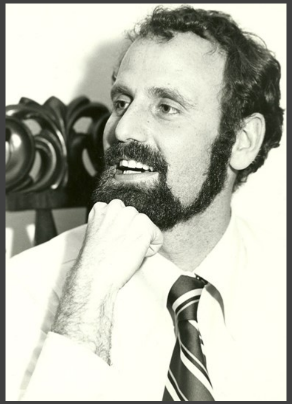
What have we learned over 30 years at the Wisconsin Integrated Cropping Systems Trial?

Randy Jackson, Professor of Grassland Ecology
Department of Agronomy, University of Wisconsin-Madison



Josh Posner

Janet Hedtcke

Gregg Sanford

UW-MADISON CENTER for INTEGRATED AGRICULTURAL SYSTEMS collaborative research on sustainability

USDA U.S. Dairy Forage Research

MICHAEL FIELDS AGRICULTURAL INSTITUTE

USDA United States Department of Agriculture National Institute of Food and Agriculture

COLLEGE OF AGRICULTURAL & LIFE SCIENCES University of Wisconsin-Madison

WICST

Established in 1990

Two locations

- (ARL) Arlington, WI – 1990 to present
- (LAC) Elkhorn, WI – 1990 to 2002

Large plots

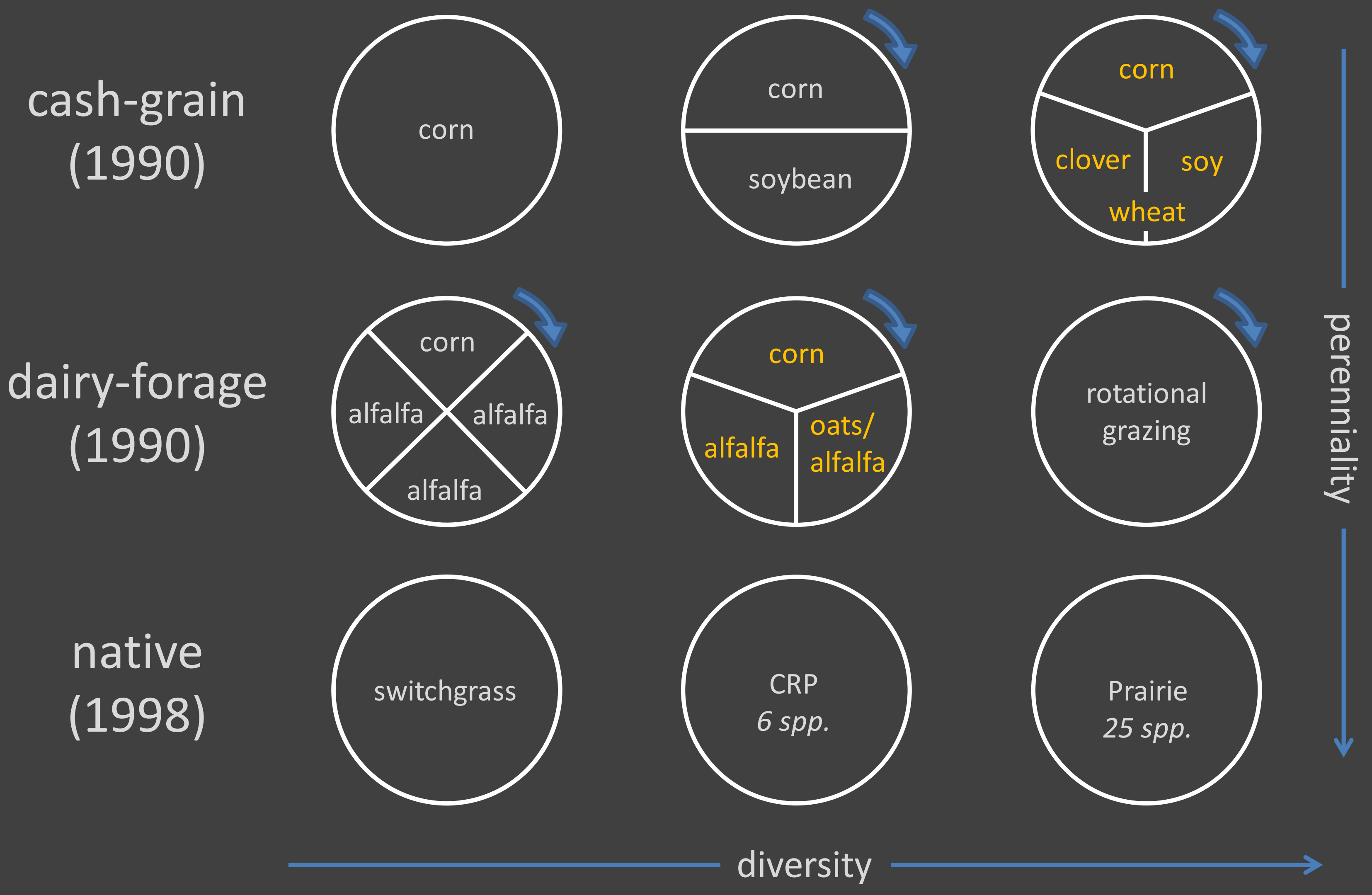
- Plot size = 0.7 ac
- Field-scale equipment

Performance metrics:

- Productivity
- Profitability
- Environment

Integrated cropping systems

4 reps
each phase every year



Core data sets

Management

- agronomic calendars
- field notes/observation
- weather

Profitability

- input prices
- elevator prices
- hay auction prices

Productivity

- yields: grain, forage, pasture
- average daily gain (cattle)
- weed biomass (mid-season)

Environment

- spring & fall nitrates
- fall soil fertility
- soil organic carbon (SOC)
- soil archive

Mark Walsh

Jimmy Sustachek

Outline

1. Productivity
   a. Yields (Posner et al. 2008)
   b. Profitability (Chavas et al. 2009)
   c. Yield stability & resilience (Sanford et al., in prep)
2. Environment
   a. Soil loss (Hedtcke, unpublished)
   b. Soil quality index (Jokela et al. 2011)
   c. SOC change (Sanford et al. 2012)
   d. SOC mechanisms (Rui et al., in prep)
3. Future: Intenisfy, extensify, and relate
   a. Sustainable intensification to build SOC (Sanford & Jackson, USDA)
   b. Expand inference space (Jackson et al., US DFRC)
   c. Feeding models & decision support tools (Kuckarik, Gratton, et al., UW2020)

Productivity

Posner JL, Baldock JO, Hedtcke JL (2008) Organic and conventional production systems in the Wisconsin Integrated Cropping Systems Trials: I. Productivity 1990-2002. ***Agronomy Journal*** 100: 253-260

Hedtcke JL (2012) Pastured heifers grow well and have productive first lactations. ***CIAS Research Brief #89***

Chavas J-PP, Posner JL, Hedtcke JL (2009) Organic and Conventional Production Systems in the Wisconsin Integrated Cropping Systems Trial: II. Economic and Risk Analysis 1993–2006. ***Agronomy Journal*** 101: 288-295

Corn yields (1990-2002)

	Normal spring (May + June ~9" ppt)	
	ARL	LAC
Cropping system	bushel/acre	
CS2: Conventional corn-soybean	173	132
CS3: Organic corn-soybean-wheat	167	124
Organic : conventional	96%	94%

