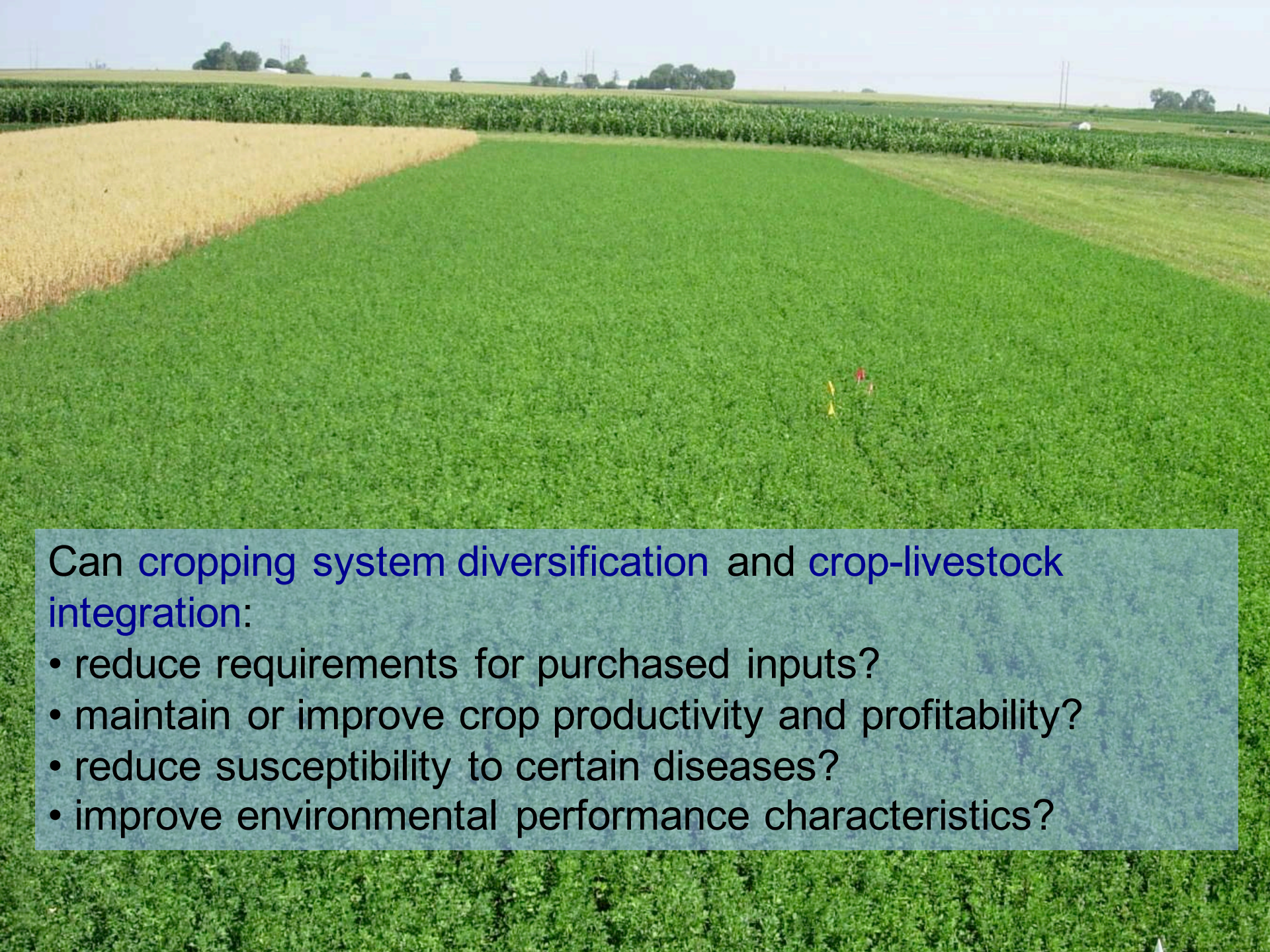
Yield reduction for major crops grown in shortened rotations or monoculture

Crop	Yield decline
Barley (Hordeum vulgare)	11-19%
Corn (Zea mays)	7-36%
Oilseed rape (Brassica napus)	3-25%
Potato (Solanum tuberosum)	10-30%
Rice (aerobic) (Oryza sativa)	19-54%
Soybean (Glycine max)	8-20%
Sugarcane (Saccharum spp.)	3-50%
Sweet potato (Ipomoea batatas)	21-57%
Wheat (Triticum aestivum)	9-20%

Bennett *et al.* (2012) Biological Reviews 87: 52-71

Emerging and continuing challenges related to low diversity

- Soil erosion
- Water quality degradation via nutrient and pesticide emissions
- Herbicide resistant weeds
- New crop diseases
- Economic volatility
- Reductions of wildlife populations, including monarch butterflies, bees and other pollinators



Can cropping system diversification and crop-livestock integration:

