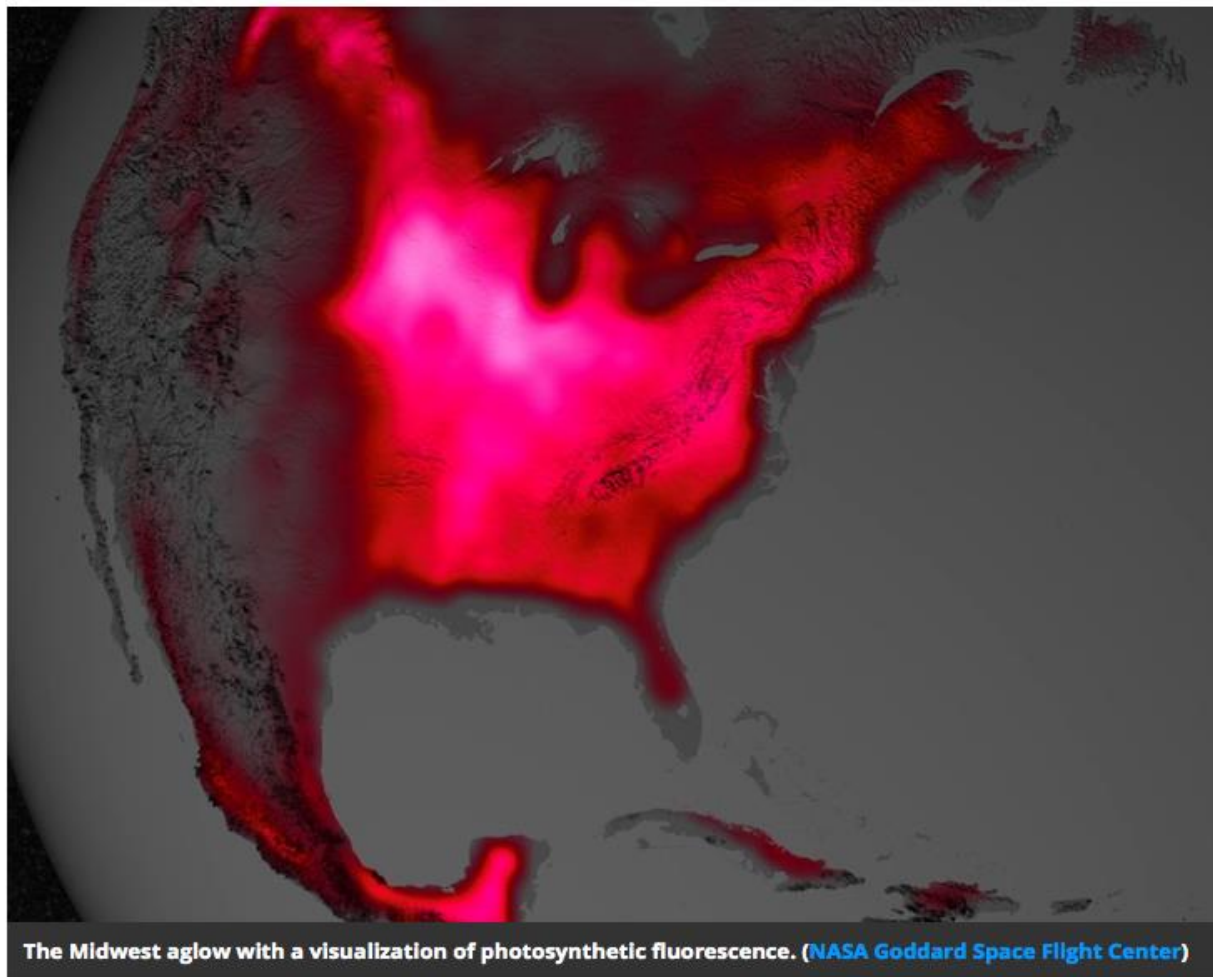


Enhancing Biodiversity in the Corn Belt to Improve Environmental Quality and Crop Production

Matt Liebman
Iowa State University



Photo: F. Kordbacheh



Under the Summer Sun, the Corn Belt Is the Most Biologically Productive Place on Earth

During the peak growing season, the corn belt outproduces the Amazon

Iowa, 2015:

2.5 billion bushels of corn harvested

554 million bushels of soybean harvested

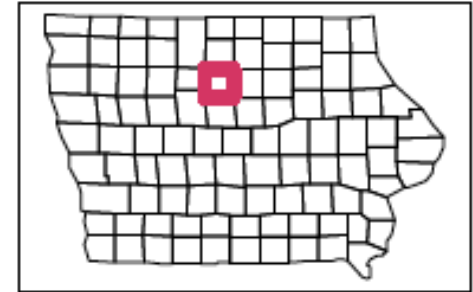
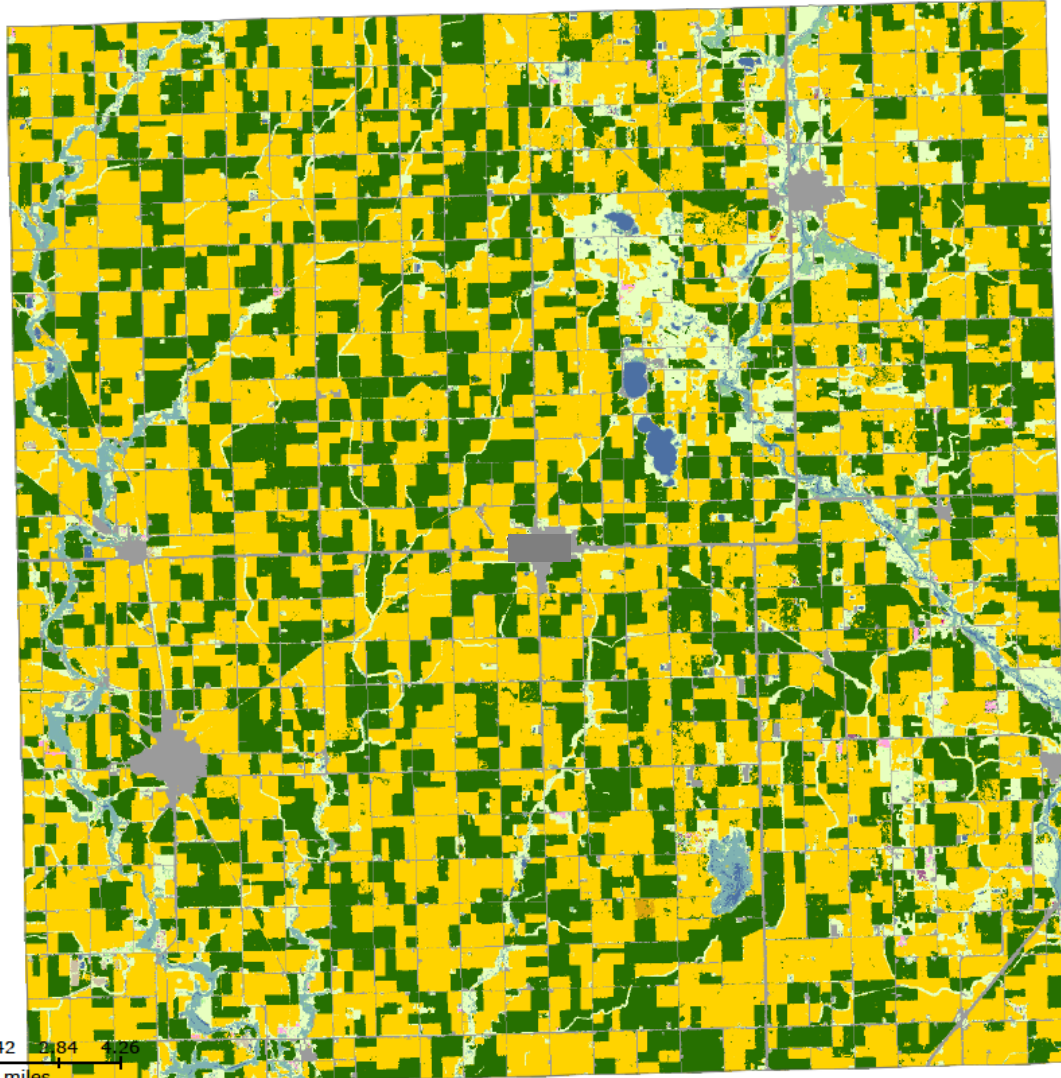
2.2 million cattle, 46.6 million hogs & pigs, 12.5 billion eggs marketed

4.0 billion gallons of ethanol produced



A SIMPLIFIED, HOMOGENEOUS LANDSCAPE

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



Wright County, 2014

583 sq. miles

(1,509 sq. km.)

