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

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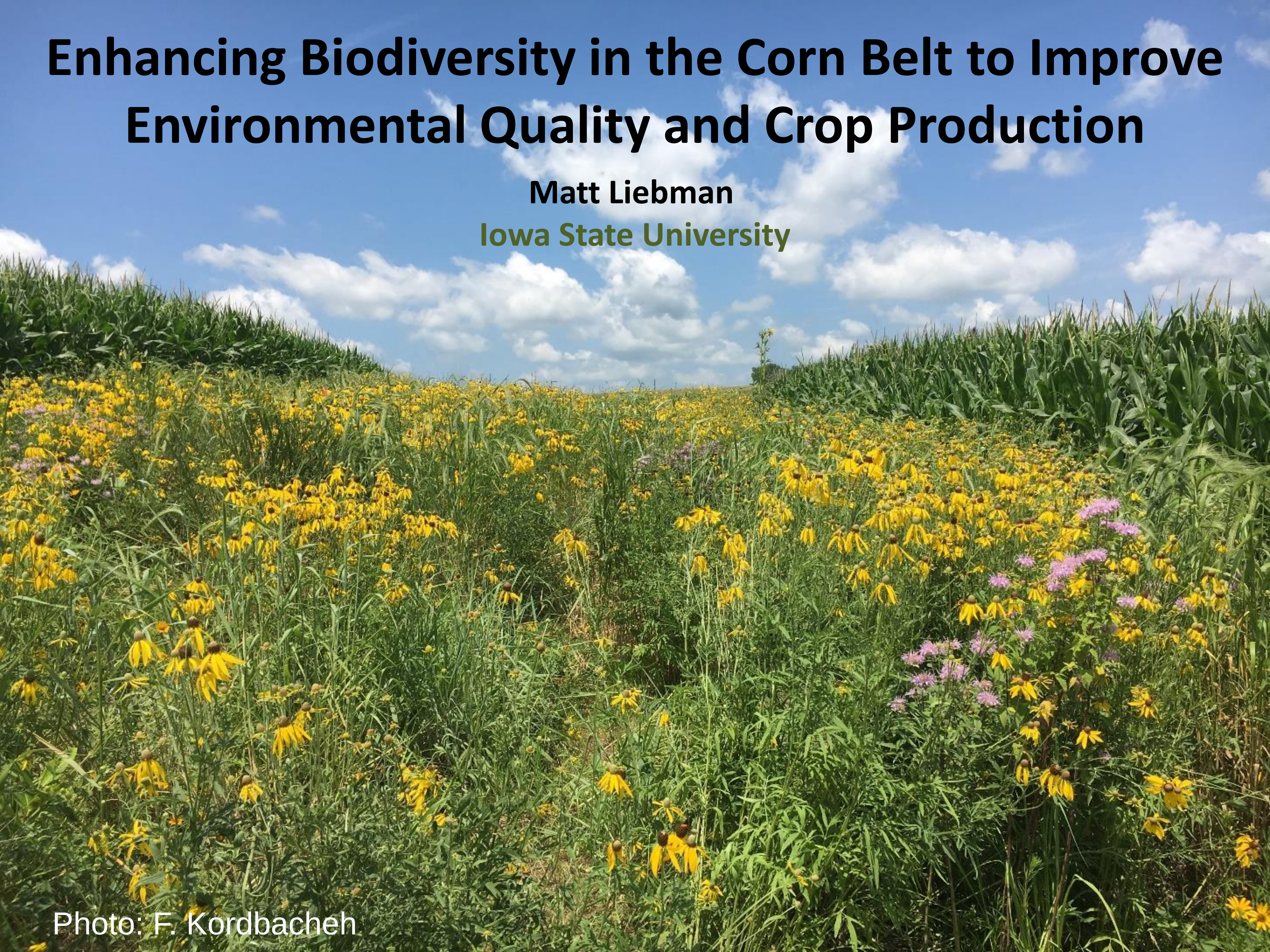
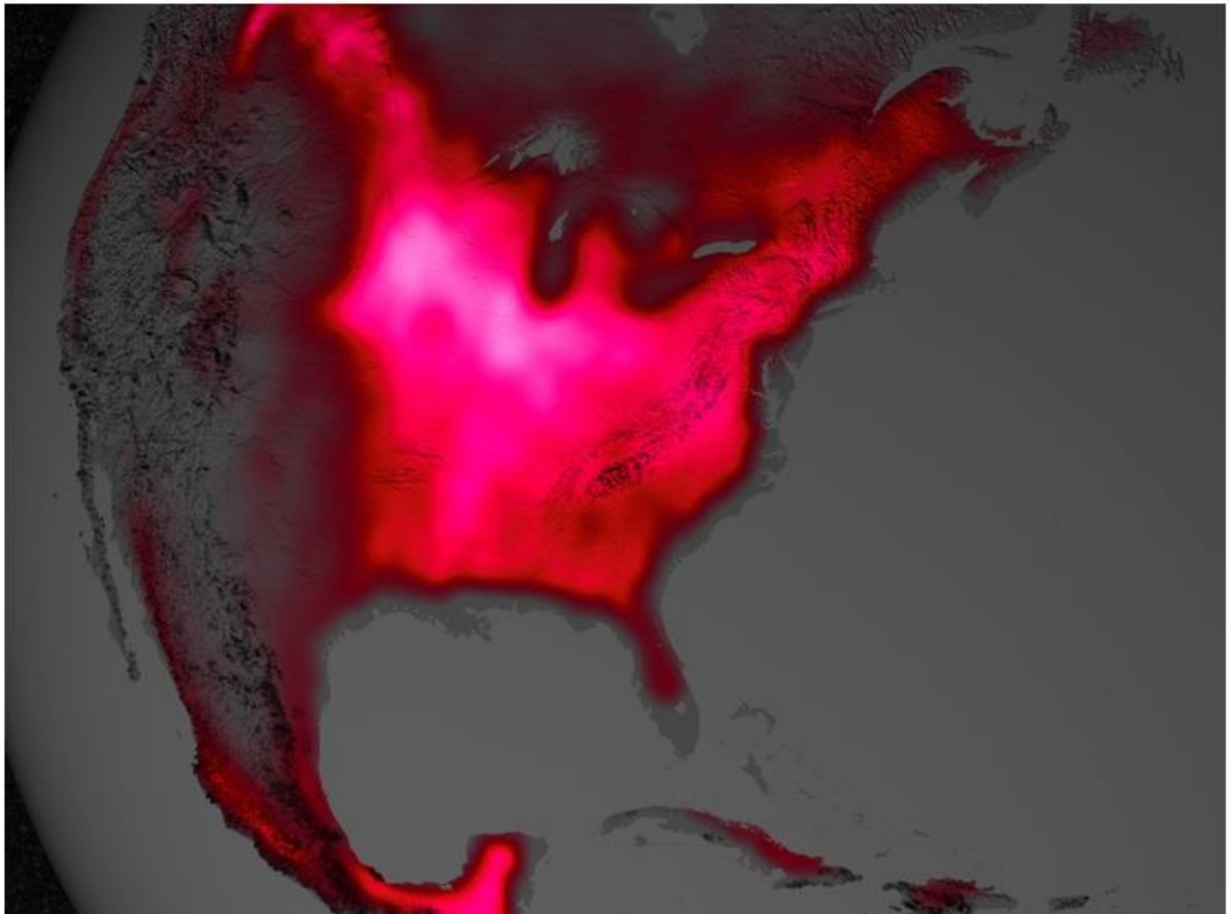