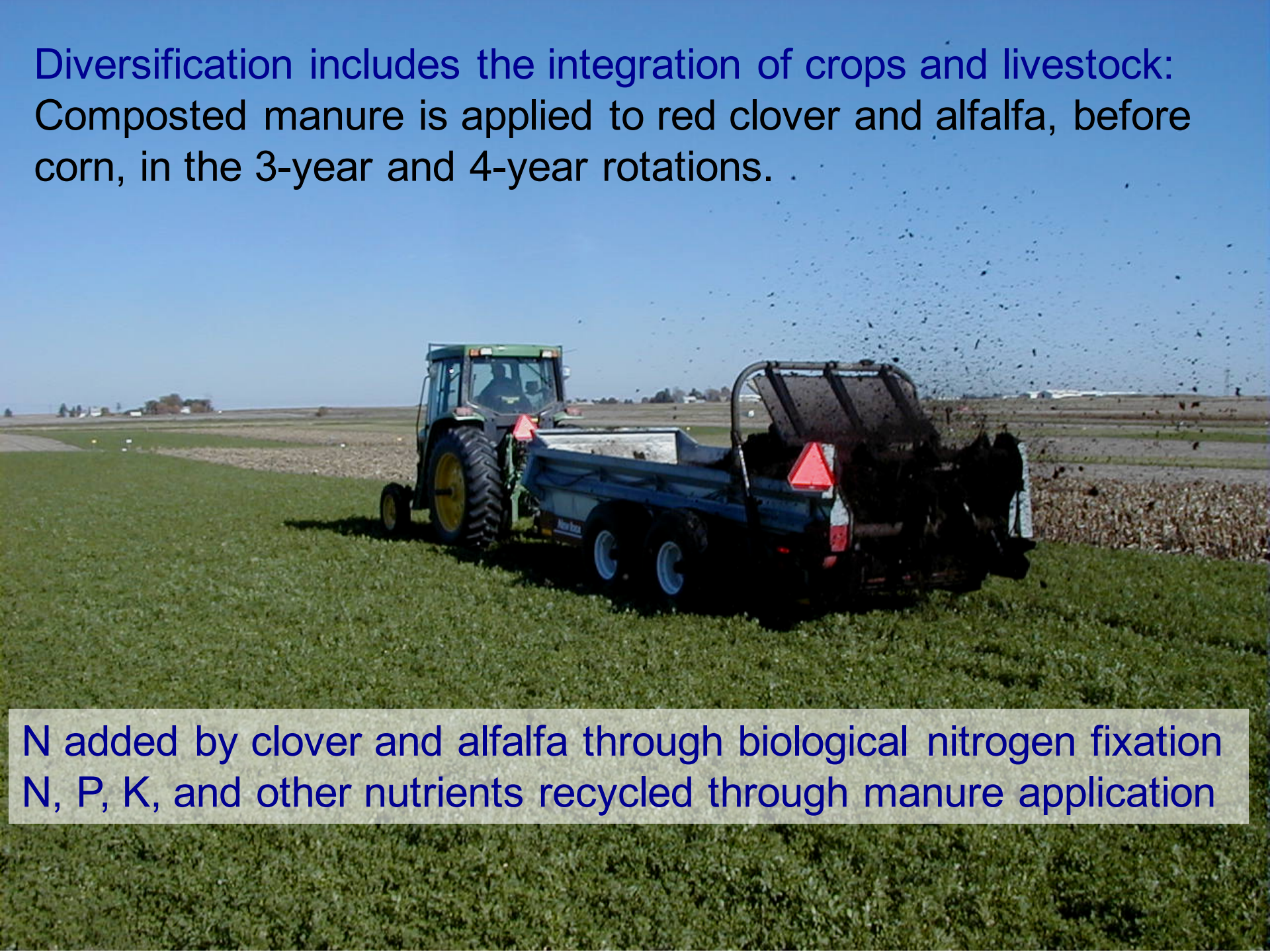
- reduce requirements for purchased inputs?
- maintain or improve crop productivity and profitability?
- reduce susceptibility to certain diseases?
- improve environmental performance characteristics?

Iowa State University Marsden Farm, Boone Co., IA

2-year rotation: corn-soybean (cash grain)
3-year rotation: corn-soybean-oat/red clover (green manure)
4-year rotation: corn-soybean-oat/alfalfa-alfalfa (hay)

36 plots, 60’ x 275’ each, all phases of each rotation present every year
2001 and 2002: base-line sampling / 2003-2005: start-up period
2006-present: mature period

Diversification includes the integration of crops and livestock: Composted manure is applied to red clover and alfalfa, before corn, in the 3-year and 4-year rotations.



N added by clover and alfalfa through biological nitrogen fixation
N, P, K, and other nutrients recycled through manure application

Nitrogen Fertility Management in Contrasting Rotation Systems

Rotation	Corn
2-year	100 lb N/acre applied at planting with additional N side-dressed according to soil test results
3-year and 4-year	(Legume residues + manure) No fertilizer N applied at planting N side-dressed according to test results

Tillage:

In the 3-year and 4-year rotations, red clover and alfalfa are incorporated with a moldboard plow in the fall preceding corn production. Moldboard plowing is not used in the 2-year rotation.

Oat production

Management practices for oat

- Soybean residue disked or field cultivated.
- Ground is then cultipacked.
- Oat (IN09201) sown with JD 1520 drill @ 80 lbs/acre with red clover @ 12 lbs/acre or alfalfa @ 15 lbs/acre.
- Row spacing: 7.5”.
- Average oat density: 22 plants per square foot.
- Direct harvest of grain with a JD 9450 combine.
- Straw raked, baled, and removed.
- Grain stubble mowed 5 to 6 weeks later for weed control.
- September alfalfa hay harvest possible when moisture is sufficient.