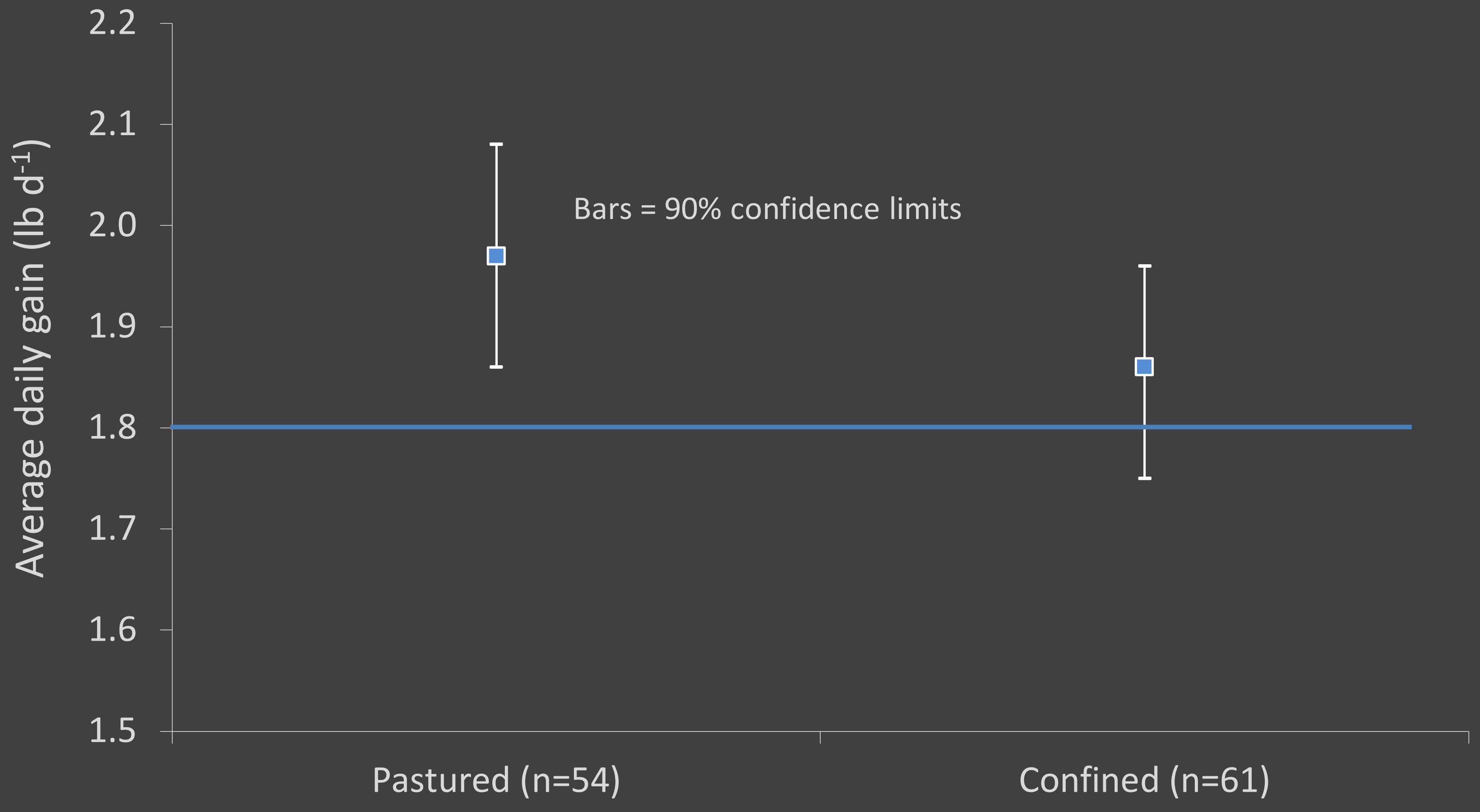
Posner et al. 2008

Soybean yields (1990-2002)

	Normal spring (May + June ~9” ppt)	
	ARL	LAC
Cropping system	bushel/acre	
CS2: Conventional corn-soybean	57	53
CS3: Organic corn-soybean-wheat	54	49
Organic : conventional	95%	92%

Posner et al. 2008

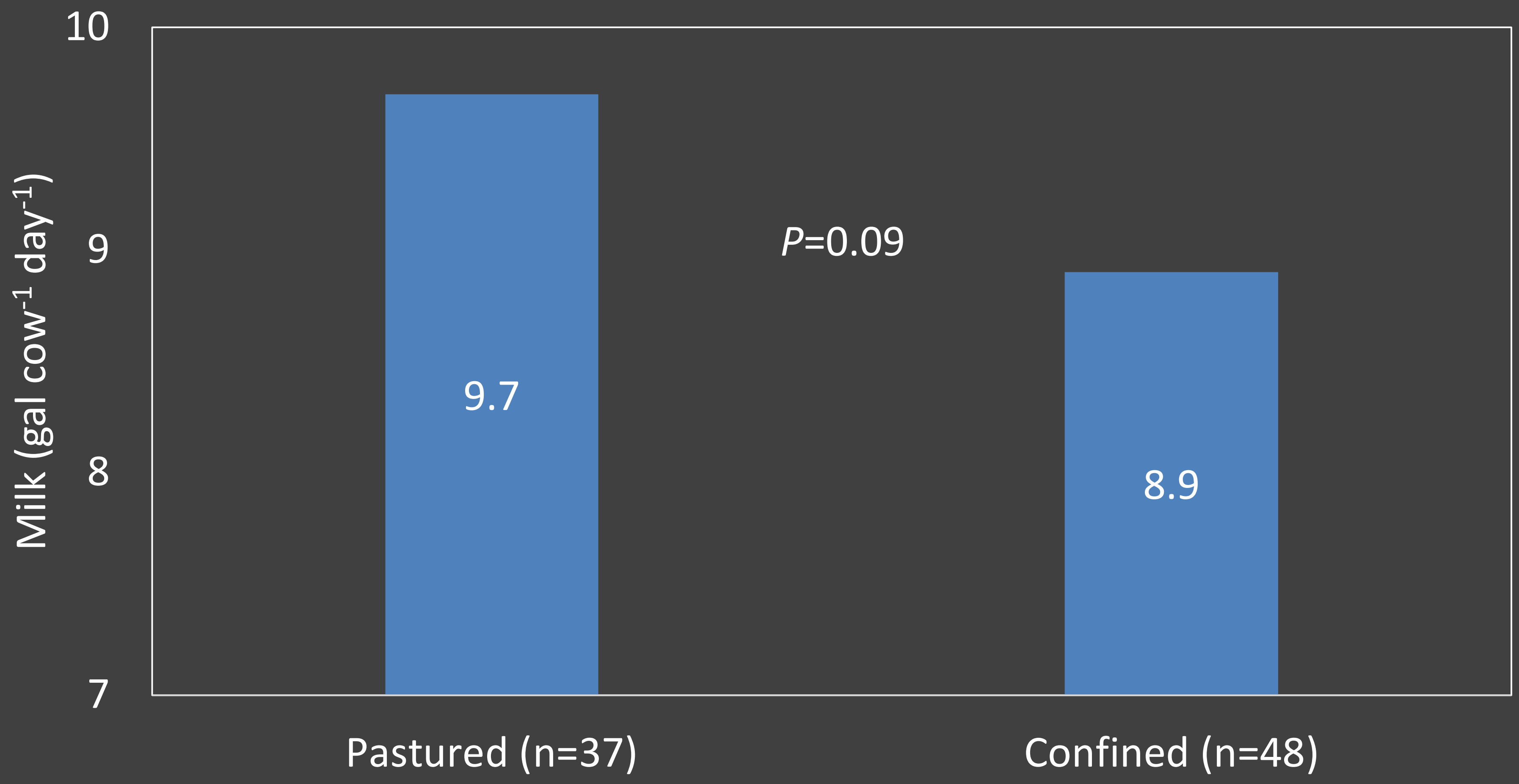
Grazed heifers performed as well as confined animals