Photo: F. Kordbacheh



The Midwest aglow with a visualization of photosynthetic fluorescence. (NASA Goddard Space Flight Center)

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

http://www.smithsonianmag.com/smart-news/under-summer-sun-midwest-corn-belt-most-biologically-productive-place-earth-180950460/?no-ist

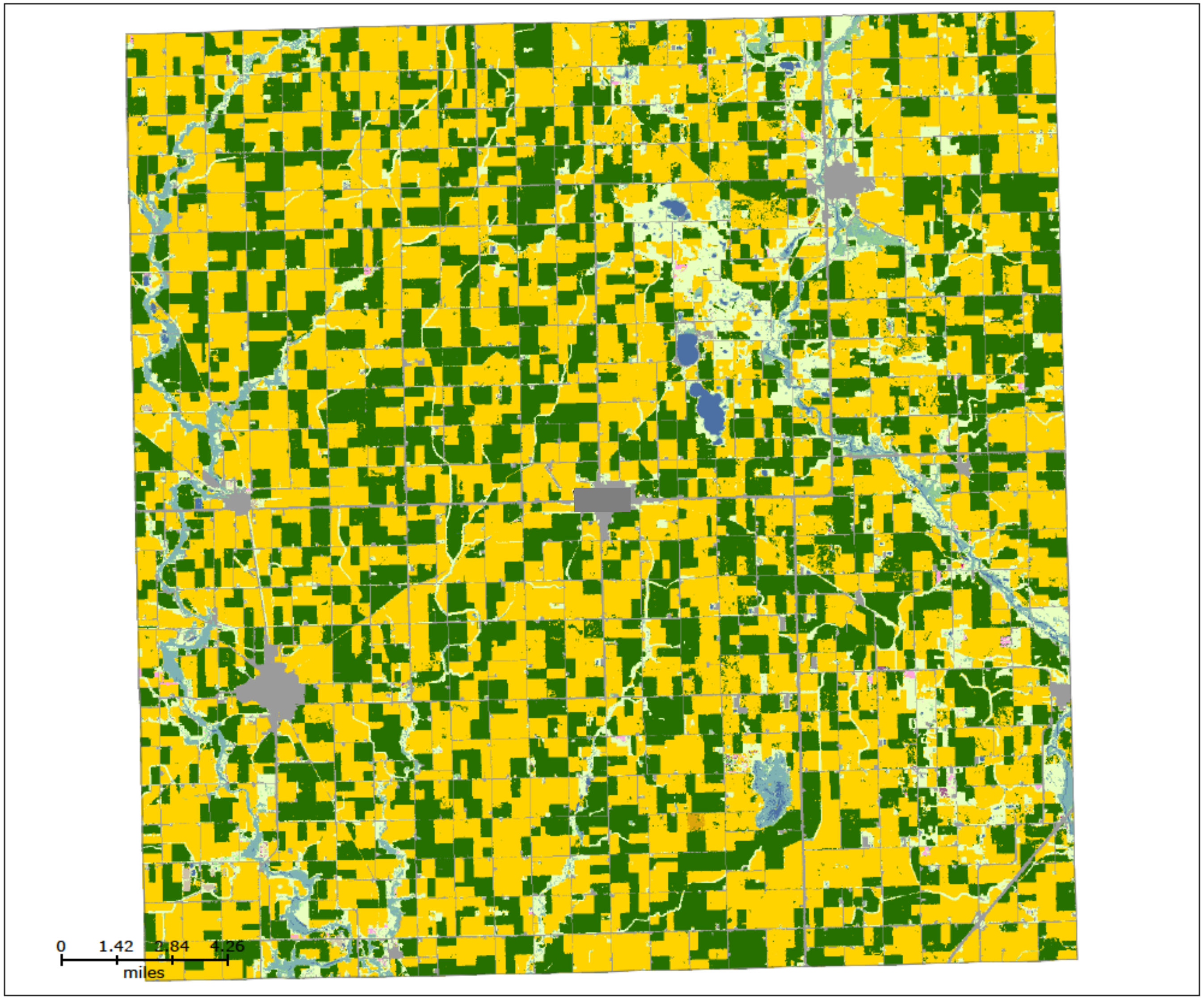
Iowa, 2015:

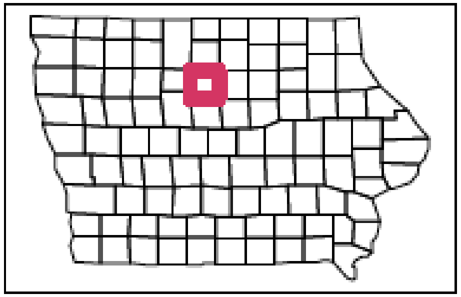
2.5 billion bushels of corn harvested
554 million bushels of soybean harvested
2.2 million cattle, 46.6 million hogs & pigs, 12.5 billion eggs marketed
4.0 billion gallons of ethanol produced

http://www.nass.usda.gov/Statistics_by_State/Iowa/Publications/Annual_Statistical_Bulletin/2016/
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, 2014
583 sq. miles
(1,509 sq. km.)

Yellow = corn
Green = soybean

USDA-NASS Cropland Data Layer

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

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USDA NIFA
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