Yellow = corn

Green = soybean

Emerging and continuing challenges related to low agroecosystem diversity in the U.S. Corn Belt

- Soil erosion
- Water quality degradation due to nutrient and pesticide discharge
- Greater frequency and severity of flooding
- Herbicide resistant weeds
- New crop diseases
- Economic volatility
- Loss of wildlife habitat and reductions of wildlife populations, including monarch butterflies, bees and other pollinators

Two ways that enhanced biodiversity might be used to address these challenges

- Diversified crop rotations integrated with livestock production
- Native, perennial vegetation placed in and around crop fields

Cropping system diversification with crop-livestock integration: the Marsden Farm experiment



Forage crop (alfalfa) produced
in rotation with corn, soybean, and oat



Recycling of nutrients and carbon
in livestock manure applied to crop fields

Iowa State University Marsden Farm, Boone Co., IA

2-year rotation: corn-soybean

4-year rotation: corn-soybean-oat/alfalfa-alfalfa (+ manure)

Experiment initiated in 2001; plots are 18 m x 84 m;
all phases of each rotation are present every year



LEOPOLD CENTER



United States Department of Agriculture
National Institute of Food and Agriculture

Management practices

	2-year rotation	4-year rotation
Manure	None	15.7 Mg/ha before corn (i.e., 1x/4 yrs)
Synthetic N fertilizer	112 kg N/ha at planting plus sidedress	None at planting, but with sidedress option
Herbicides	Broadcast in corn and soybean phases	Broadcast in corn and soybean phases, none with oat and alfalfa

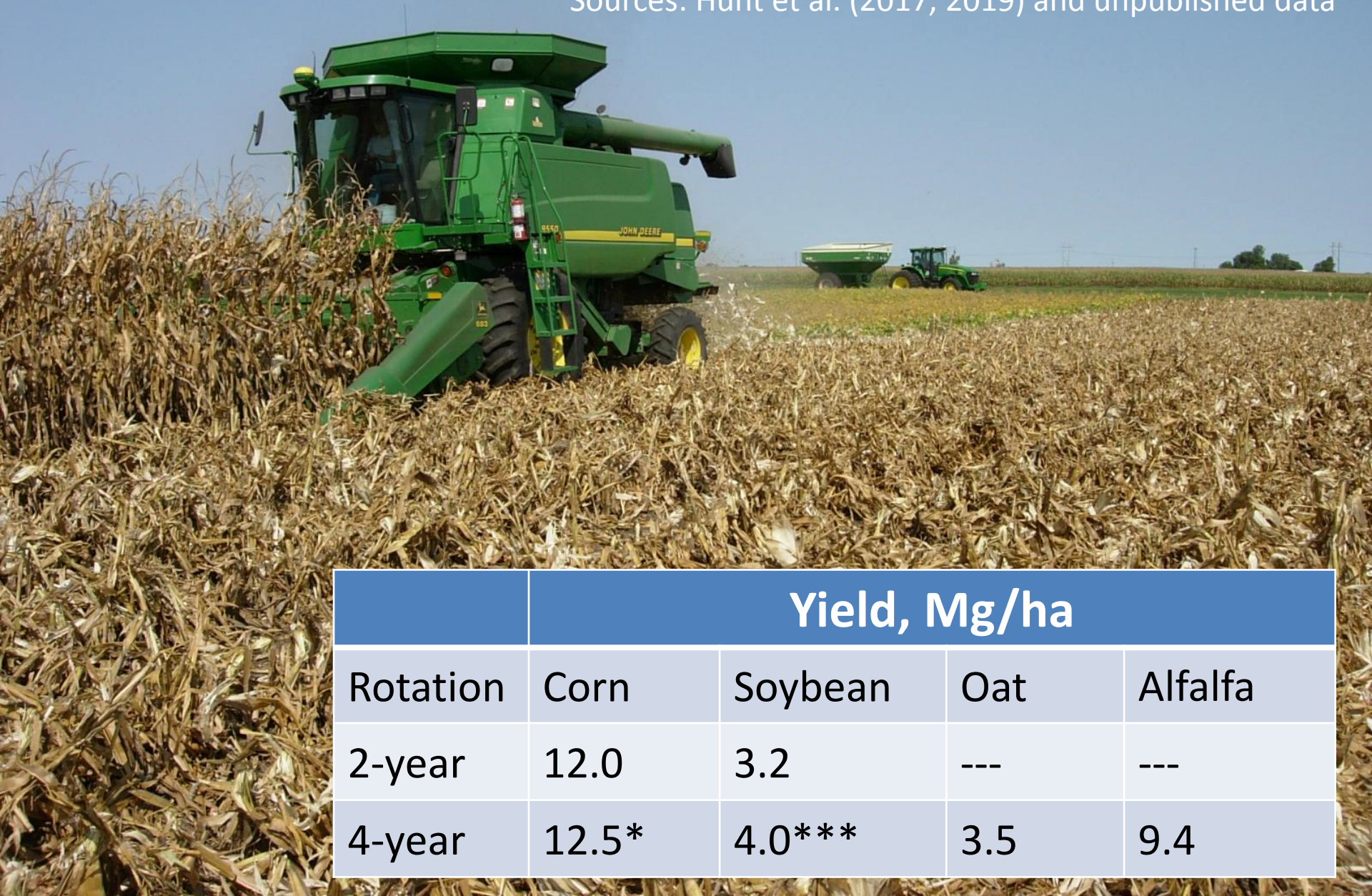
Mean annual mineral N fertilizer and herbicide use, 2008-2017

	N fertilizer			Herbicides	
Rotation	2-year	4-year		2-year	4-year
	kg N/ha			kg a.i./ha	
Corn	175	31		1.06	1.06
Soybean	0	0		1.59	1.59
Oat	--	0		--	0
Alfalfa	--	0		--	0
Rotation av.	88	8		1.32	0.66
Reduction		-91%			-50%

Herbicide regimes that reduce the mass of active ingredients applied by 97% have also been used effectively.