Hedtcke 2012

Haley MeLampy

Grazed heifers performed as well as confined animals



Hedtcke 2012

Grazing most profitable WICST system

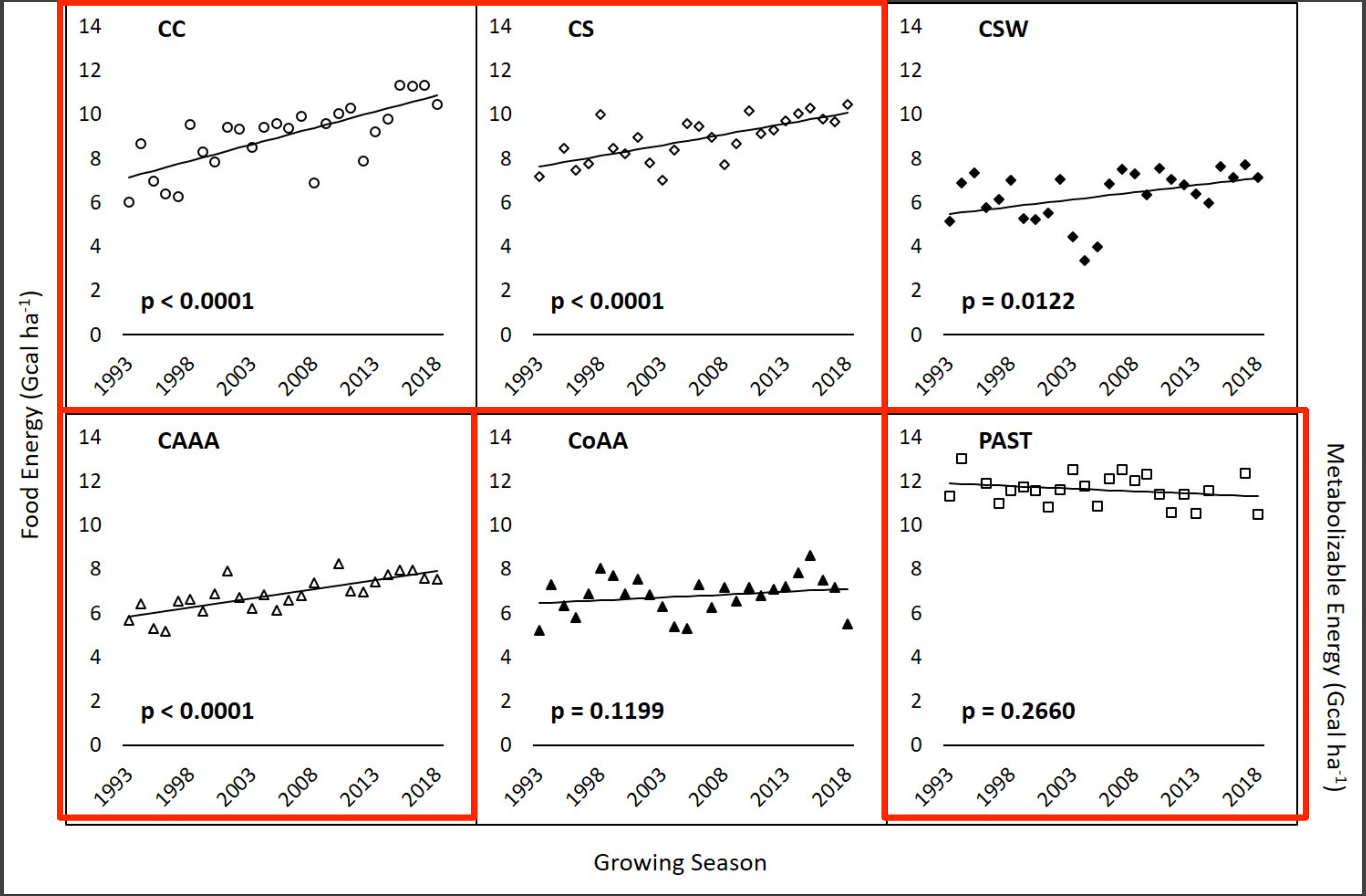
Table 3. Economic mean returns under alternative scenarios in the Year 2000.

System	Arlington: No government payment or organic premium (Scenario 1)	Arlington: Government payment only (Scenario 2)	Arlington: Government payment + organic premium (Scenario 3)	Elkhorn: No government payment or organic premium (Scenario 1)	Elkhorn: Government payment only (Scenario 2)	Elkhorn: Government payment + organic premium (Scenario 3)
	$ ha^{-1}					
S1 Continuous corn	365d†	540c	540b	69d	199d	199c
S2 No-till corn-soybean	465c	574b	574b	361b	416b	416b
S3 Organic grain corn-soybean-wheat	335d	423d	784a	212c	275d	581a
S4 Intensive alfalfa	535b	535c	535b	212c	212d	212c
S5 Organic forage	528bc	528c	717a	376b	376c	528a
S6 Rotational grazing	735a	735a	735a	592a	592a	592a

† Within a scenario (column), numbers followed by a different letter are significantly different at the 0.05 level.

Chavas et al. 2009

Energy yields over 26 years



Yield resistance (observed/predicted)

-2sd palmer Z index (drought)

- year: 2012

System p<0.0001

Organic & Pasture: CoAA, CSW, PAST; Corn: CC

System	CoAA	CSW	PAST	CS	CAAA	CC
Estimate	1.0231	1.0127	0.9946	0.9787	0.9376	0.7905
Group	A	A	A	AB	B	C

+2sd palmer Z index (excess)

- year: 2018

System p<0.0001

Corn-Soybean: CS, CSW; Perennials: CAAA, PAST, CoAA

System	CS	CSW	CC	CAAA	PAST	CoAA
Estimate	1.0395	1.0057	0.9621	0.9551	0.9282	0.7756
Group	A	AB	BC*	C*	C*	D*

Environment

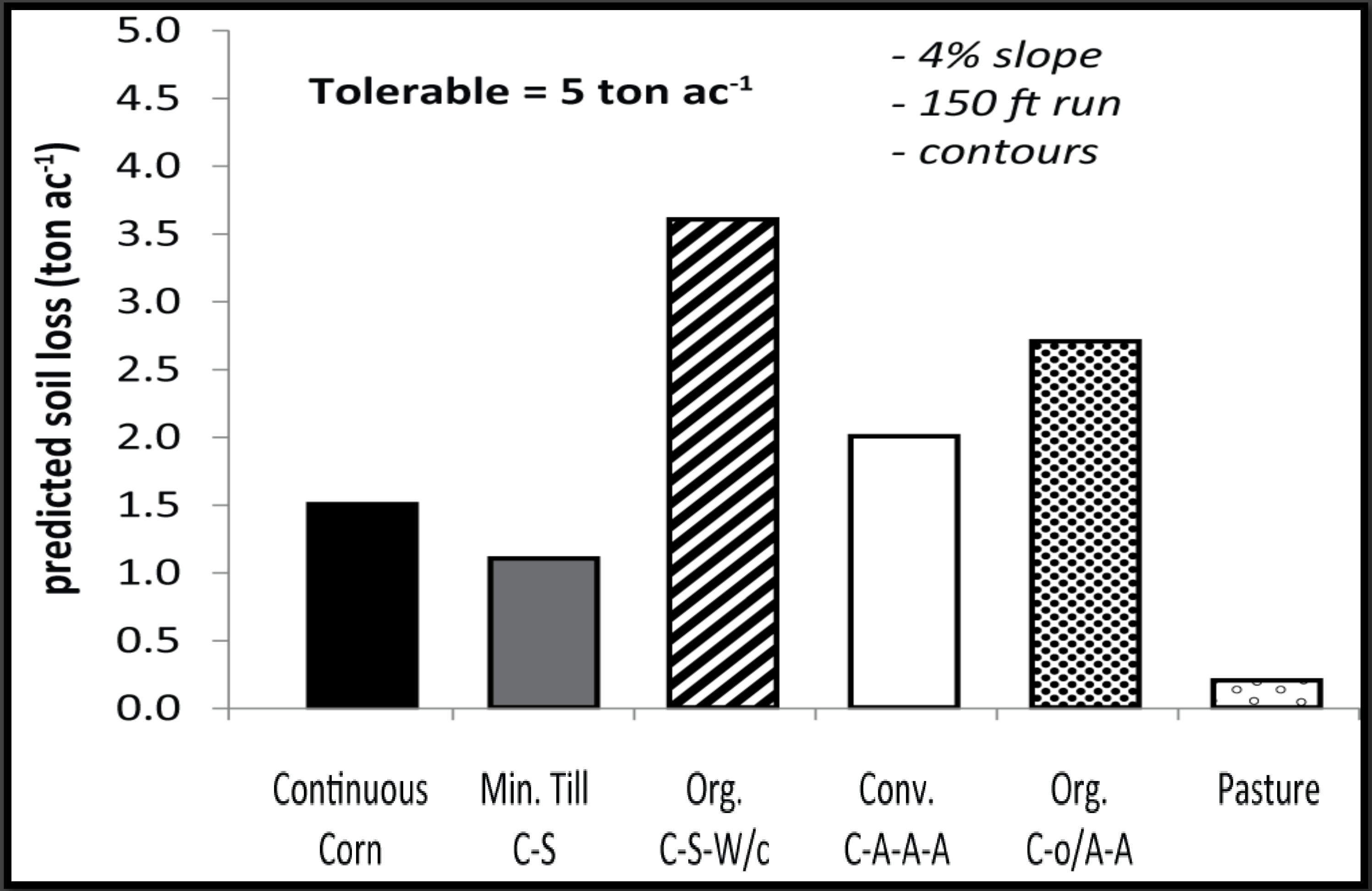
Sanford GR, Posner JL, Jackson RD, Kucharik CJ, Hedtcke JL, Lin T-L (2012) Soil carbon lost from Mollisols of the North Central U.S.A. with 20 years of agricultural best management practices. ***Agriculture, Ecosystems & Environment*** 162: 68-76