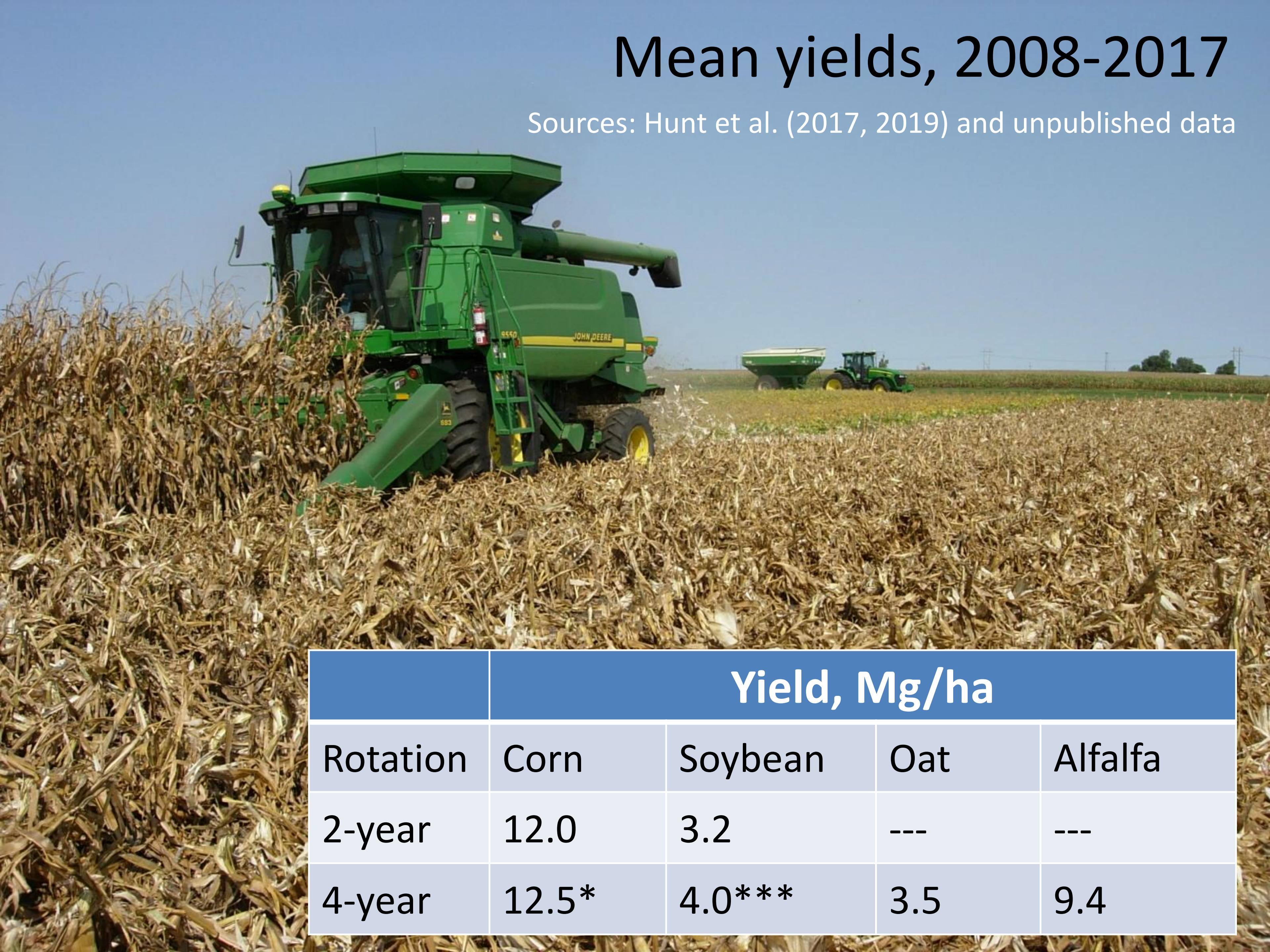
Mean annual mineral N fertilizer and herbicide use, 2008-2017

	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

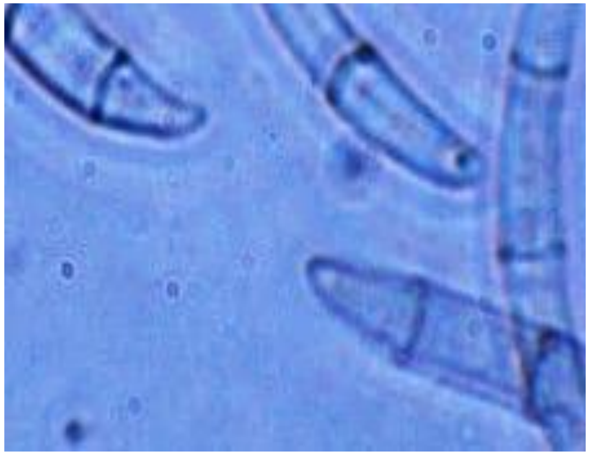
Sources: Hunt et al. (2017, 2019) and unpublished data



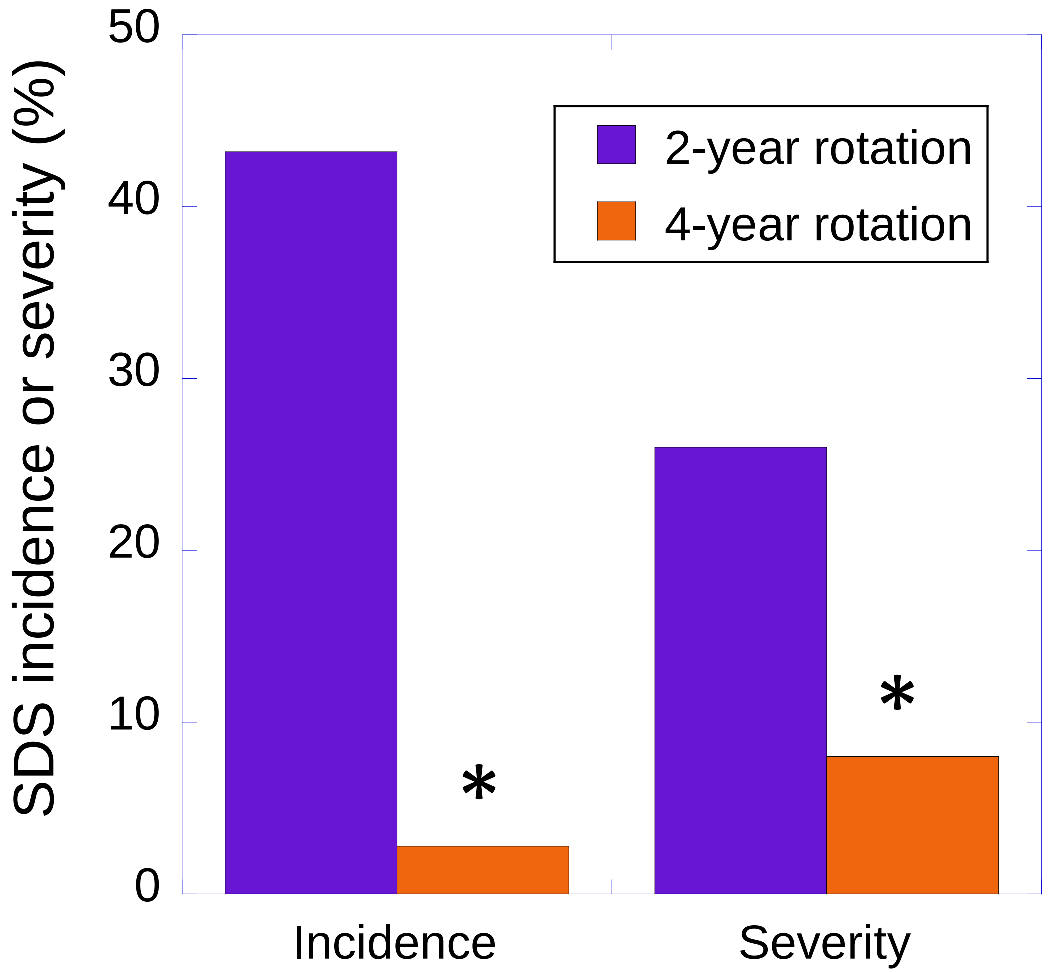
	Yield, Mg/ha			
Rotation	Corn	Soybean	Oat	Alfalfa
2-year	12.0	3.2	---	---
4-year	12.5*	4.0***	3.5	9.4