Mean yields, 2008-2017

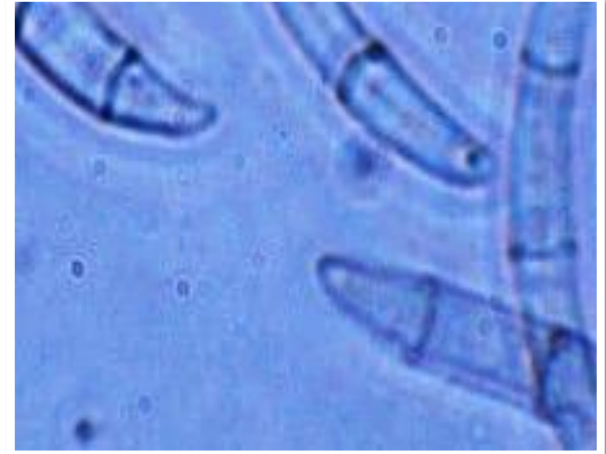
Sources: Hunt et al. (2017, 2019) and unpublished data



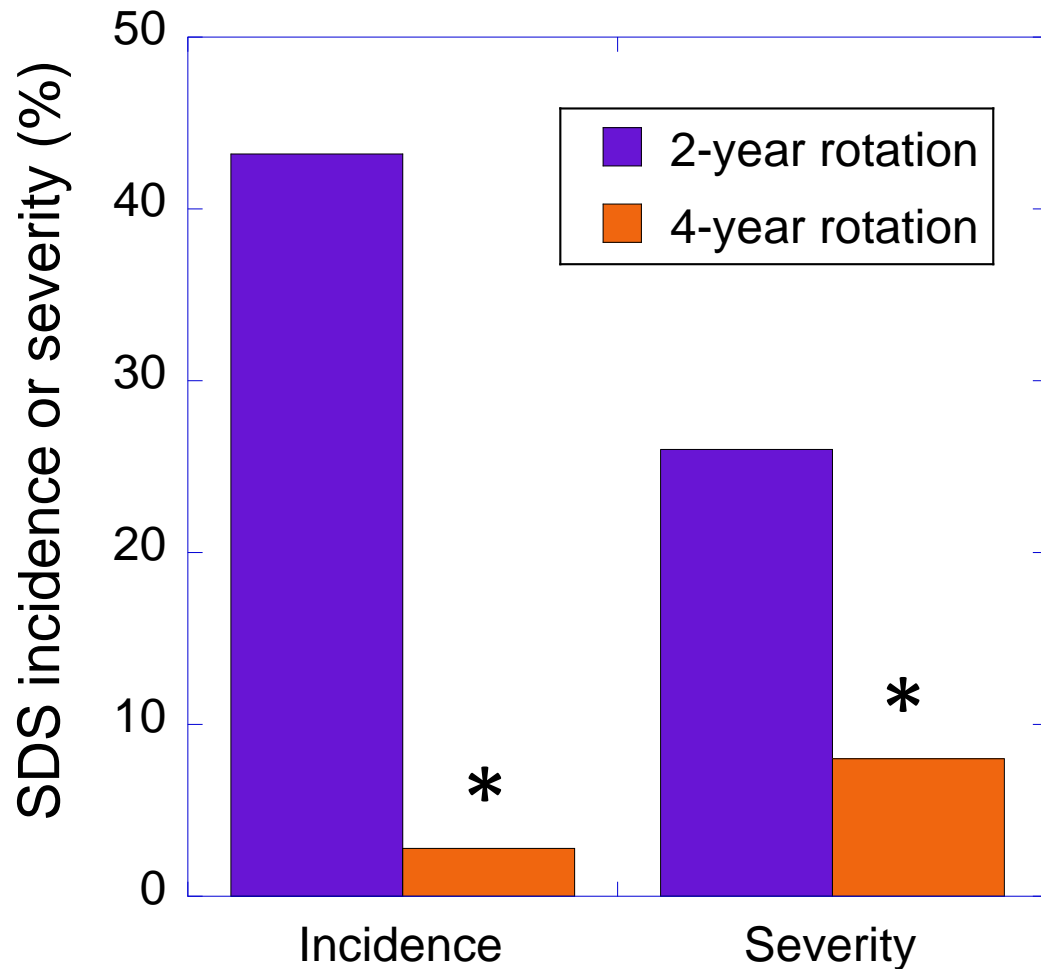
	Yield, Mg/ha			
Rotation	Corn	Soybean	Oat	Alfalfa
2-year	12.0	3.2	---	---
4-year	12.5*	4.0***	3.5	9.4

Soybean 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

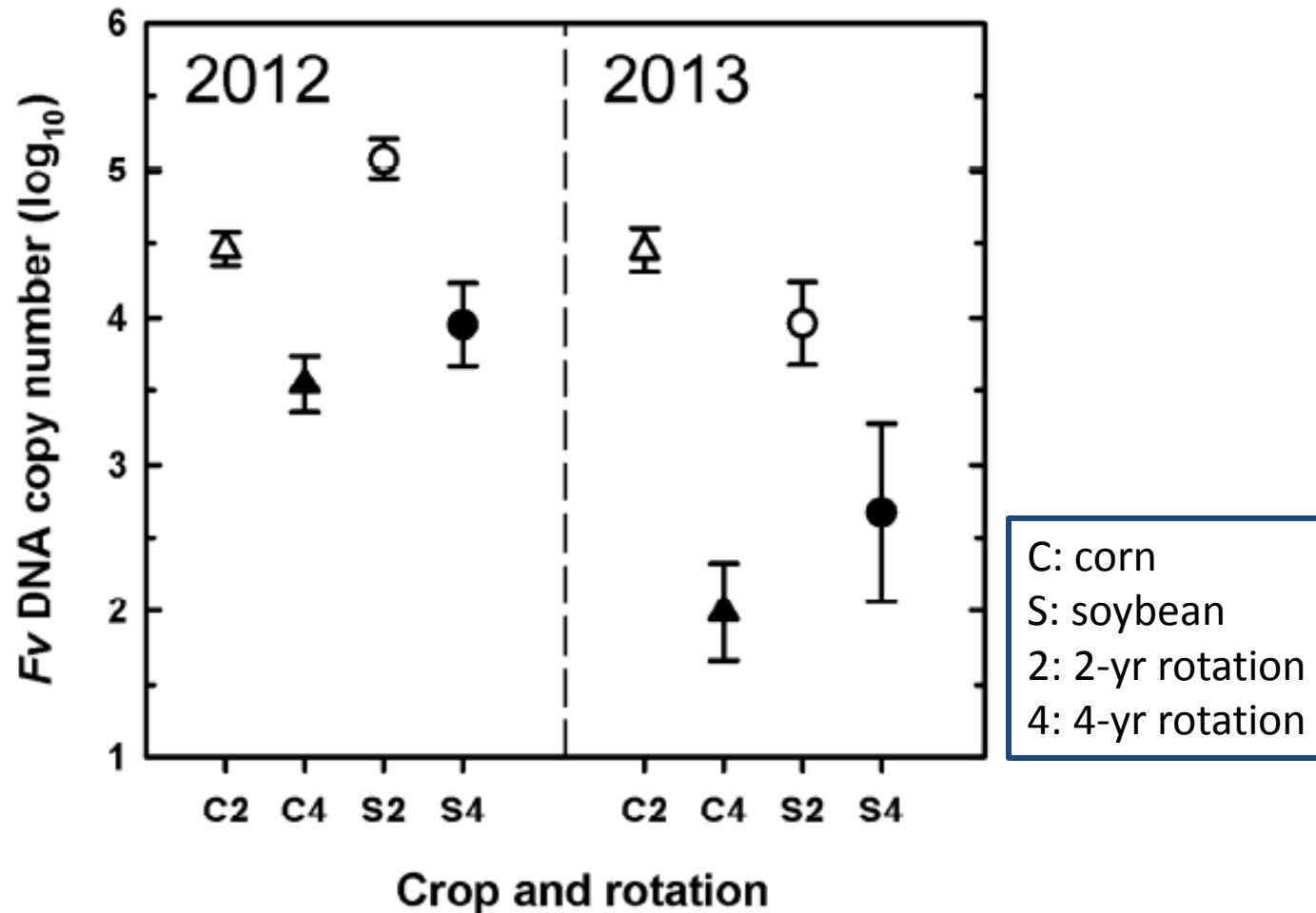


A large reduction in soybean sudden death syndrome was observed in the longer rotation during 2010-2015.