Cates AM, Ruark MD, Hedtcke JL, Posner JL (2016) Long-term tillage, rotation and perennialziation effects on particulate and aggregate soil organic matter. ***Soil and Tillage Research***, 155: 371-380

Vereecke L, Silva E (201x) Soil microbial metagenomics in the Wisconsin Integrated Cropping Systems Trial. *In prep*

Jokela W, Posner J , Hedtcke J, Balser T, Read H (2011) Midwest cropping system effects on soil properties and on a soil quality index ***Agronomy Journal*** 103: 1552-1562

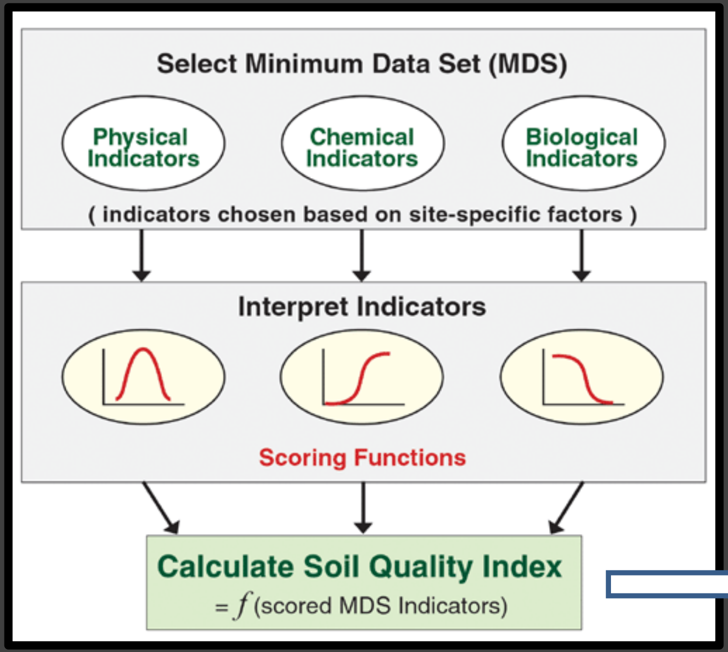
Soil loss (RUSLE2)



Hedtcke et al., unpublished

Soil quality index (SQI)

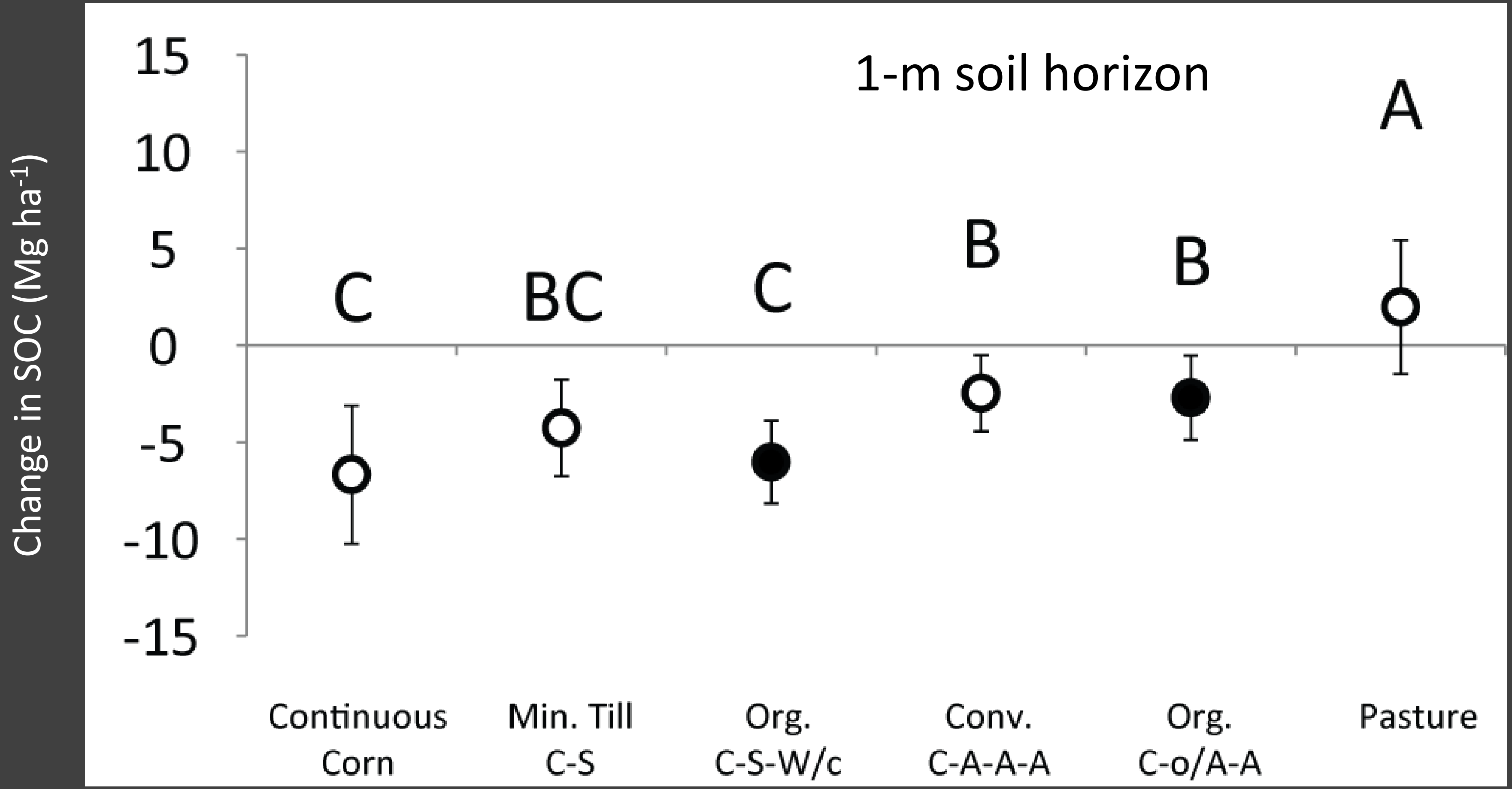
- SOC
- water-stable aggregates
- water holding capacity
- mineralizable N
- microbial biomass C
- bulk density
- water-filled pore space
- soil pH
- soil test P



Cropping system	0-5 cm	5-20 cm
Pasture	96	84
All others	87	78
P-value	*0.01*	*>0.05*