Restrictions on Crop Rotation for Various Herbicides

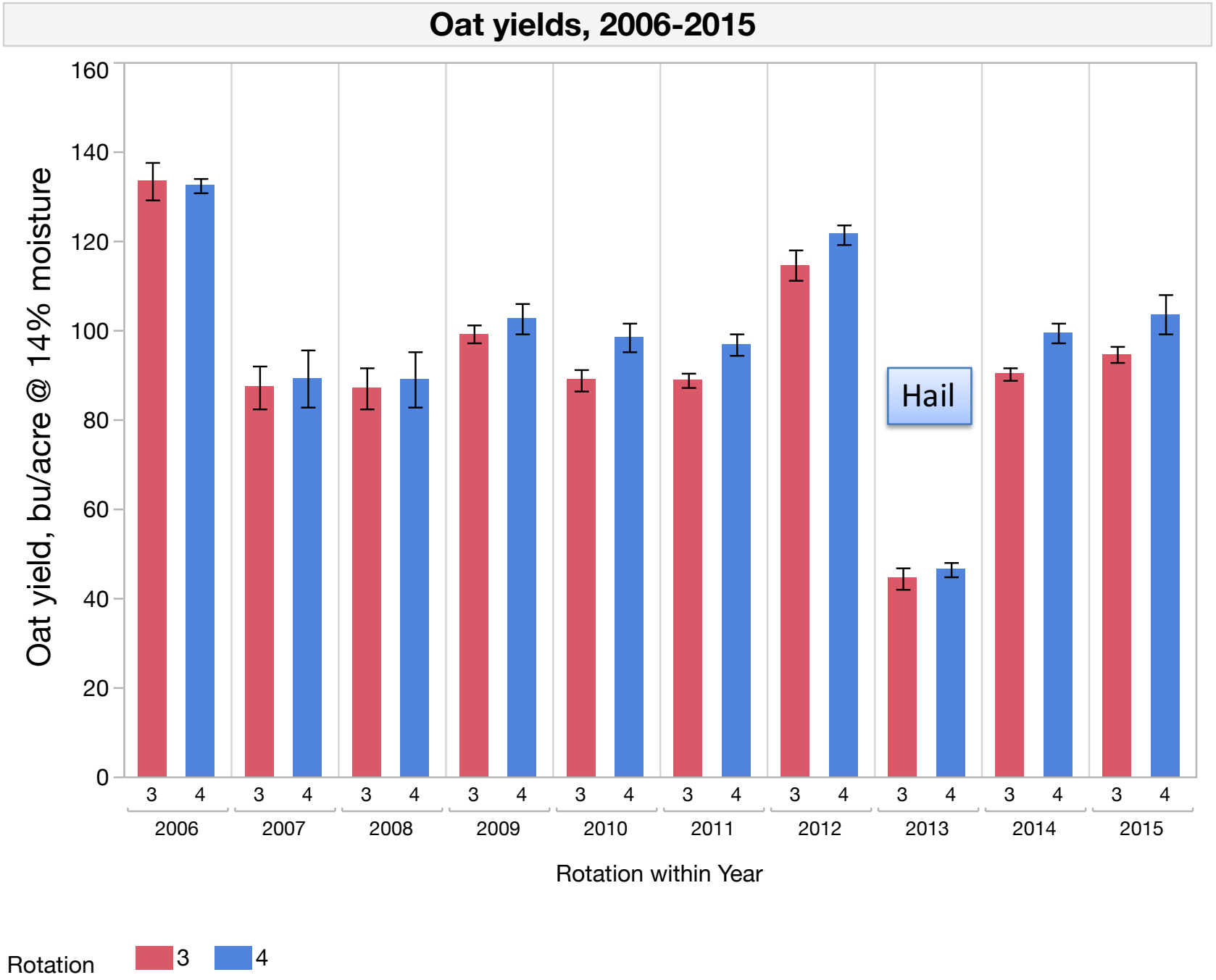
Herbicide: active ingredient and product	Months Before Planting		
	Oat	Alfalfa	Clover
atrazine (many products)	21	21	21
acetochlor (Harness/Surpass/Breakfree)	18	9	9
chloransulam-methyl (FirstRate)	30	9	30
flumioxazin (Valor)	12	12	12
isoxaflutole (Balance Flex)	18	10	18
pyroxasulfone (Zidua)	18	10	18
sulfentrazone (Spartan/Authority)	30	12	18

Source: Weed Control Guide for Ohio, Indiana and Illinois

Mean oat yield, 2006-2015

Rotation system	Yield, bu/acre @ 14% moisture
3-year, oat with red clover	93 ± 3.5
4-year, oat with alfalfa	98 ± 3.6
	p = 0.002