Soybean yield increased significantly as SDS incidence and severity decreased ($p < 0.008$).

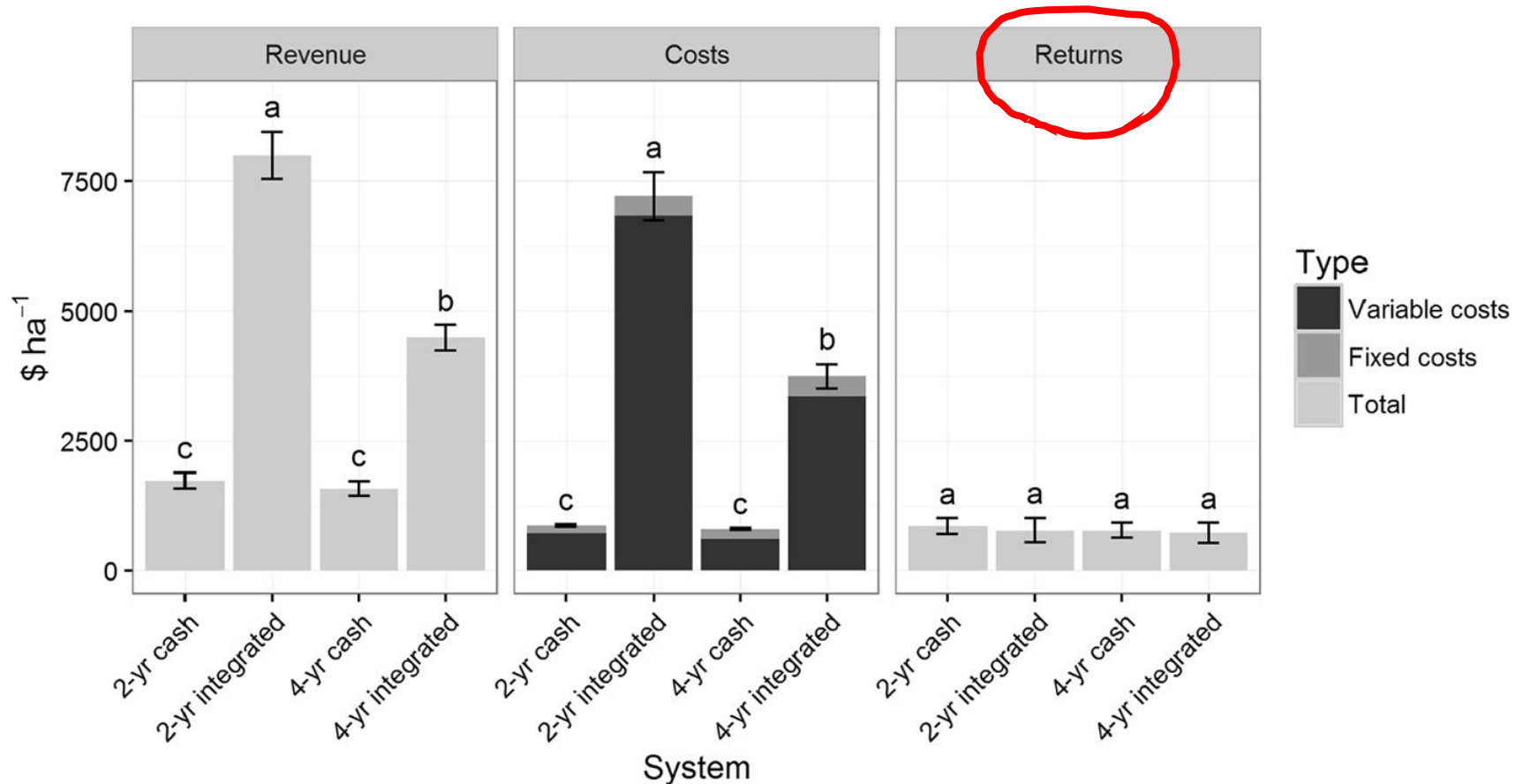
The amount of DNA of *Fusarium virguliforme* per gram of soil was much lower in the longer rotation.



Diversification reduced costs and did not affect crop profitability in 2008-2017

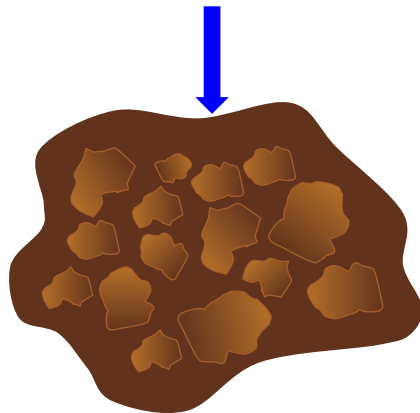
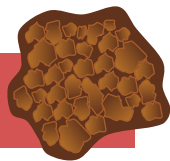
Economic indicators	units	4-yr rotation	2-yr rotation	Response ratio
Annual crop production costs (excluding land)	\$/ha	677	838	0.81***
Annual net returns to land and management for crops	\$/ha	883	835	1.06 ^{NS}

Returns to land and management were similar among systems when considering both crops and livestock