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



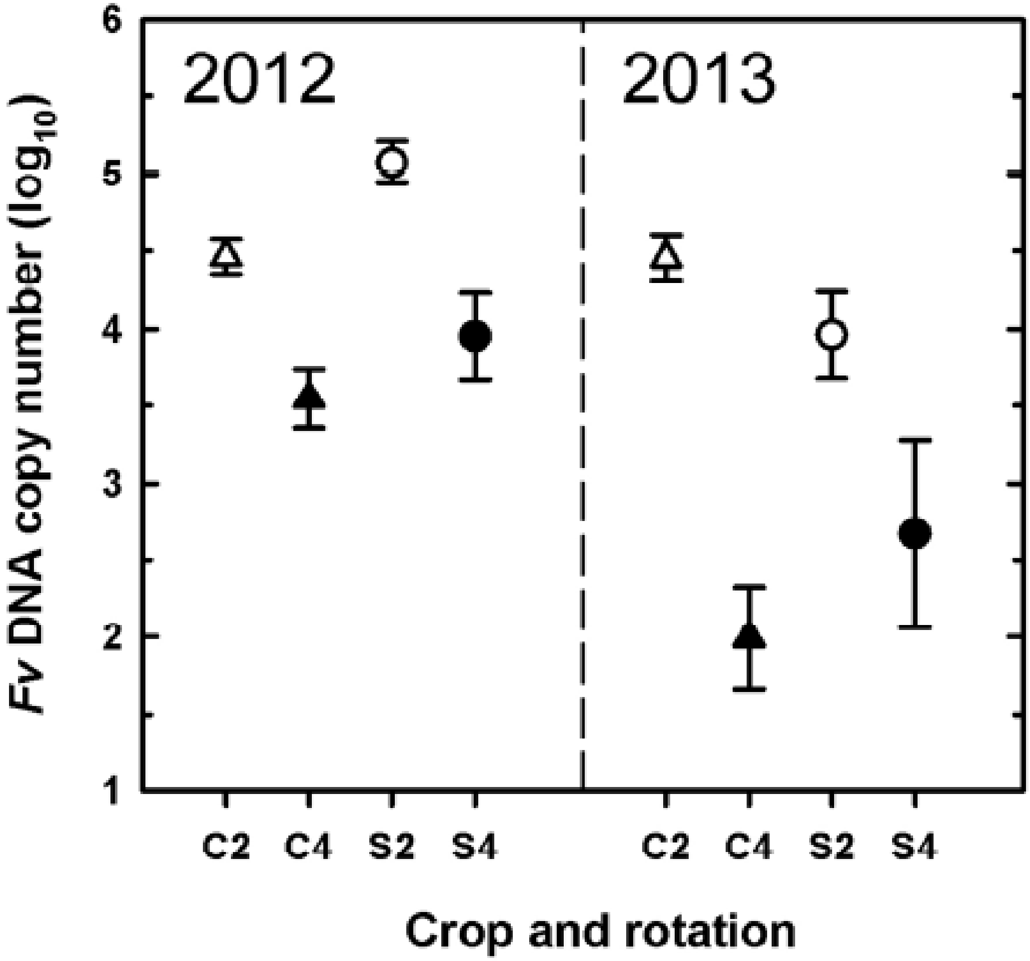
A large reduction in soybean sudden death syndrome was observed in the longer rotation during 2010-2015.



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

Leandro et al. (2018), doi:10.1094/PDIS-11-16-1660-RE

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



C: corn
S: soybean
2: 2-yr rotation
4: 4-yr rotation

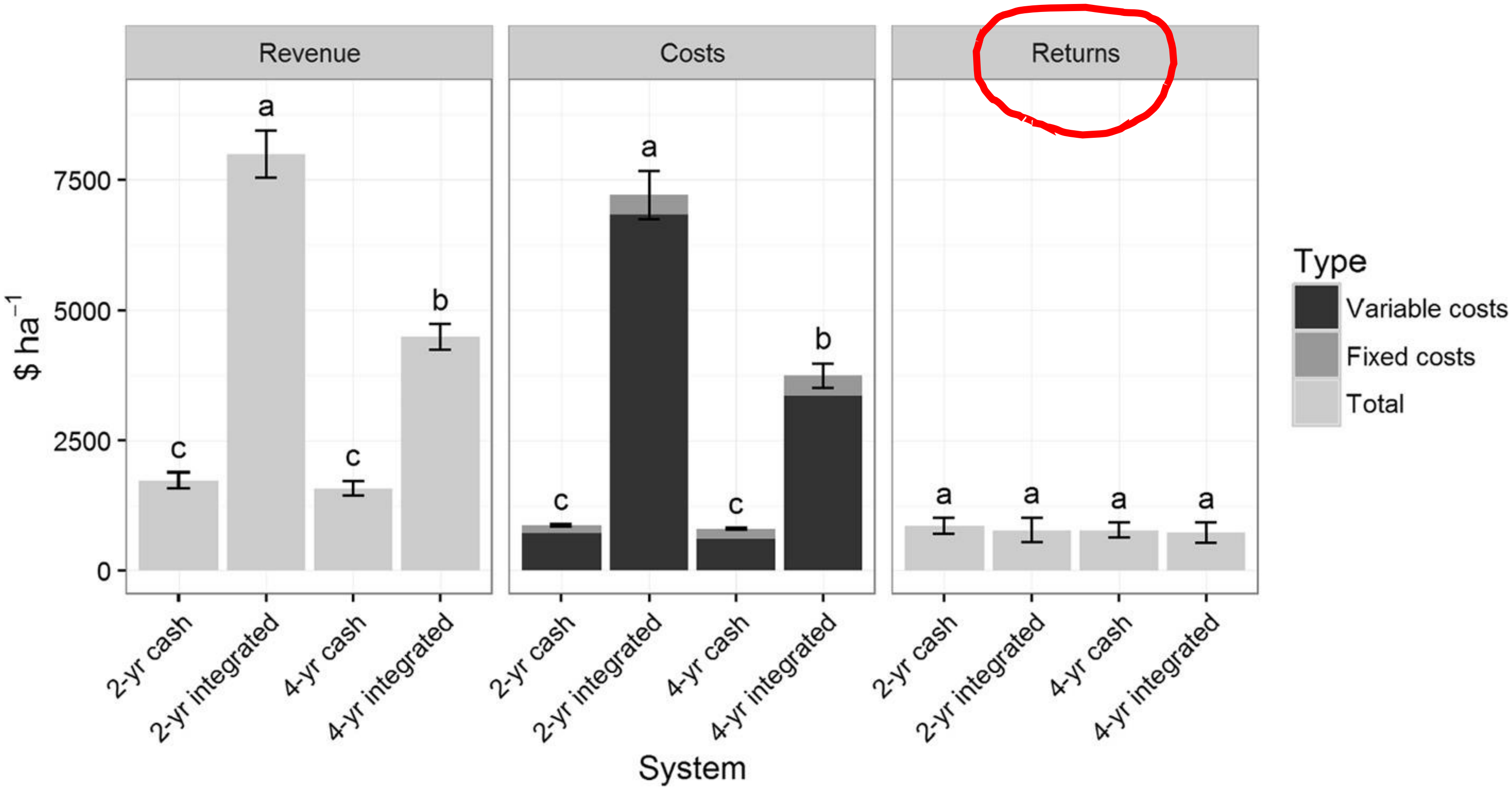
Leandro et al. (2018), doi:10.1094/PDIS-11-16-1660-RE