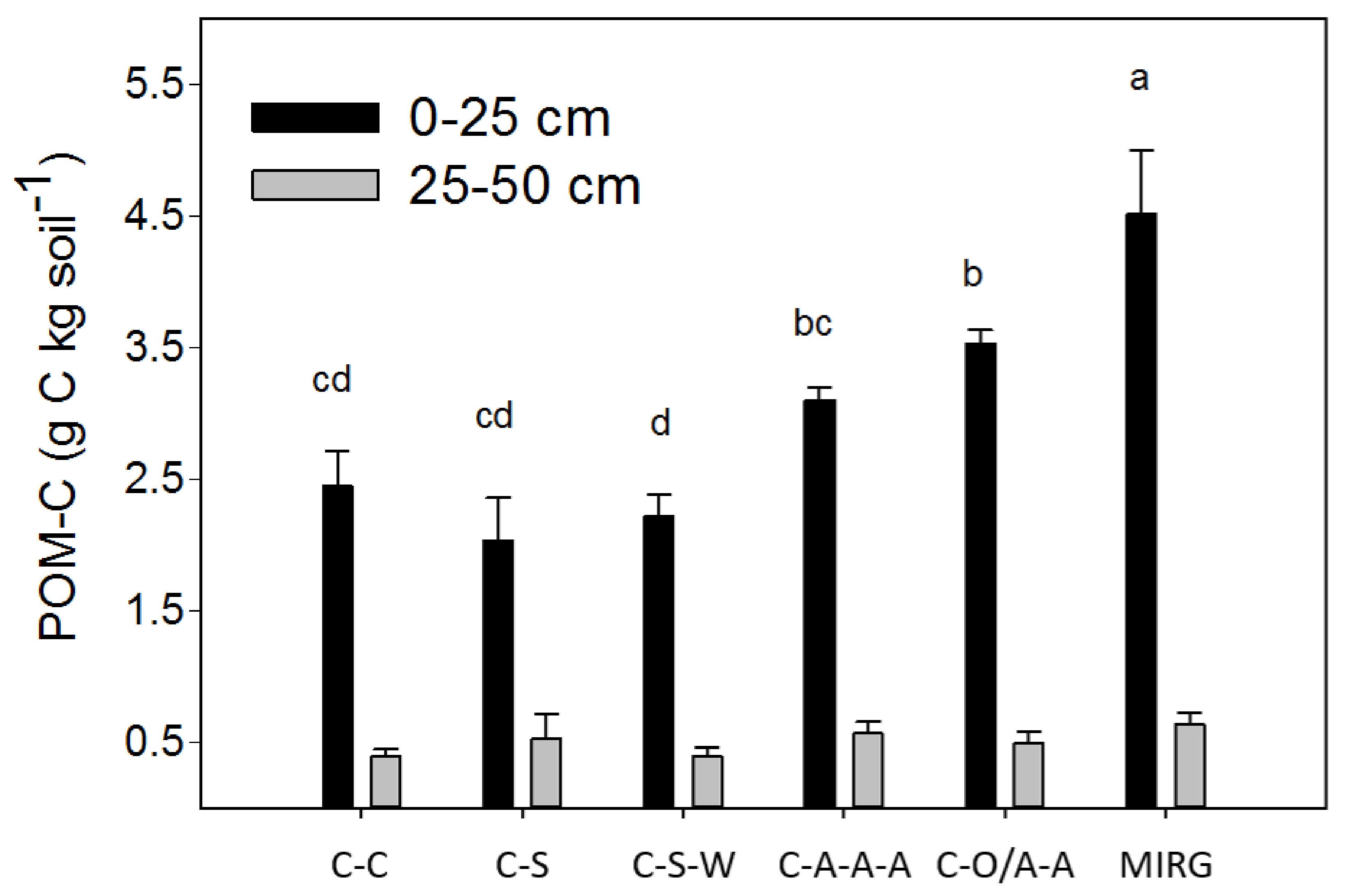
Jokela et al. 2011

Most systems losing soil organic carbon



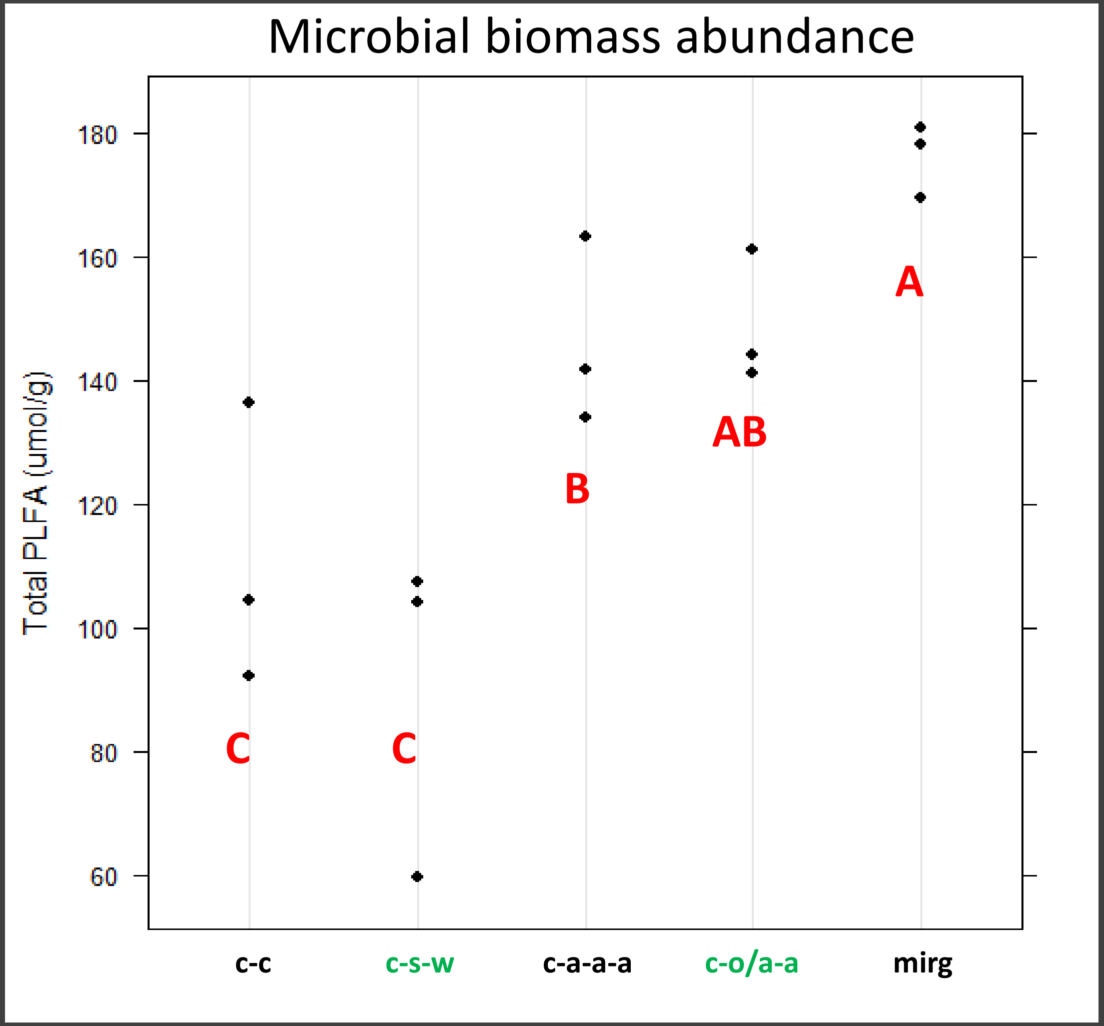
Sanford et al. 2012