Average test weight: 35 lb/bu
Range: 33 to 38 lb/bu

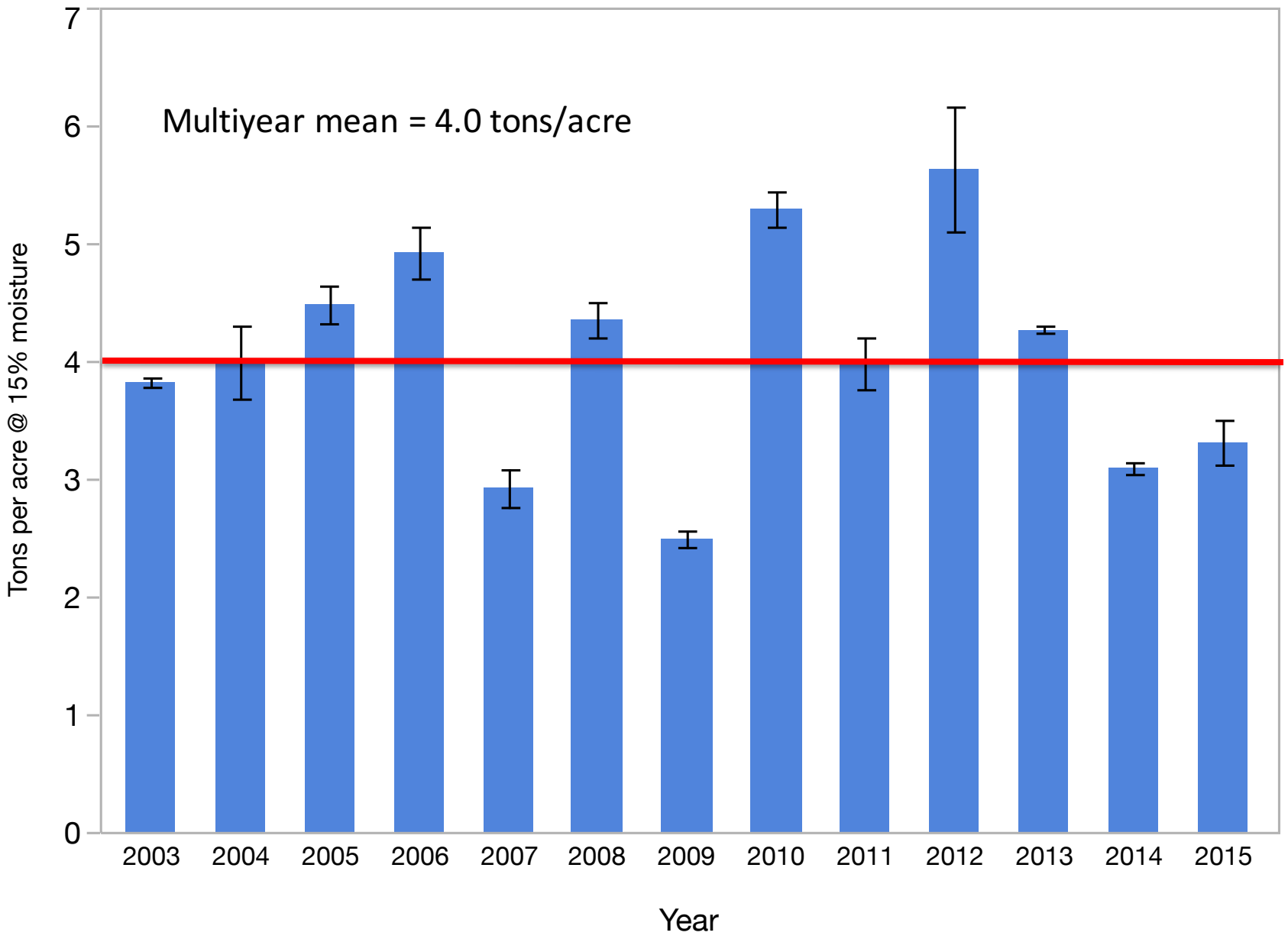

Oat yields, 2006-2015
Oat yield, bu/acre @ 14% moisture
160
140
120
100
80
60
40
20
0
Hail
3 4 3 4 3 4 3 4 3 4 3 4 3 4 3 4 3 4 3 4
2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Rotation within Year
Rotation
3
4

Red clover growing in oat stubble

Seeding-year red clover


Second-year alfalfa

Alfalfa yield, 2003-2015



Average Nitrogen Content of Legumes in October, 2006-2013

	Shoots	Roots (to 12”)	Total
		lb N/acre	
Red clover (1st year)	112	43	155
Alfalfa (2nd year)	47	74	121

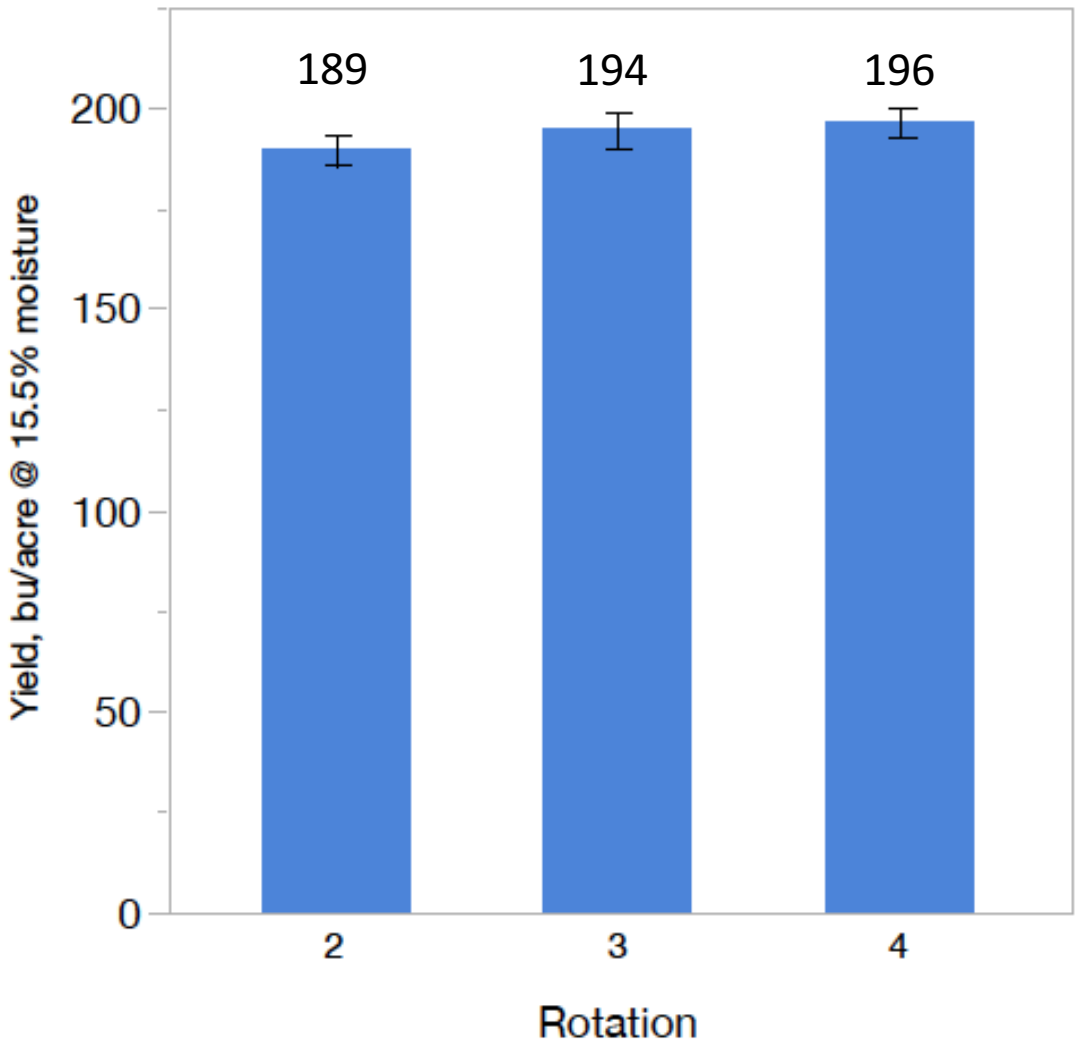
Average N content of composted manure applied at 7 tons/acre: 101 lbs N/acre

Mean annual mineral N fertilizer use, 2006-2015

Rotation	2-year	3-year	4-year
	lb N/acre		
Corn	148	23	21
Soybean	2	2	2
Oat	--	2	2
Alfalfa	--	--	2
Rotation average	75	9	6
Reduction		-88%	-92%