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}

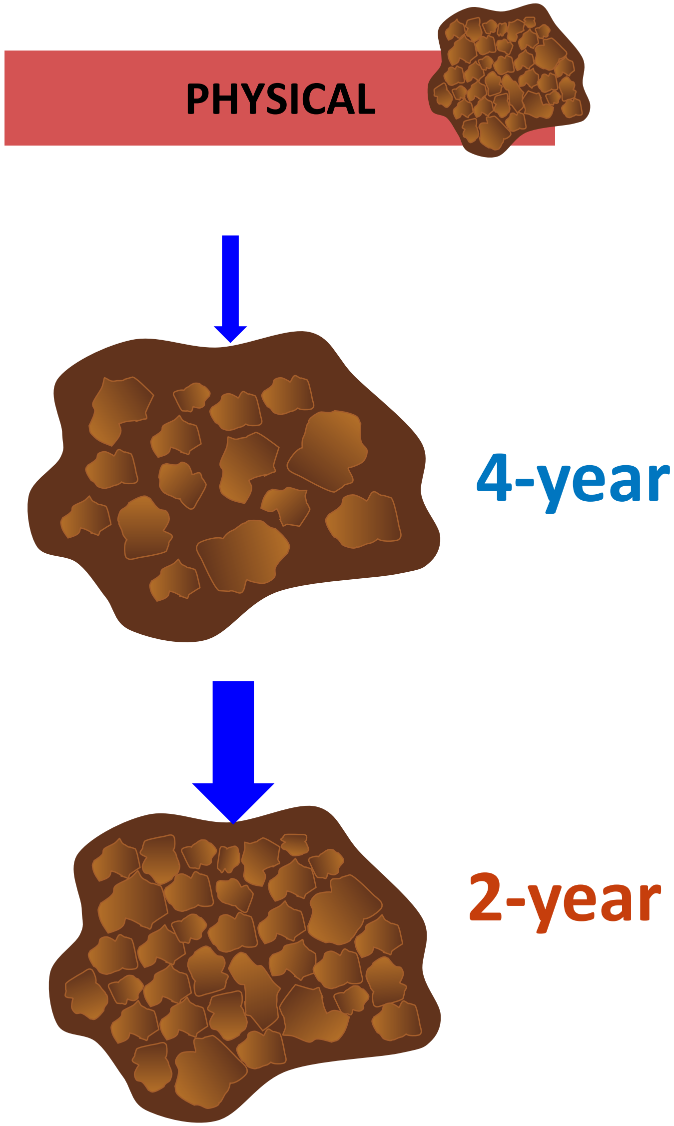
Hunt et al. (2019) doi:10.1021/acs.est.8b02193 and unpublished data

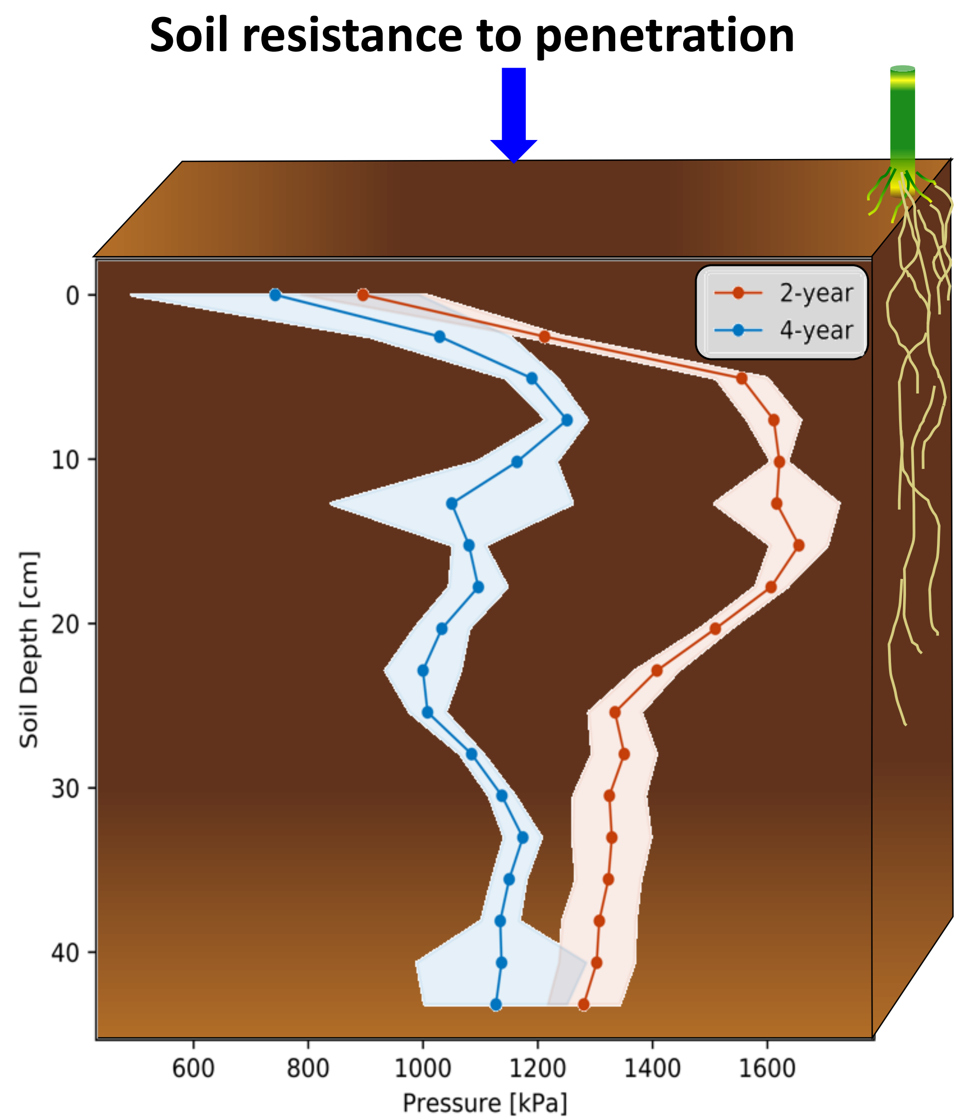
Returns to land and management were similar among systems when considering both crops and livestock



cash: only crops
integrated: crops + livestock

Poffenbarger et al. (2017), http://dx.doi.org/10.1016/j.agsy.2017.07.001





Diversification reduced soil resistance to penetration by 25.8% Baldwin-Kordick 2019