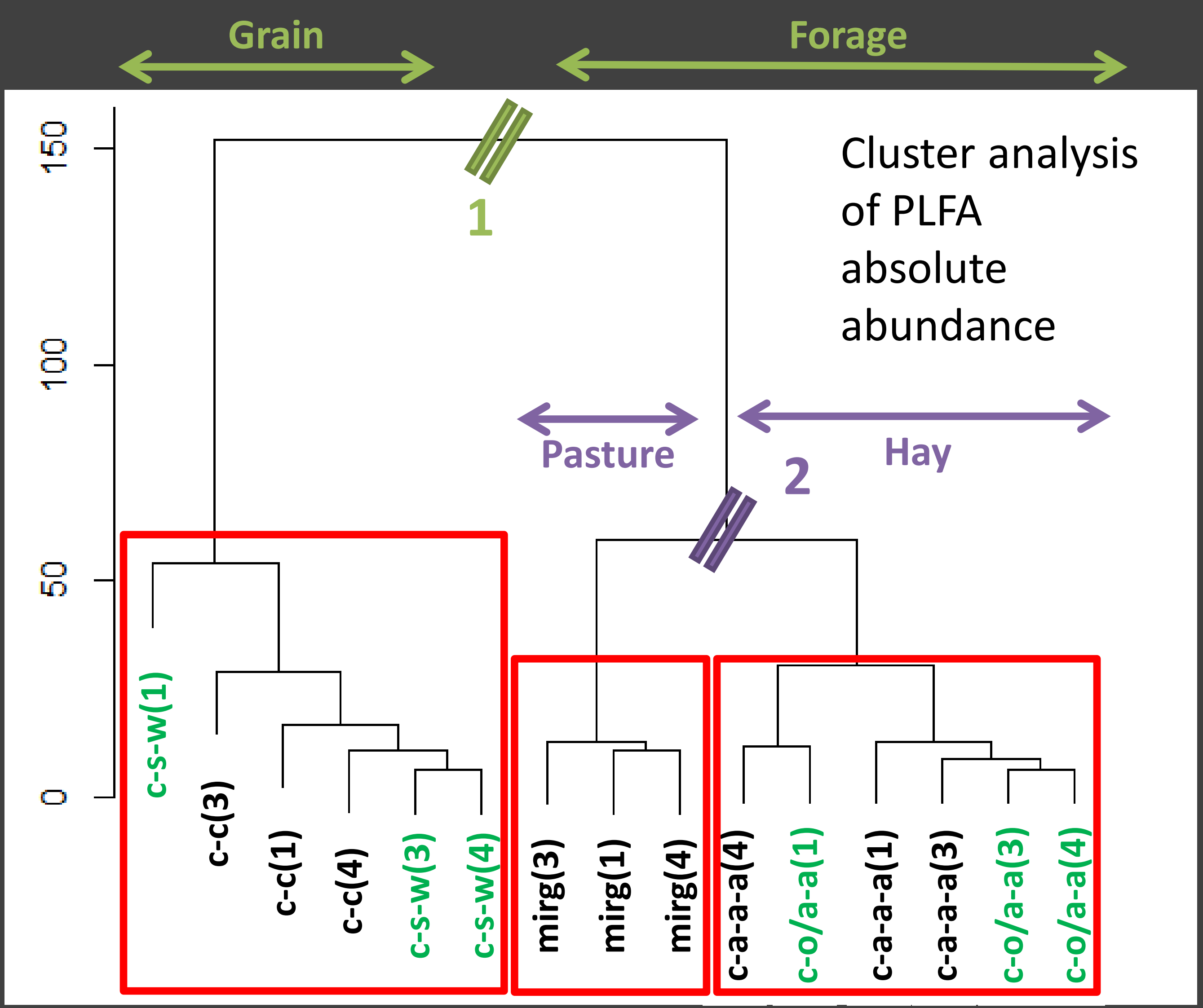
C accumulating in surface POM…



Cates et al. 2016

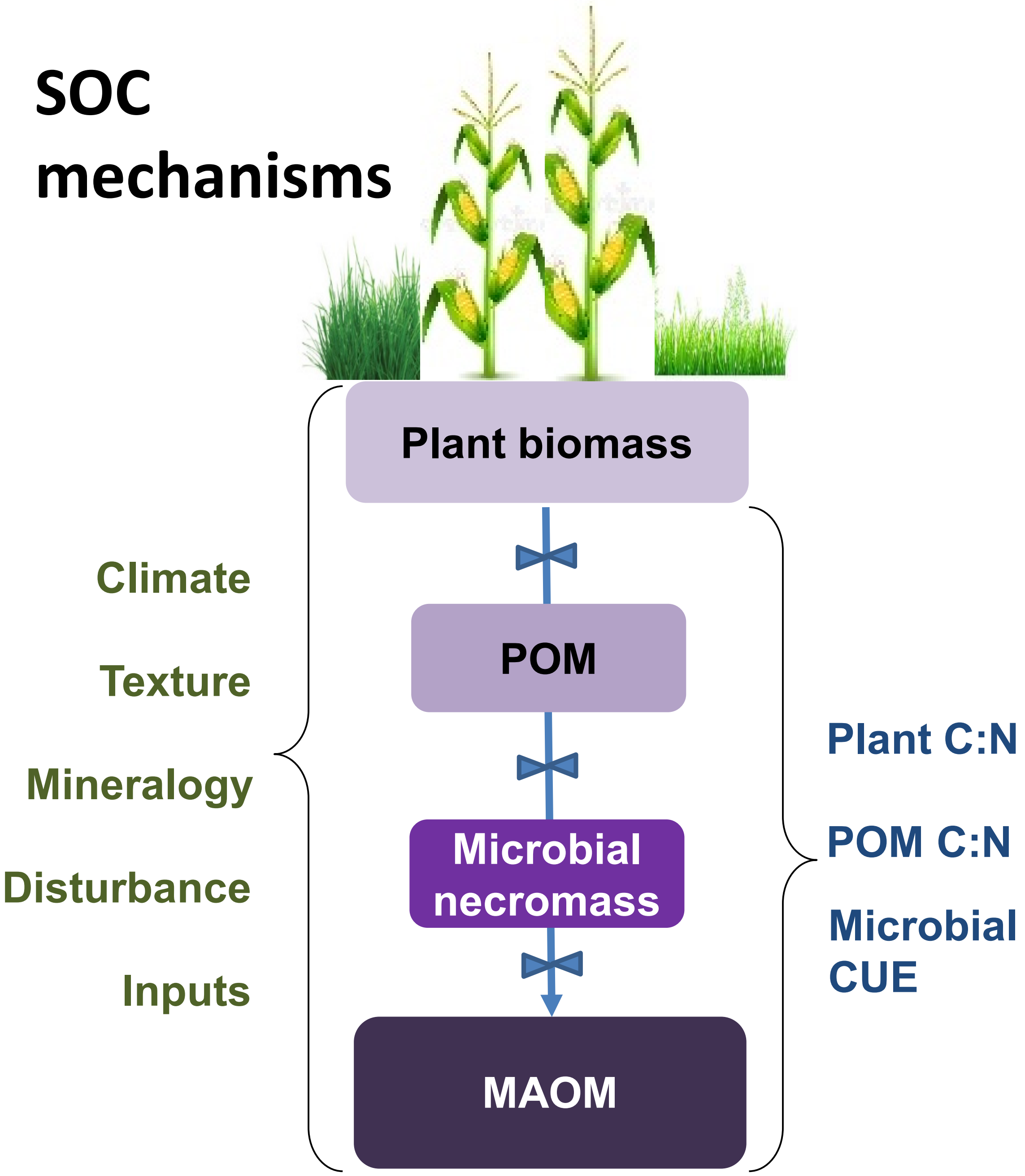
…and microbial biomass…whose composition differs by cropping system