JOHN DEERE

Corn yields, 2008-2015



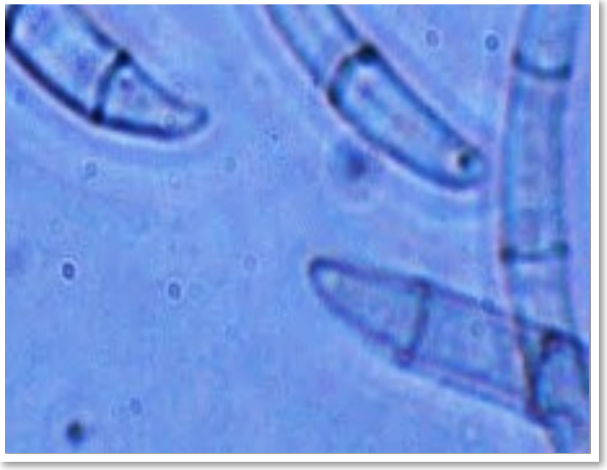
2-yr vs. 3-yr and 4-yr: p=0.02

3-yr vs. 4-yr: p=0.50

Can adding oat and forage legumes to corn- and soybean-based cropping systems reduce problems with plant diseases?

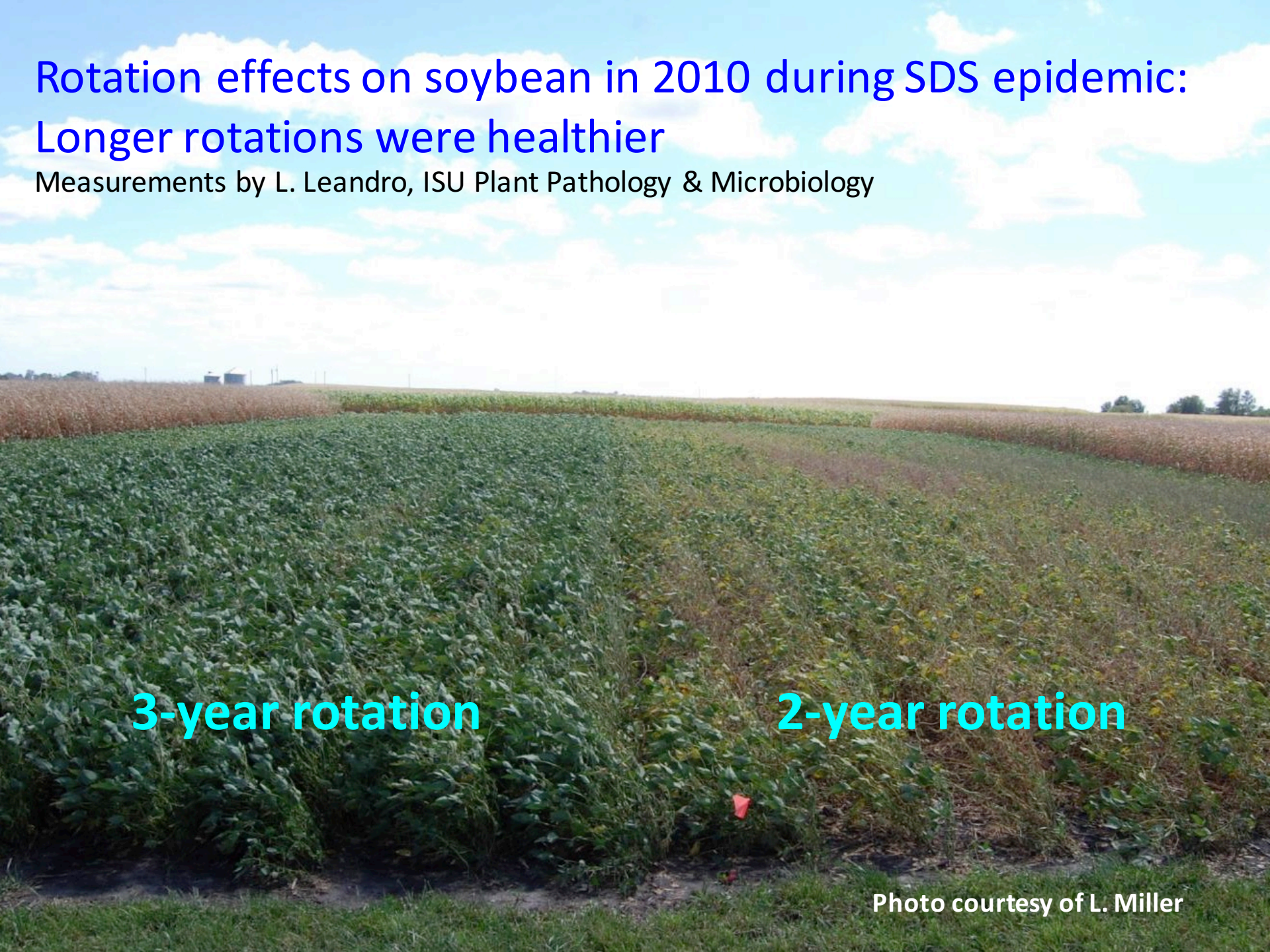
Sudden Death Syndrome

- Caused by a soilborne fungus - *Fusarium virguliforme*
- Root infection causes root rot and poor root vigor
- Leaf symptoms caused by fungal toxins moved from roots to leaves
- Disease favored by cool, wet weather
- Yield losses can be severe