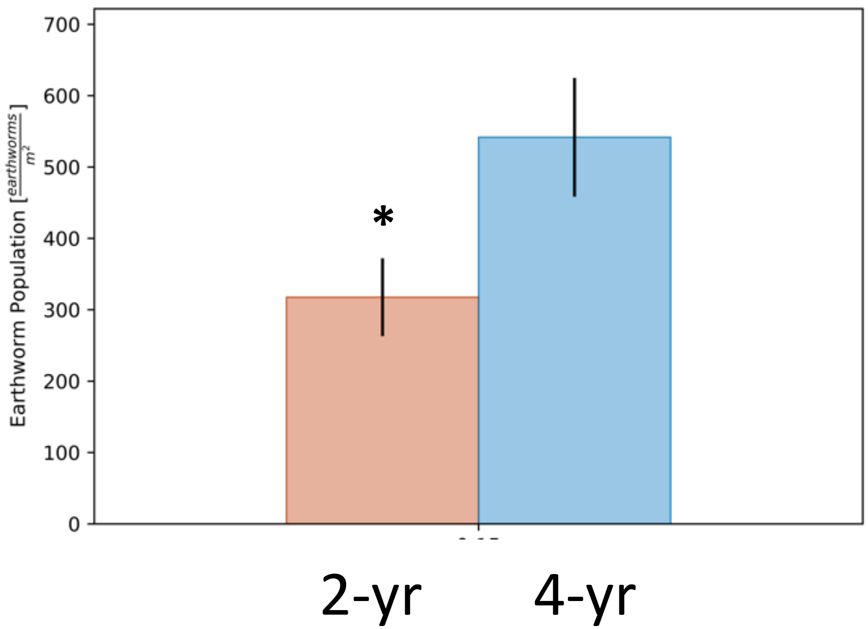
Diversification increased soil particulate organic matter C and microbial biomass.

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

Baldwin-Kordick 2019

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***

Hunt et al., unpublished data

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***

Hunt et al. (2017) doi:10.1021/acs.est.6b04086,
Hunt et al. (2019) doi:10.1021/acs.est.8b02193, and unpublished data

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

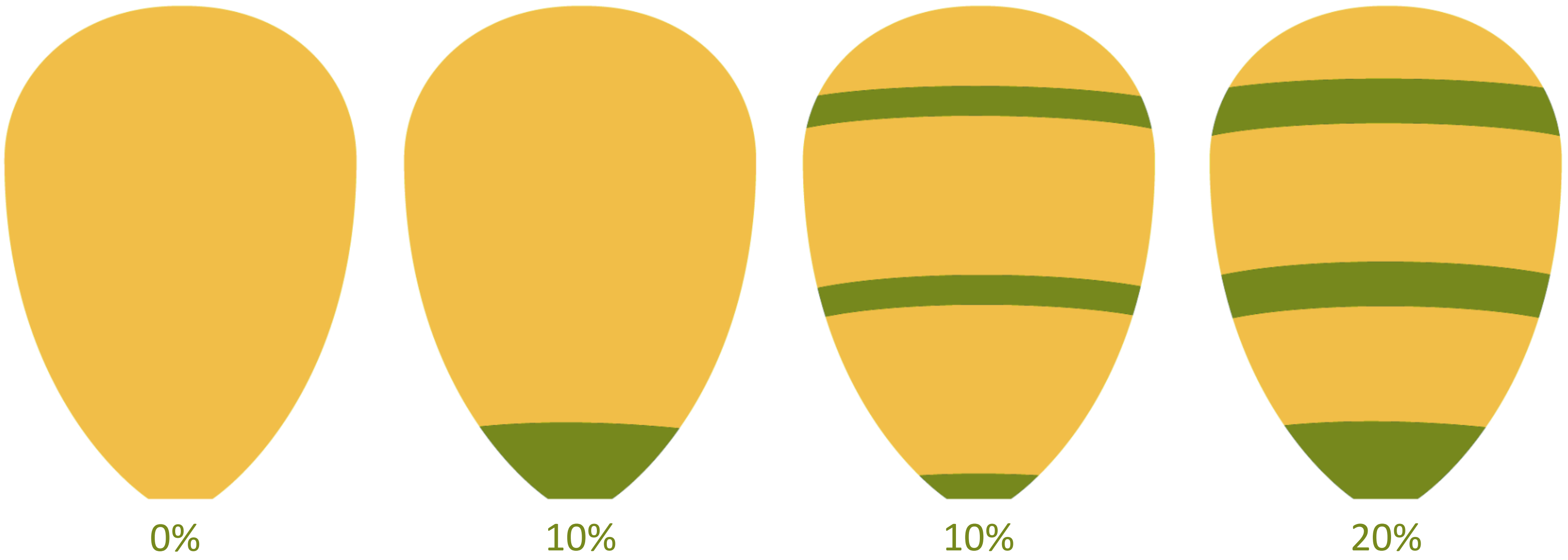
STRIPS is a team of scientists, educators, farmers, and extension specialists working on the prairie strips farmland conservation practice.

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



= no-till corn and soybean ***row crops***

= reconstructed ***prairie***

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 NO_3-N concentrations**
- **77% reduction in total P loses 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