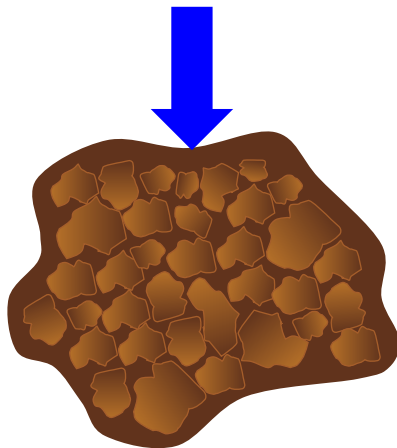


cash: only crops
integrated: crops + livestock

PHYSICAL

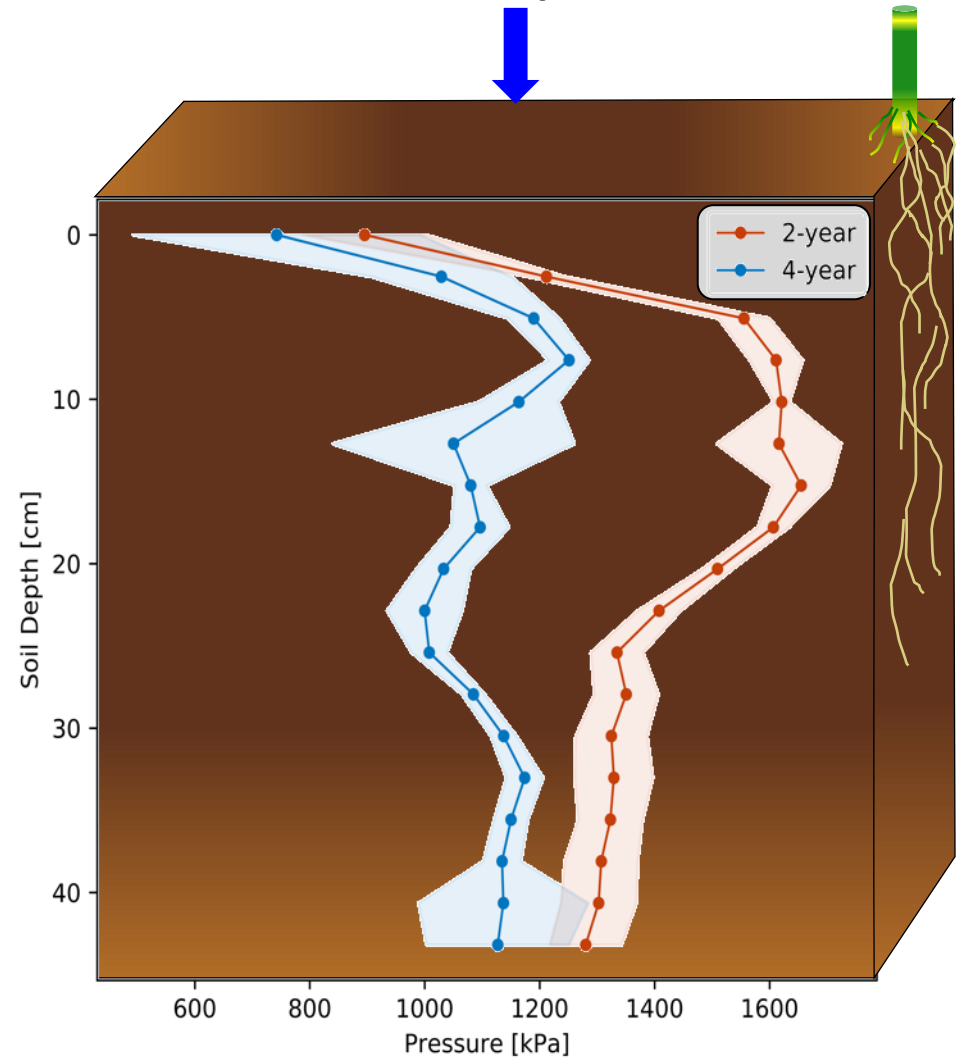


4-year



2-year

Soil resistance to penetration



Diversification reduced soil resistance to penetration by 25.8%

Baldwin-Kordick 2019

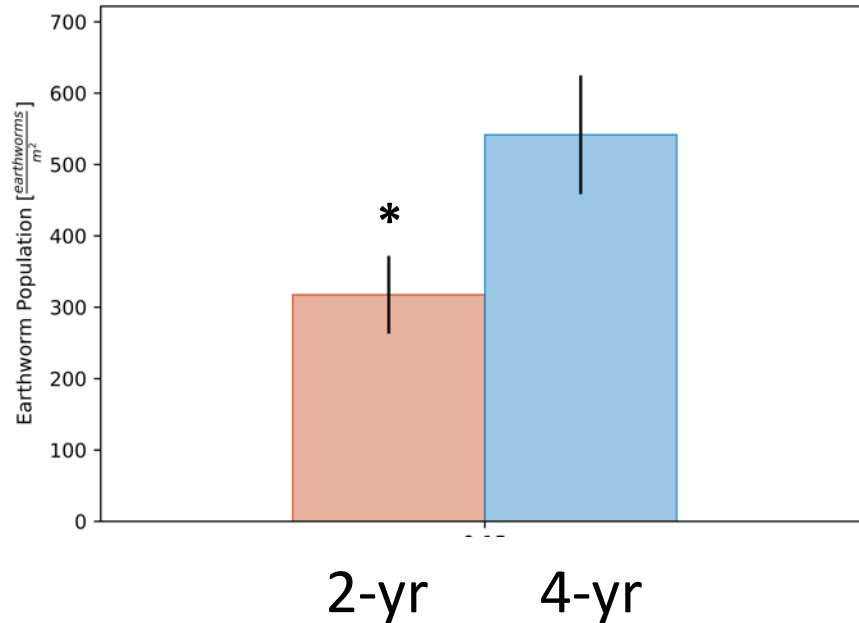
Diversification increased soil particulate organic matter C and microbial biomass.

Measurements made in corn phase, 0-20 cm depth.

Rotation	Particulate organic matter carbon	Microbial biomass carbon
	mg POM-C cm ⁻³ soil	µg C g ⁻¹ soil
2-year	1.86 b	312.6 b
4-year	2.38 a	472.2 a

Sources: Lazicki et al. 2016; King & Hofmockel 2017.

Earthworm abundance



Compared to the 2-year rotation, the 4-year system had 71% more earthworms



Diversification enhanced ground beetle activity density and species diversity in 2003-2004

Performance indicator	4-year rotation	2-year rotation	Response ratio
Activity density	39.33	27.01	1.46*
Species richness	11.09	8.25	1.34*



Poecilus chalcites

<https://bugguide.net/node/view/466671/bgimage>

O'Rourke et al., (2008), Environ. Entomol. 37: 121–130.

Models were used to evaluate other environmental effects

- GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation)
- USEtox (human and ecotoxicological impacts of chemicals)
- ArcSWAT (Soil and Water Assessment Tool)
- InMAP (Intervention Model for Air Pollution)

Dr. Jason Hill, U MN



Dr. Natalie Hunt, U MN

Diversification reduced fossil energy use and increased energy use efficiency

	Units (per year)	4-year rotation	2-year rotation	Response Ratio
Fossil energy consumed	GJ/ha	3.38	9.50	0.36***
Energy in harvested crop materials	GJ/ha	115.5	119.7	0.96 ^{NS}
Energy gain ratio	GJ in crop materials/GJ in fossil energy	37.0	13.5	2.75***

Diversification reduced pollution

Environmental impact	Units (per year)	4-year rotation	2-year rotation	Response Ratio
Herbicide aquatic ecotoxicity	CTUe/ha	2175	4349	0.50**
Soil sediment loss	Mg/ha	1.04	2.55	0.56**
N discharge in run-off	kg/ha	6.19	10.01	0.62*
P discharge in run-off	kg/ha	1.64	2.32	0.71*
PM _{2.5} emissions	kg/ha	5.25	13.71	0.38***
GHG emissions	kg CO ₂ -eq/ha	276	779	0.36***

Increasing cropping system diversity and reintegrating crop and livestock production can help meet productivity, profitability, and environmental quality goals

Hunt et al. 2019. Env. Sci. & Tech., doi:10.1021/acs.est.8b02193

Hunt et al. 2017. Env. Sci. & Tech., doi:10.1021/acs.est.6b04086

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



Cropland diversification with strips of prairie vegetation: watershed-scale experiments and on-farm trials



Image: Wright Co., Lynn Betts

Why prairie?

- Perennial cover
- Deep roots
- Stiff, erect stems
- Diverse
- Native



Photograph by Jim Richardson



Photograph by Sarah Hirsh

Source: Asbjornsen et al. 2014



Science-based Trials of Row-crops Integrated with Prairie Strips

STRIPS is a team of scientists, educators, farmers, and extension specialists working on the prairie strips farmland conservation practice.