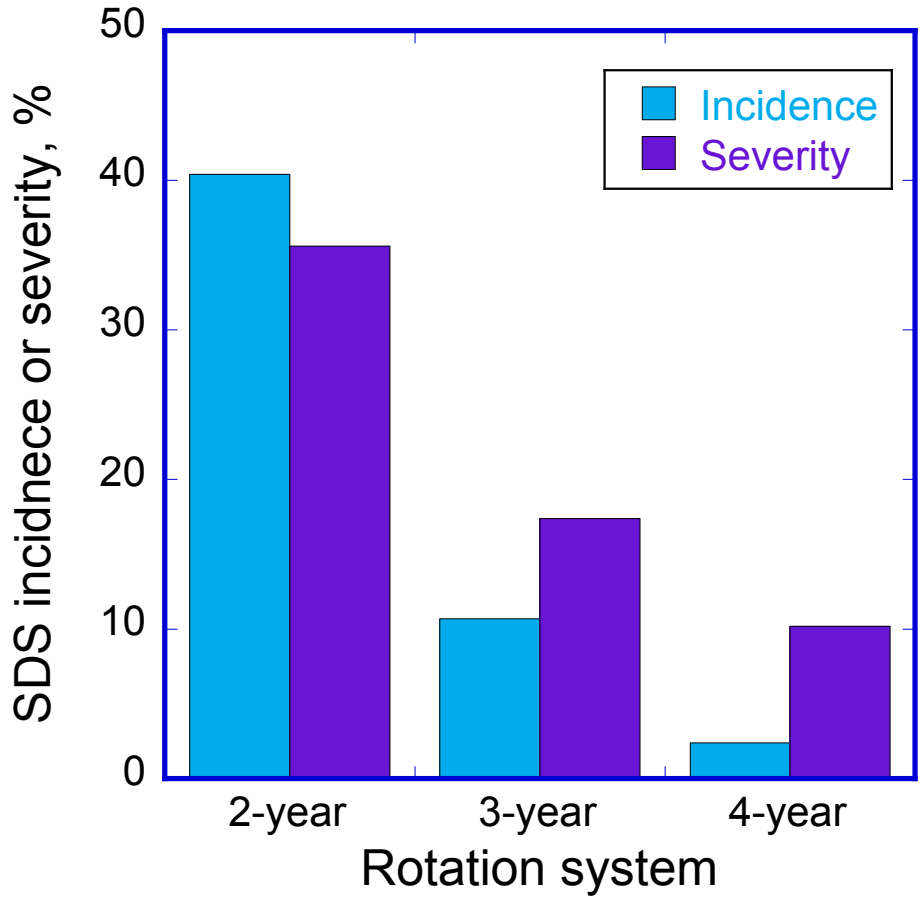
Rotation effects on soybean in 2010 during SDS epidemic: Longer rotations were healthier

Measurements by L. Leandro, ISU Plant Pathology & Microbiology



Mean SDS incidence and severity, 2010-2014, as affected by rotation system

Rotation effects were highly significant (p<0.001)



Source: L. Leandro, ISU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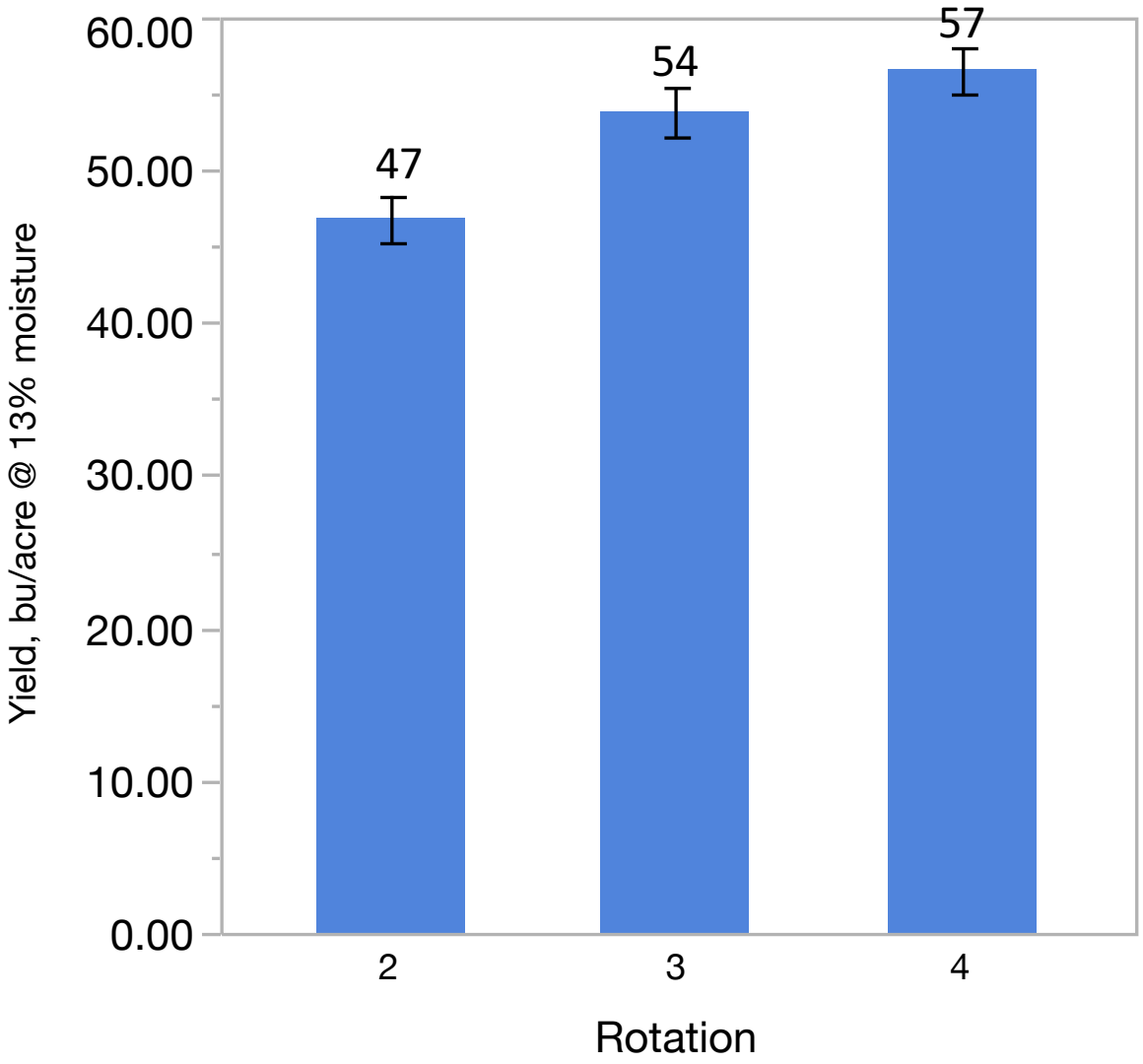
Soybean yields, 2008-2015