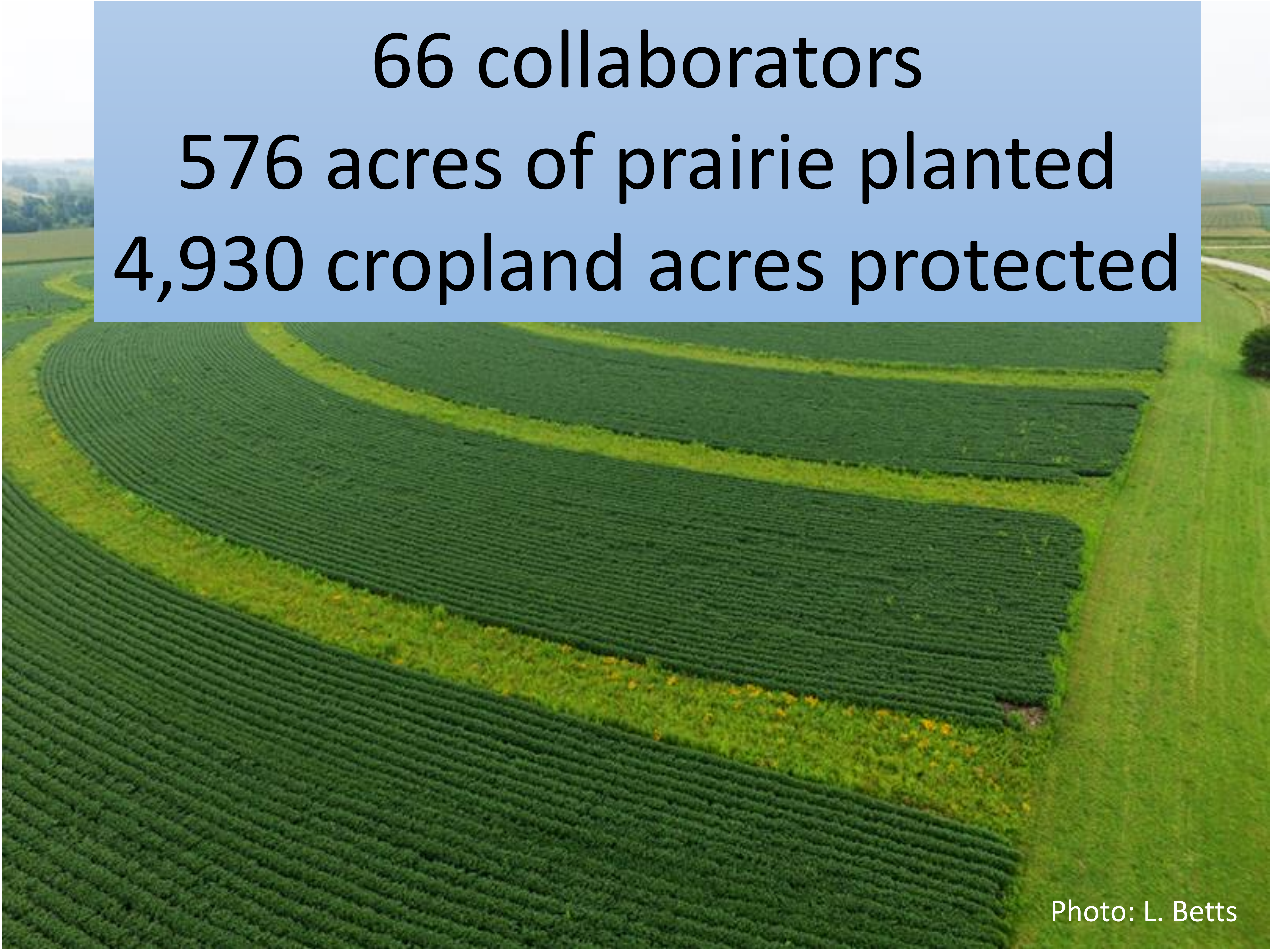


Photo: L. Betts

Building a community of support

Iowa State University of Science and Technology — Science with Practice
College of Agriculture & Life Sciences
Leopold Center
U.S. Fish & Wildlife Service — Department of the Interior
Forest Service — U.S. Department of Agriculture

The McKnight Foundation
Iowa Department of Agriculture and Land Stewardship
DNR
Iowa Flood Center
IAWA — Iowa Agriculture Water Alliance
The Walton Family Foundation

USDA Agricultural Research Service
NIFA
FSA — Farm Service Agency
North Central SARE — Sustainable Agriculture Research & Education
McIntire-Stennis Program
NSF

AgSolver
Committee on Agricultural Development
CropLife Foundation
Des Moines Water Works — Water You Can Trust for Life
The Eastern Iowa Airport — Cedar Rapids

Iowa Natural Heritage Foundation
Iowa Soybean Association
N
Roeslein Alternative Energy, LLC
Sand County Foundation
W

Tallgrass Prairie Center — Restoring a National Treasure
Trees Forever — Planting a better tomorrow™
USGS — science for a changing world
Valley Stewardship Network — Partners in stewardship of land and water
Whiterock Conservancy

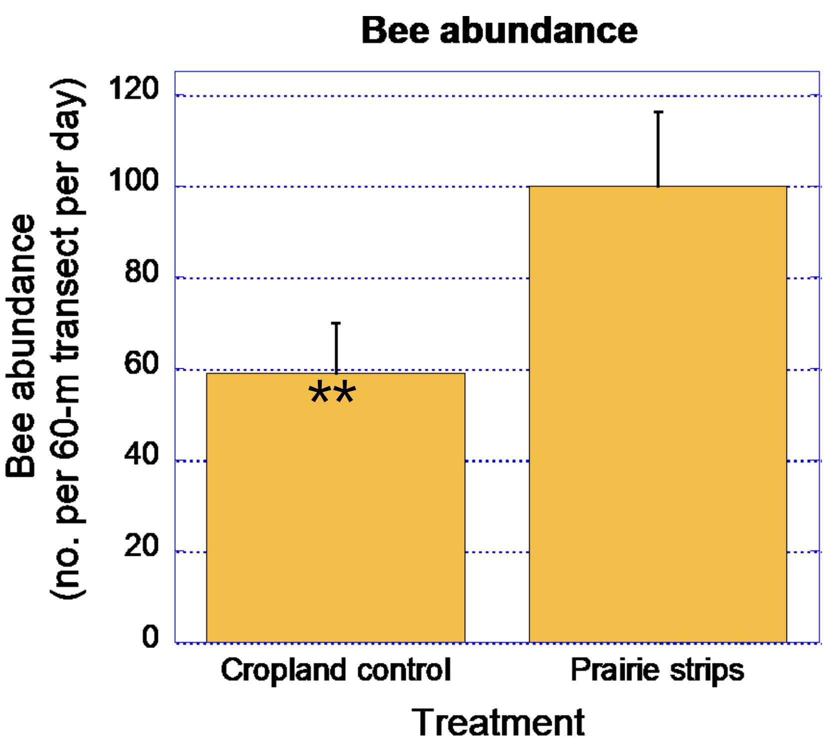
Outreach: Field days with cooperating farmers

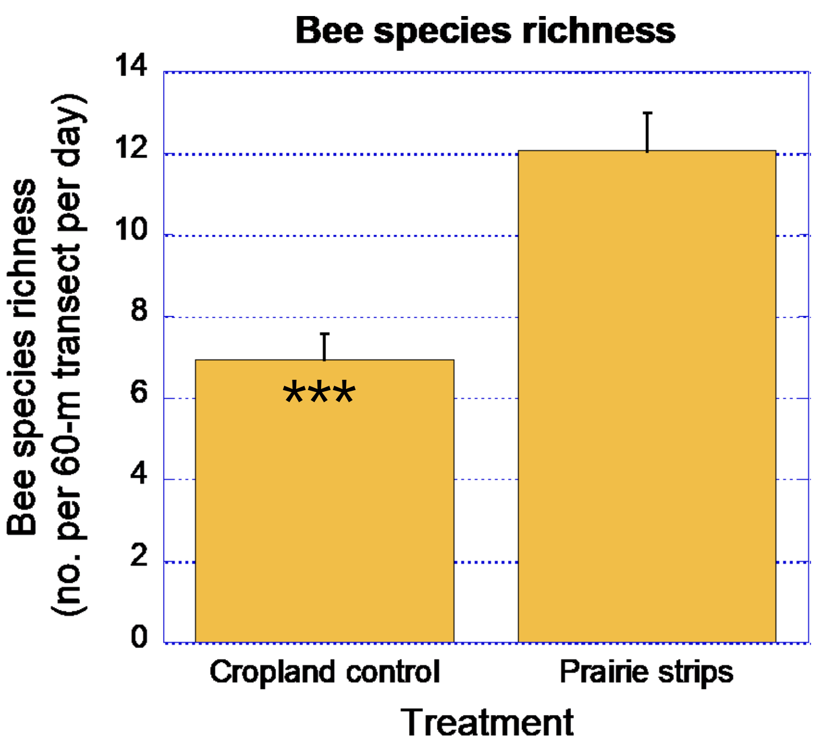
Outreach: www.prairiestrips.org

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.