STRIPS 1:

Research and
demonstration on small
experimental watersheds



Photo from A. MacDonald

Experimental Treatments

12 catchments; 0.5–3.2 hectares; 6–11% slope

Randomized Incomplete Block Design:

3 reps X 4 treatments X 3 blocks



STRIPS 1

2-year corn/soybean rotation, no tillage



Photo: NSNWR, Jasper Co., Drake Larsen

STRIPS 1: Multi-year measurements of multiple performance indicators



Small changes, big impacts: 2008-2015

Effects of adding 10% prairie to no-till corn-soy fields:

- 37% reduction in water runoff
- 70% reduction in total N losses in surface runoff
- 72% reduction in subsurface NO₃-N concentrations
- 77% reduction in total P losses in surface runoff
- 95% reduction in soil loss
- two-fold increase in bird abundance
- no effect on per acre yields
- cheaper than terraces; cost comparable to cover crops

Sources: Zhou et al. 2010; Helmers et al. 2012; Zhou et al. 2014; Schulte et al. 2017

STRIPS 2: On-farm research and refinement



Photo: Tama Co., Tim Youngquist

66 collaborators
576 acres of prairie planted
4,930 cropland acres protected

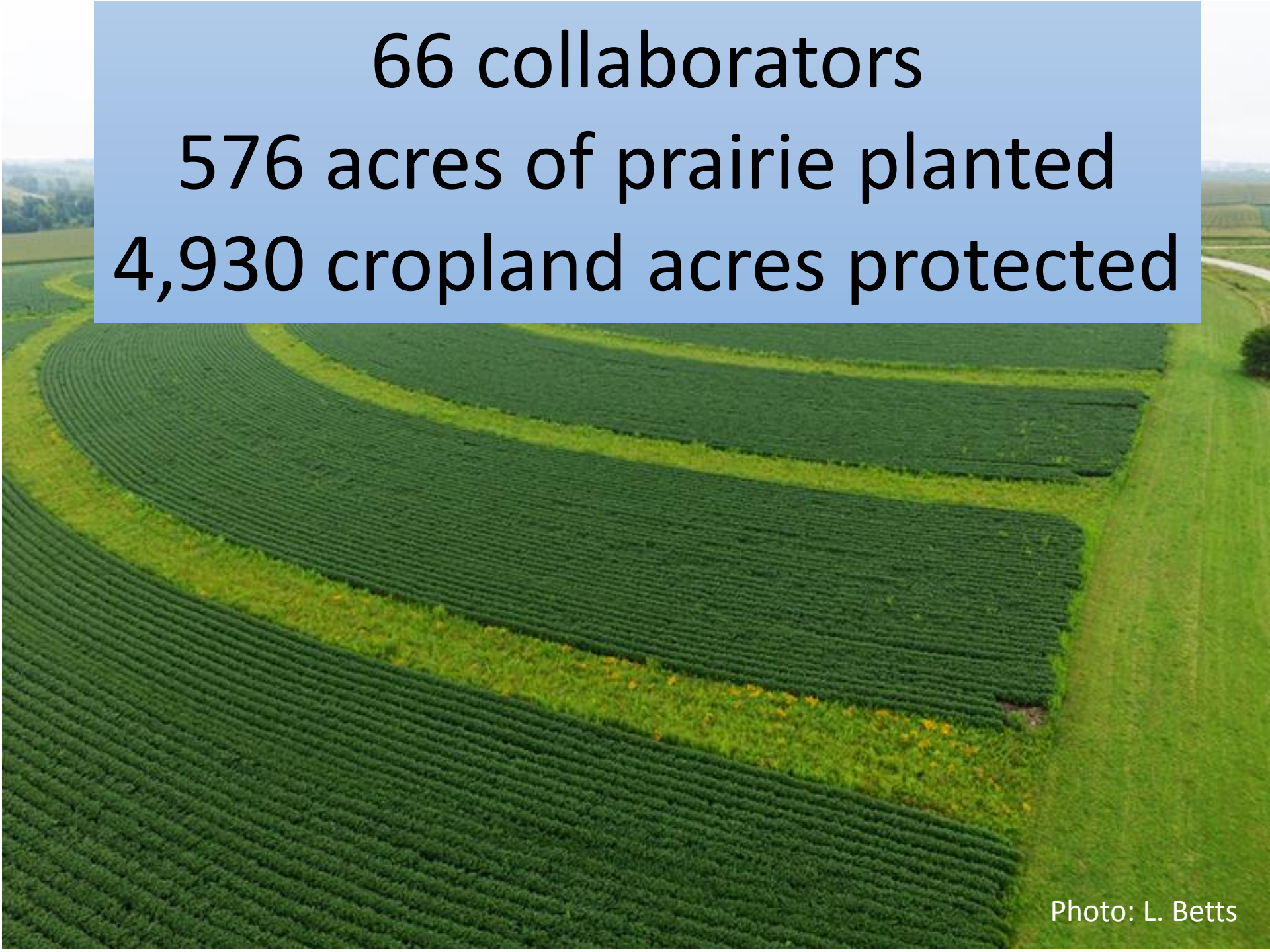


Photo: L. Betts

Building a community of support



**College of
Agriculture &
Life Sciences**



**Agricultural
Research
Service**



**McIntire-Stennis
Program**



**Committee on
Agricultural
Development**



**THE EASTERN
IOWA AIRPORT
CEDAR RAPIDS**



**Iowa
Natural Heritage
Foundation**



**IOWA SOYBEAN
Association**



**Tallgrass Prairie
CENTER**
Restoring a National Treasure



Planting a better tomorrow™



Outreach: Field days with cooperating farmers



Image courtesy of
Practical Farmers of Iowa

Outreach: www.prairiestrips.org

Prairie Strips: Small Changes, Big Impacts



"Want to stem soil and biodiversity loss, enhance fresh water supplies, curtail climate change, and improve people's lives? Then enhance agriculture with perennials and partnerships."

— Lisa Schulte Moore, STRIPS team scientist



"This is the kind of agriculture I love—to talk about the sustainability, about being able to say that I found it? Hop matters to me."

— Seth Watkins, farmer

Researchers have found that converting as little as 10 percent of a cropland field to prairie can help reduce soil erosion, retain nutrients, provide habitat for native species without impacting per-acre crop yield. A study has demonstrated that native prairie species in narrow strips along field edges can reduce soybean farm costs. A low cost way to implement these changes can be achieved.

Science

In 2007, researchers at the University of Illinois at Urbana-Champaign and the USDA Farm Service Agency (FSA) conducted the Science-based Trials of Row-crops Integrated with Prairie Strips (STRIPS). The trials have found that strategically planting native prairie in farmland provides benefits to the land, water, soil, and wildlife well beyond the area of land converted.

The Cost of Prairie Strips

What are prairie strips?

Prairie strips are a tool for improving the health and function of row crop farm fields. Researchers at Science-based Trials of Row-crops Integrated with Prairie Strips (STRIPS) have found that strategically planting native prairie in farmland provides benefits to the land, water, soil, and wildlife well beyond the area of land converted.

How much does prairie planting cost?

Table 1 represents typical costs for a prairie strip planting after soybean. The range of costs is calculated based on average land rent across cropland quality, as measured by its Corn Suitability Rating (CSR). The water runoff from every nine acres of row crops can be treated with just one acre of perennial prairie. So, for every ten acres of farmland, the average total annual cost of converting one acre of cropland to prairie ranges from \$280 to \$390. In other words, converting a tenth of every acre from annual crop to prairie costs between \$28 to \$39 per year.

Some farms may experience higher "opportunity costs" than the average farm (e.g. in terms of foregone rent or revenue), thus annual costs can scale higher in these cases. However, the USDA Farm Service Agency also offers 15-year CRP contracts, farmers could receive a total cost reduction of approximately 75 percent, thus costing about \$8 per year per crop acre treated with prairie. Other sources of financial support are also available (see reverse side).