2-yr vs. 3-yr and 4-yr: p<0.0001

3-yr vs. 4-yr: p=0.13

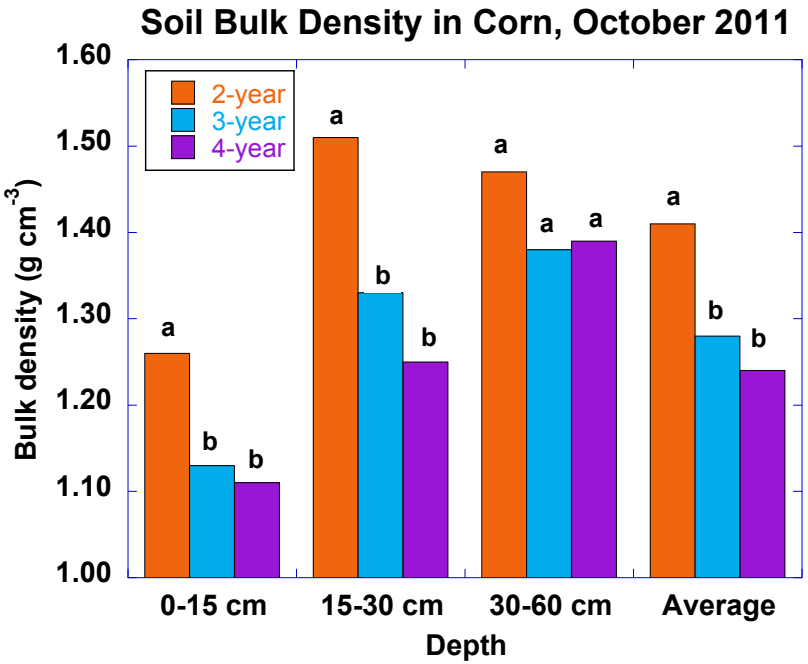
Environmental indicators

Fossil Energy Inputs [GJ ha^{-1} yr^{-1}], 2008-2014

	2-Year Rotation	3-Year Rotation	4-Year Rotation
Fuel for Operations	2.6	2.0	1.8
Fertilizer	5.5	0.9	0.9
Herbicide	0.4	0.3	0.2
Seed Production	0.3	0.3	0.3
Grain Drying	1.5	1.0	0.8
Total Energy Costs	**10.3**	**4.5**	**3.9**

About 0.6 barrels of oil equivalent = about 25 gallons diesel equivalent per acre

Cropping System Effects on Soil Physical Properties



Soil Quality Indicators in Corn

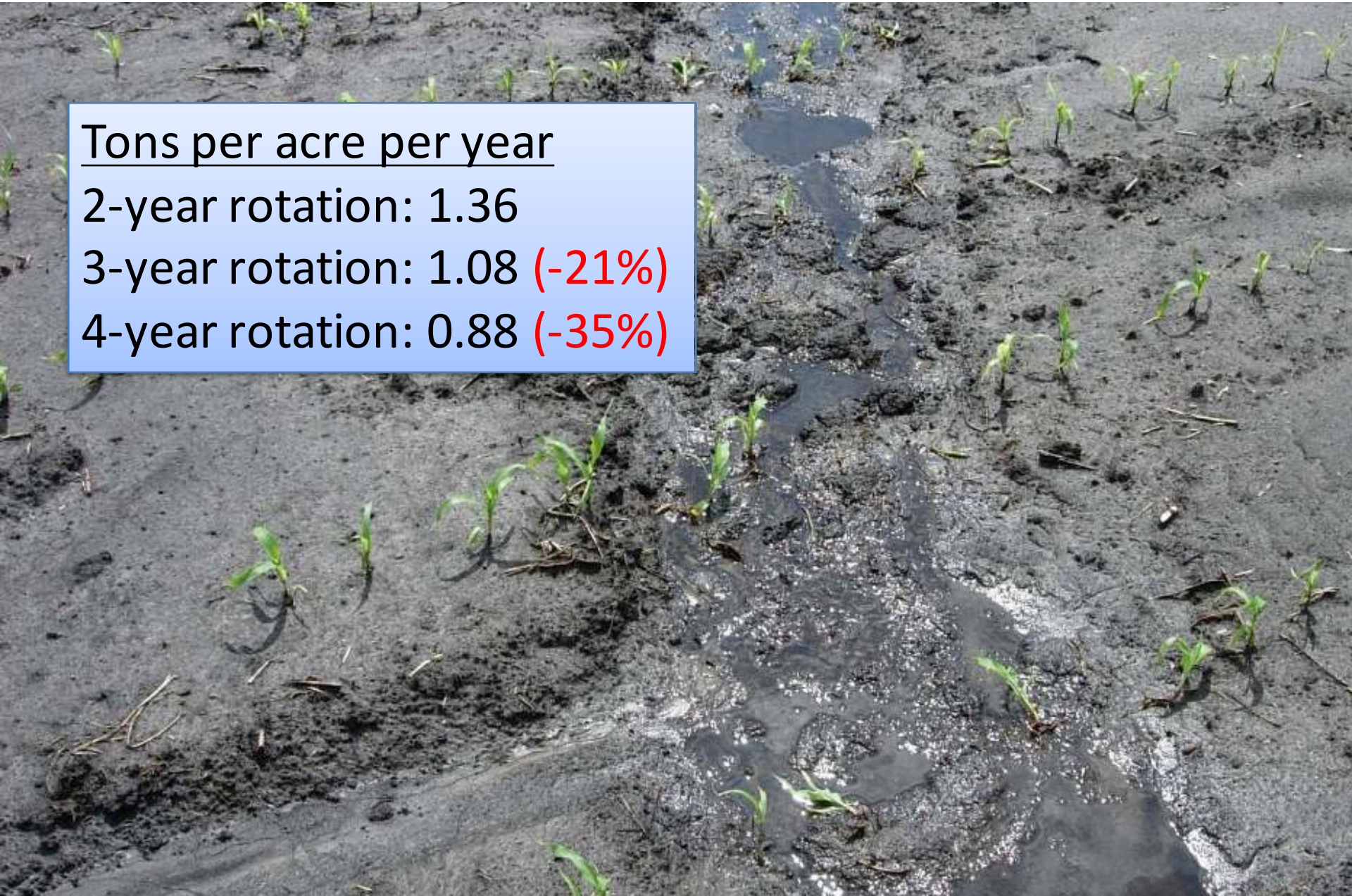
(0-20 cm)