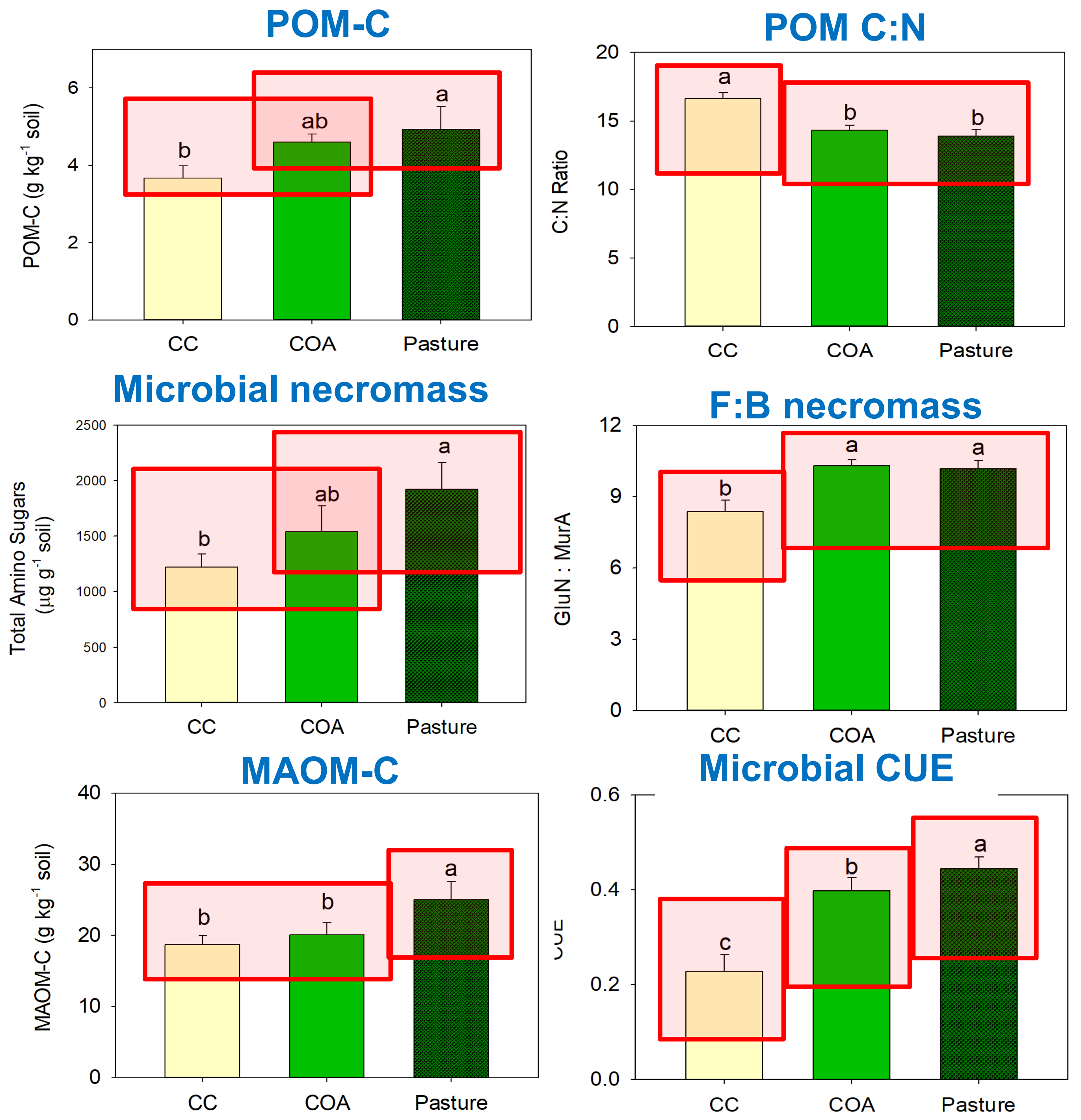




Vereecke, in prep

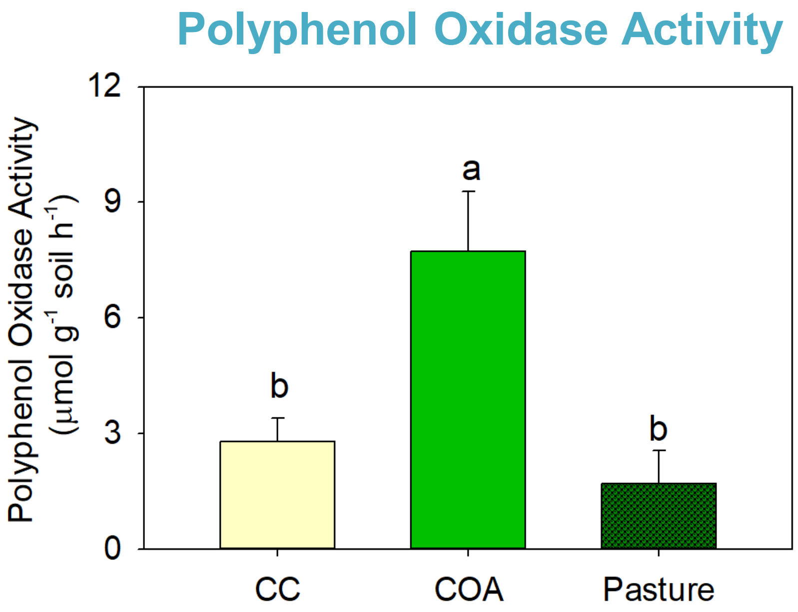
SOC mechanisms

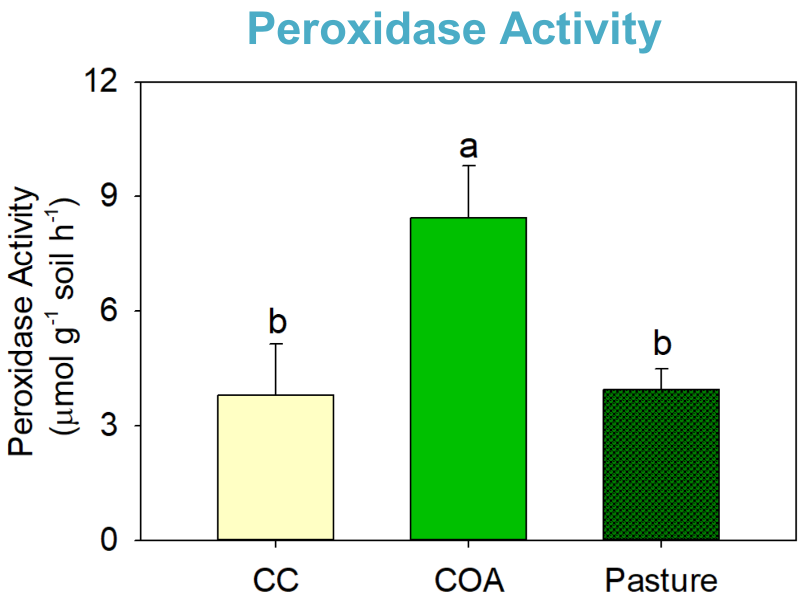


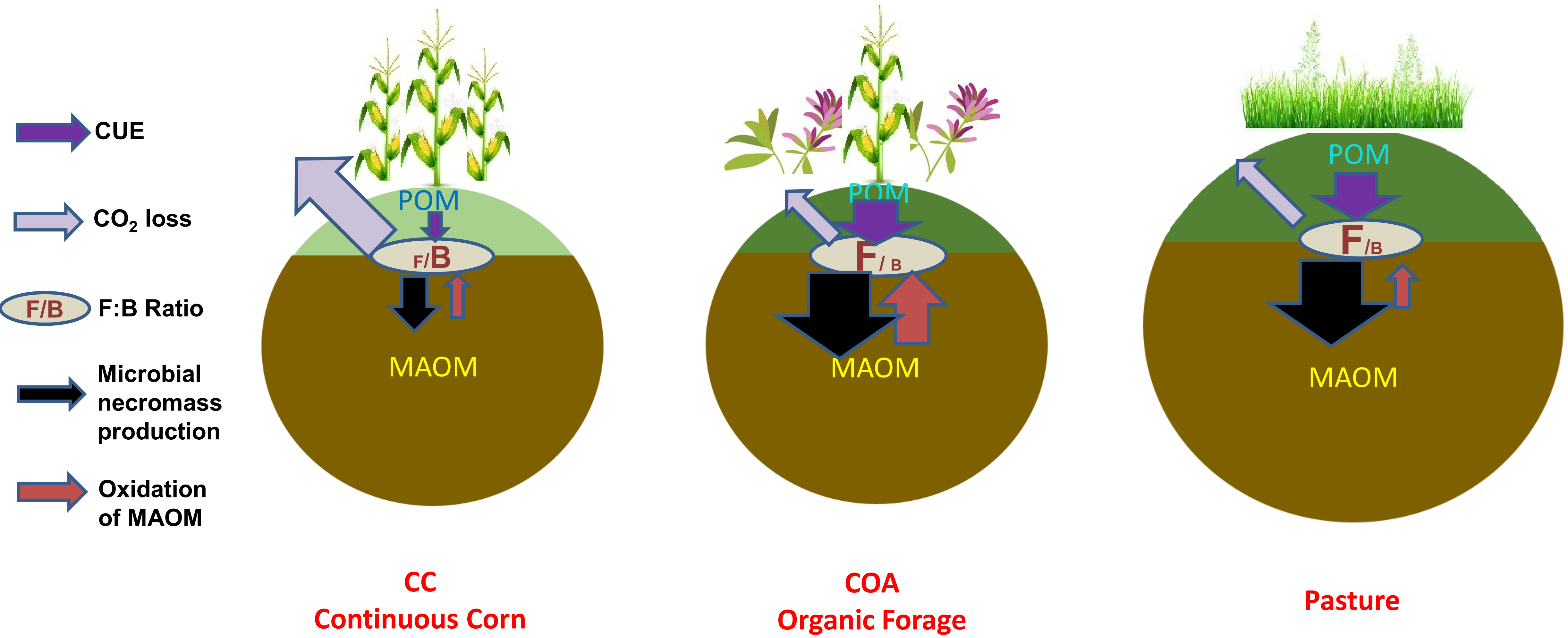


Rui, in prep

Higher oxidative enzyme activity in COA







CUE
CO_2 loss
F/B
F:B Ratio
Microbial necromass production
Oxidation of MAOM
POM
F/B
MAOM
POM
F/ B
MAOM
POM
F/B
MAOM
CC
Continuous Corn
COA
Organic Forage
Pasture

Summary of past & current research

Productivity

1. Organic ~ Conventional when weeds controlled
2. Perennials more reliable in drought, annuals in excess
3. Organic and pasture yields have room for impro