Table 1. Annualized total costs of prairie strips calculated over a 15-year management period at a 2% discount rate (in 2017 dollars)

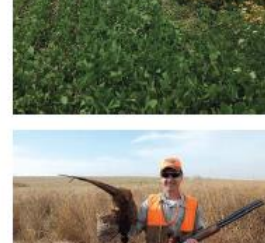
Per acre of prairie	High quality (CSR 82)	Medium quality (CSR 73)	Low quality (CSR 60)
Per protected crop acre	\$353	\$319	\$279
Per protected crop acre with CRP	\$35	\$32	\$28
	~ \$8	~ \$8	~ \$8

See following page for detailed cost breakdown

Farming with Prairie Strips: Frequently Asked Questions

Prairie strips is a conservation practice that uses native plants and animals to improve soil health, reduce erosion, and provide habitat for wildlife.

Farming with Prairie Strips



Iowa farmers adopt new technology when benefits are clear

Prairie strips are a proven tool for improving and protecting row-cropped farm fields. Iowa State University researchers have shown that areas of native prairie planted in the right places in a farm field can provide benefits that far outweigh losses from converting a small portion of a crop field to prairie. They developed this practice through the Science-based Trials of Row-crops Integrated with Prairie Strips (STRIPS) project.

The perennial prairie that once covered 85 percent of the state produced the fertile topsoil that makes Iowa farmland so productive. Returning just 10 percent of farm fields — usually some of the least productive acres — to prairie plants can protect soil, reduce nutrient movement into waterways, help meet targets set in the Iowa Nutrient Reduction Strategy, and increase pollinators and wildlife habitat and diversity. Crop production potential on the land between the strips is unchanged, while the incorporation of prairie plants into farm fields can create opportunities for other sources of revenue, including livestock forage, energy biomass, hunting leases, and honey and native seed production. Prairie strips could form a component of an integrated pest management approach.

Prairie strip plantings require minimal land conversion and maintenance, and are among the lowest cost best management practices that can be added to a field, especially when combined with a Conservation Reserve Program (CRP) contract. Ongoing studies continue to document the long-term benefits of prairie strips in farming systems.

Benefits could outweigh implementation costs

Farmland management decisions can present trade-offs between the long-term health and sustainability of the land and maximum yearly profit. The cost of establishing prairie strips compares favorably to other conservation practices that build soil health and manage nitrogen, phosphorus, and sediment. Landowners can receive financial and/or technical assistance from many programs.

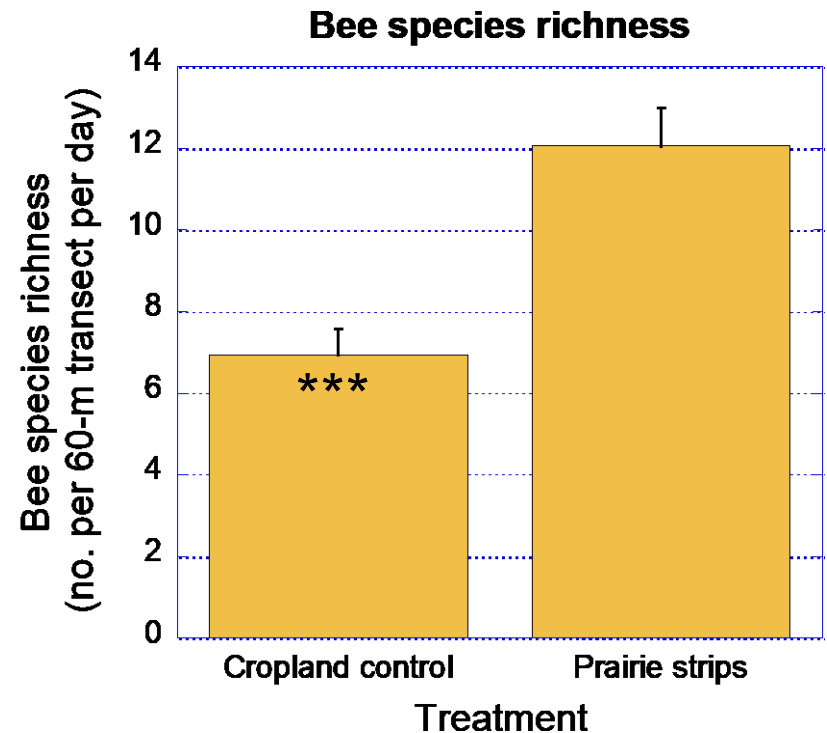
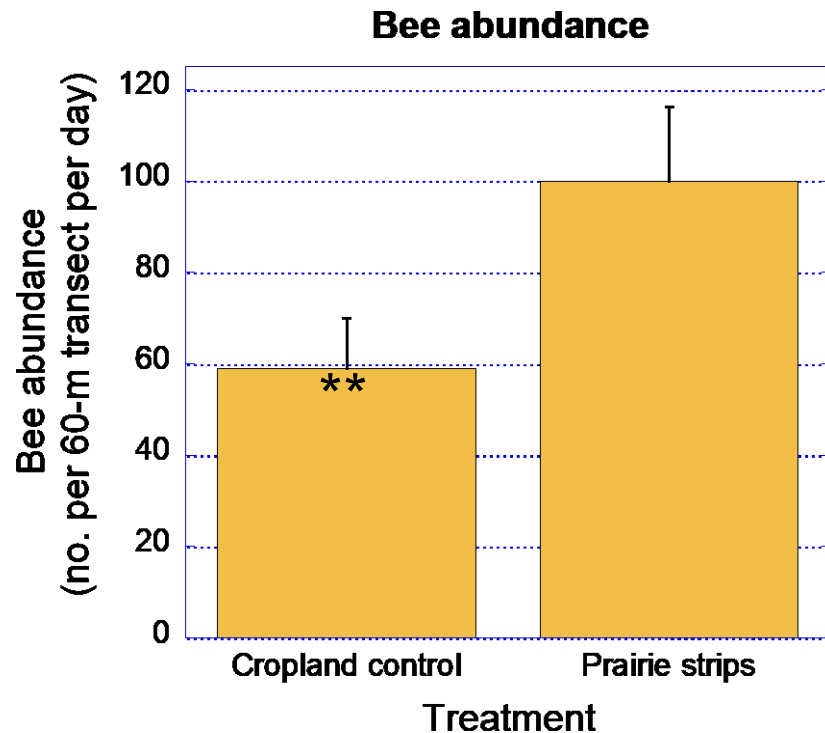
The average total annualized cost of converting one acre of cropland to prairie ranges \$280 to \$390. If using a "10 percent solution" the cost of protecting a farm field ranges \$28 to \$39 per acre per year. The majority of these costs are land rent or foregone revenue, followed by seed and maintenance costs. Within a 15-year CRP contract from the USDA Farm Service Agency, the total cost to a farmer can be reduced by about 75 percent.

On-farm research / training the next generation of scientists



Image: Jasper Co.; Anna MacDonald

On-farm research in 2016-2017 indicated that prairie strips supported a greater number of bees and more bee species than nearby crop fields.