Source: Kordbacheh et al., *in review*

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

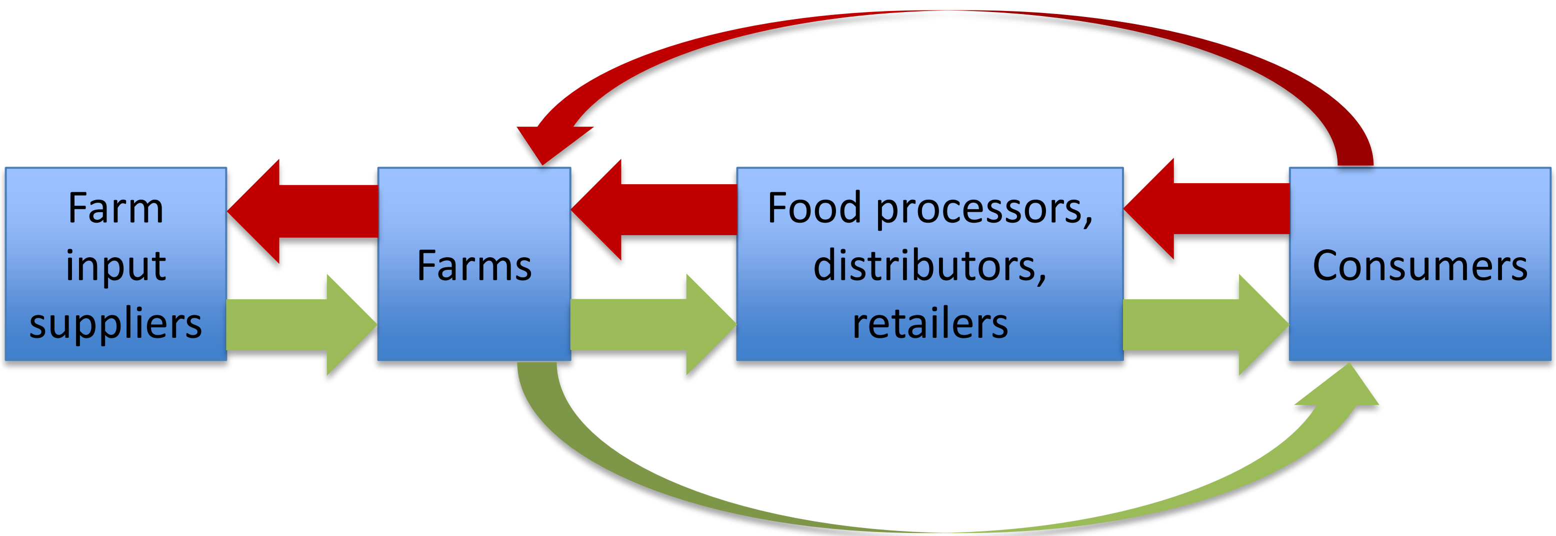
- Government policy
- Market “pull”
- Farmer-to-farmer information exchange

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

Source: Environmental Working Group, http://www.ewg.org

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.

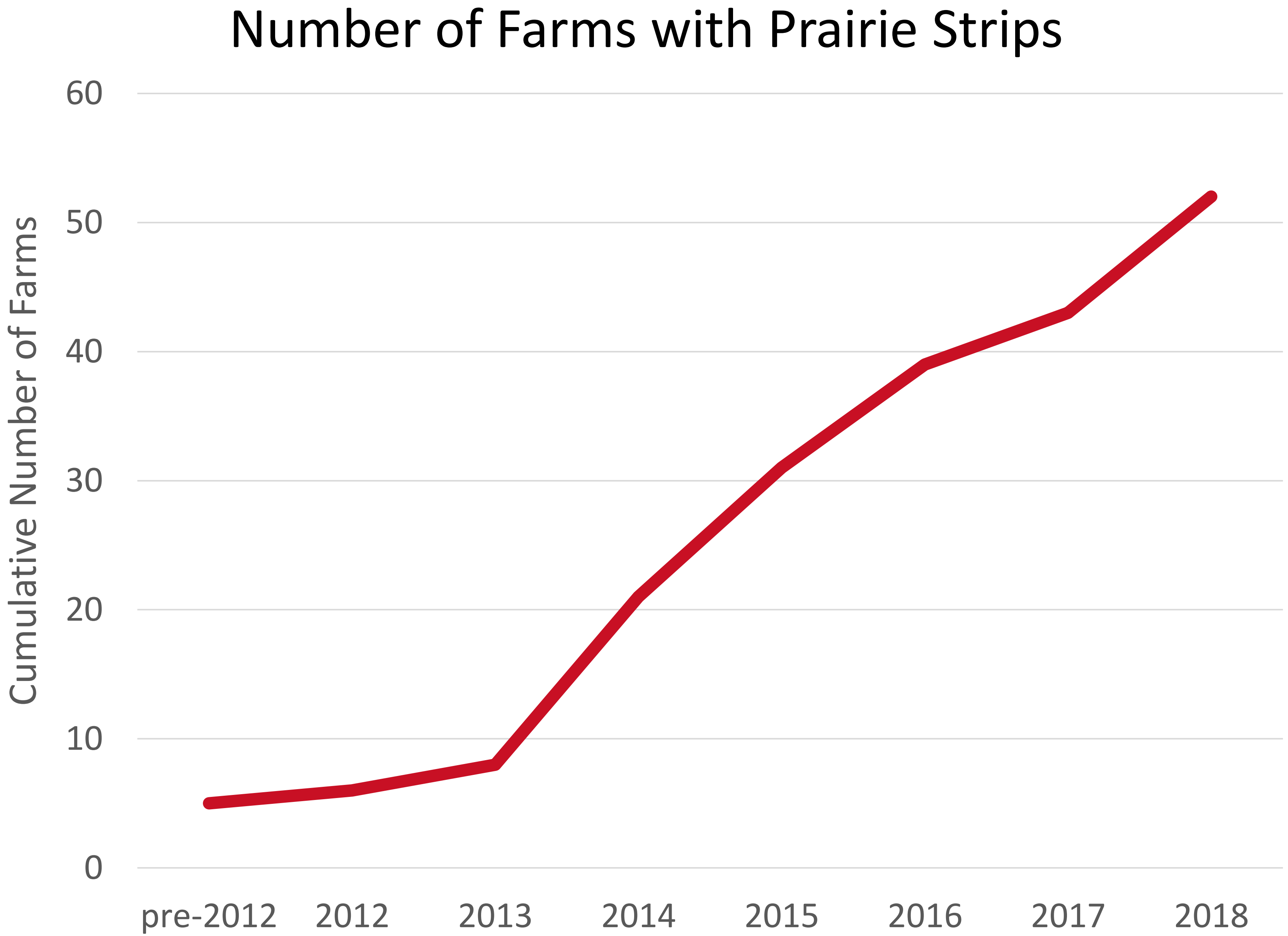
Diversification reduced damage to human health

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 CO_2-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
Cumulative Number of Farms
60
50
40
30
20
10
0
pre-2012
2012
2013
2014
2015
2016
2017
2018

Number of 'Treated' Acres for Farms with Prairie Strips