Rotation	Particulate organic matter carbon	Microbial biomass carbon	Potentially mineralizable nitrogen
	mg POM-C cm^{-3} soil	µg C g^{-1} soil	mg PMN cm^{-3} soil
2-year	1.86 b	312.6 c	30.8 b
3-year	2.44 a	388.7 b	42.1 a
4-year	2.38 a	472.2 a	38.3 a

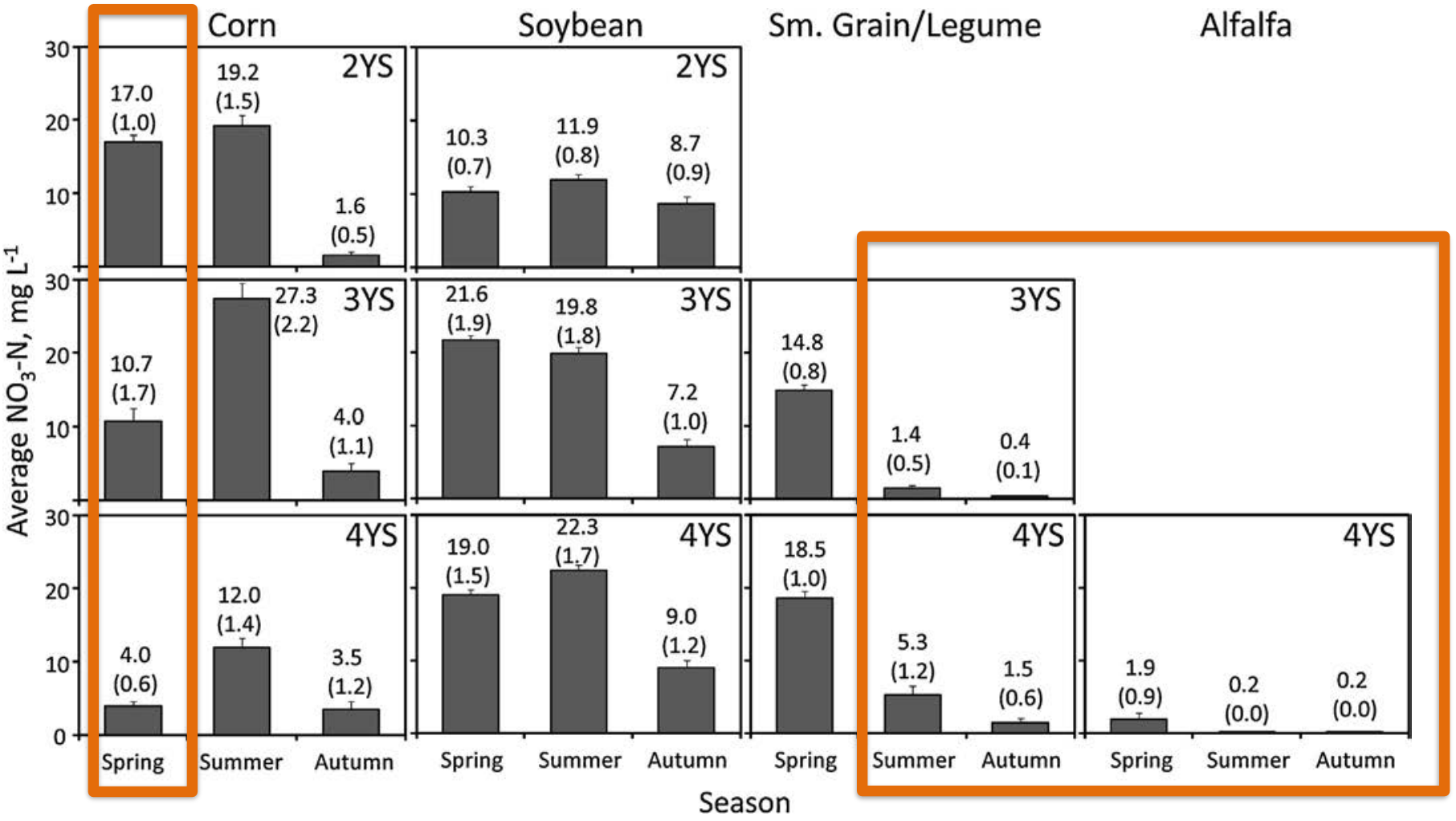
Soil managed with longer rotations has more POM-C, microbial biomass, and PMN.

Sources: Lazicki et al., in review; King, 2014.

Estimated Sheet and Rill Erosion (RUSLE2)



Mean NO_3-N concentrations in water samples collected under each cropping system, 2004-2011



Tomer & Liebman (2014)

Economic Analyses
Cost and Price Assumptions

Input costs were taken from ISU Extension's annual report "Costs of Crop Production in Iowa," and from local businesses. Machinery operation and labor costs were based on field notes and ISU's "Estimating field capacity of farm machines."

Grain and hay prices were taken from marketing year averages provided by the Iowa office of the USDA National Agricultural Statistics Services. Subsidy payments and insurance pay-outs were not included in revenue figures.

Manure was assumed to be generated by on-farm or near-by livestock and without cost for the material, but with labor and machinery costs for spreading.

Analyses were conducted for 2008-2015 data.

Economic performance, 2008-2015

	Rotation system		
	2-year	3-year	4-year
Gross returns ($/acre)	705 a	631 b	658 ab
Costs of production (including labor, but not land, $/acre)	349 a	260 c	283 b
Profits (returns to land and management, $/acre)	356 a	371 a	375 a

Diversity → lower gross returns, lower costs, similar profits

A. Johanns, *unpublished data*

Increasing cropping system diversity can balance productivity, profitability, and environmental health

Davis et al. 2012. PLoS ONE doi:10.1371/journal.pone.0047149