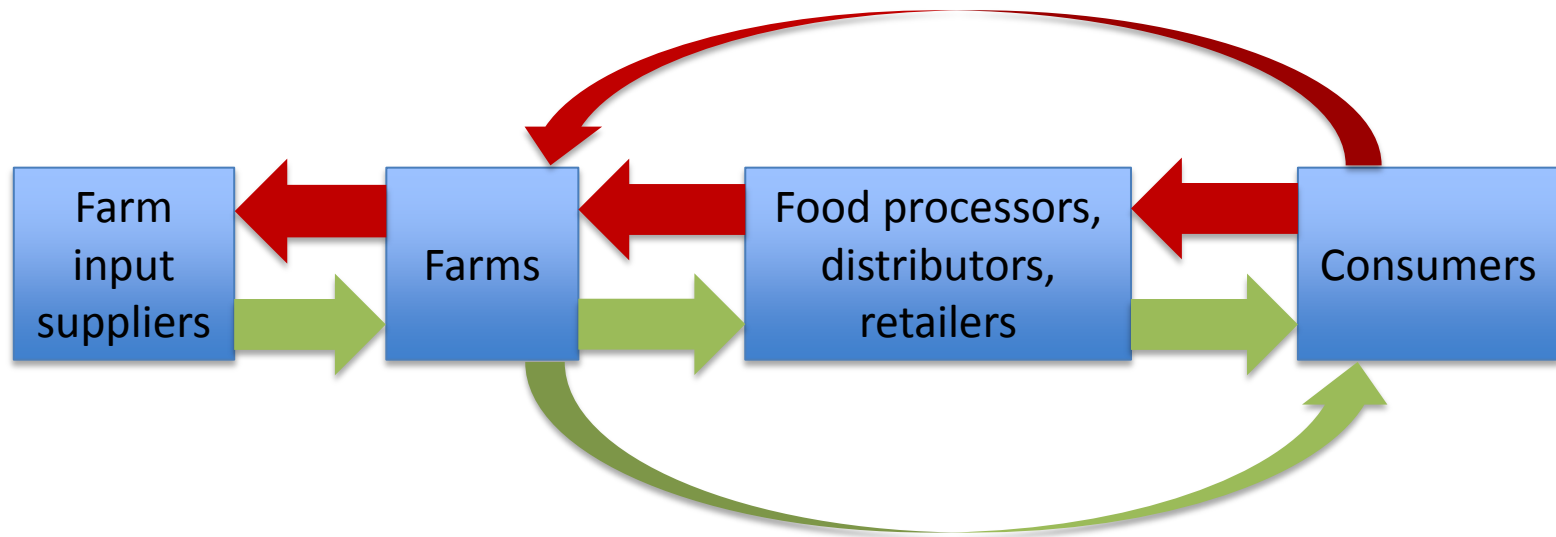
Three paths to changes in land use and shifts in farming practices

- Government policy
- Market “pull”
- Farmer-to-farmer information exchange

Federal Agricultural Payments, 1995-2016

	Iowa (#2)	U.S.
Commodity subsidies	\$18.5 billion	\$198.2 billion
Crop insurance subsidies	\$5.5 billion	\$78.1 billion
Conservation programs	\$5.0 billion	\$46.2 billion
Disaster payments	\$0.8 billion	\$31.0 billion
Total	\$29.8 billion	\$353.5 billion
Total per year	\$1.4 billion	\$16.1 billion

U.S. consumers spend more than \$1.4 trillion per year on food and beverages, about two-thirds of which accrues to processors, distributors, and retailers.



Source: USDA-Economic Research Service

Farmer-to-farmer information exchange



Long-term agroecological research projects can provide credible information to policy makers, industry personnel, consumers, and farmers about:

- (1) agronomic, economic, and environmental characteristics of contrasting farming systems;
- (2) effects that are powerful, but slow to be seen;
- (3) system response to stress factors.

Diversification reduced damage to human health

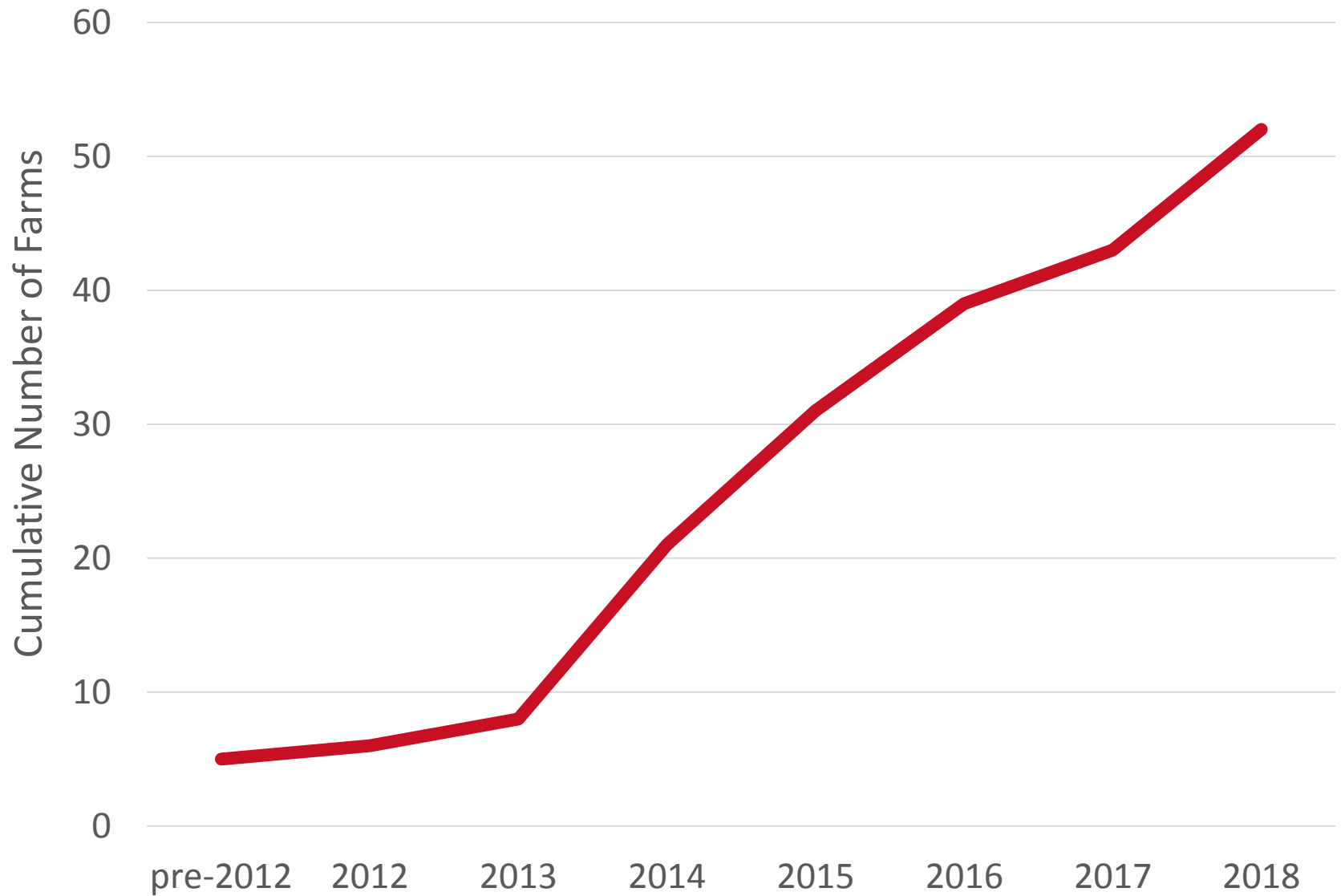
Damage agents	Units	4-year rotation	2-year rotation	Response ratio
GHGs & PM _{2.5}	\$/ha/year	342	767	0.44***

Social Cost of GHGs = \$43/Mg CO₂-eq.; “intended to include (but not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change.” Interagency Working Group on Social Cost of Carbon (2013); Shindell (2015)

InMAP calculates particulate emissions and, using epidemiological concentration-response functions, health impacts of exposure to primary and secondary PM_{2.5}. Economic damage is then calculated using a ‘Value of a Statistical Life’ equal to \$9.5 million (U.S.E.P.A. 2018).

Hunt et al., unpublished data

Number of Farms with Prairie Strips



Number of 'Treated' Acres for Farms with Prairie Strips