Profitability

1. Organic > Conventional w/
2. Managed grazing mo

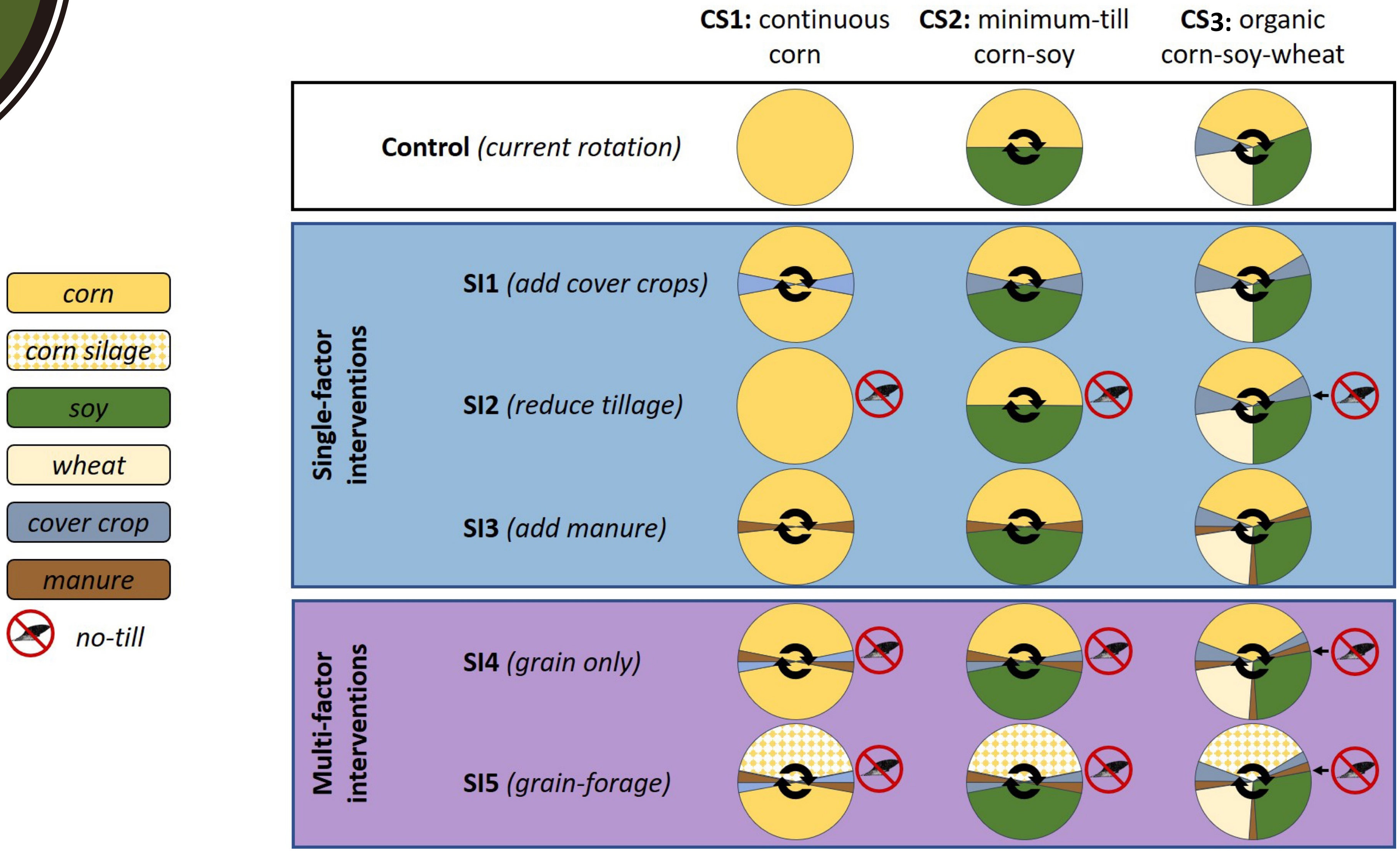
Grassland!

Environment

1. W ment in organic systems resulting in higher soil losses
2. al systems losing soil C, perennials holding on
3. xploring microbial mechanisms for SOC accrual

Future

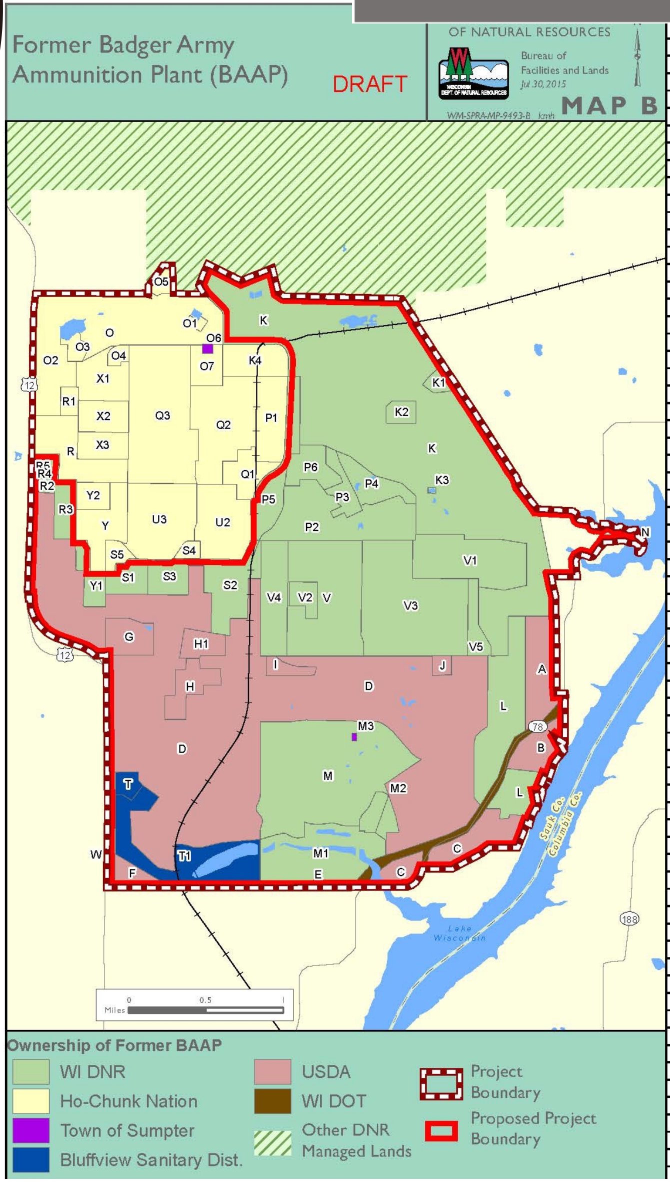
Intensify



US Dairy Forage Research Center

Future

Extensify



A	North River Corridor Buffer	89
B	South River Corridor Buffer	55
C	Southeast Corner	114
D	North and East Magazines	1,669
E	South Buffer	12
F	Southwest Corner	20
G	Conservation Club Area	45
H	Propellant Burning Ground	45
H1	Gate 16 Change Houses	30
I	Landfill # 2 Area	17
J	Inert Disposal Area	10
K	Northeast Corner	1,168
K1	Landfill #5	12
K2	Deterrent Burning Ground	
K3	Wood Duck Pond	
K4	East Ball Powder Pilot Plan	
L	River Corridor	
M	North Magazines	
M1	Settling Ponds/South Magaz	
M2	Geotube Laydown Area	
M3	Thoelke Cemetery	
N	River Pump	
O	Northwest Corner	
O1	Filtration Plant	
O2	Miller Cemetery	
O3	Ballistics Range	
O4	Solvent Recovery Still	
O5	Cannon Range	
O6	Pioneer Cemetery	
O7	West Ball Powder Pilot Plan	
P1	Historic Shops Area	
P2	Rocket Paste Area	
P3	Old NG	
P4	NG Pond Area	
P5	Railroad Scale Area	
P6	New Acid & New NG	
Q1	Box Wash Area	
Q2	B & C Line Rest Houses	
Q3	B & C Line Central Area	
R	Production Support and Lab	
R1	Old Acid Area	
R2	Well #1	
R3	Maintenance & Salvage Are	
R4	Administration Area	
R5	Building 200	
S1	Ball Powder Wet Line	
S2	Metal Rest Houses	
S3	Ball Powder Coating Line	
S4	Ball Powder Dry Houses	
S5	Ball Powder Rework	
T	WWTP Area	
T1	IRM/MIRM/Final Creek/SP1	
U2	D&E Lines Rest Houses	
U3	D&E Lines Central Area	
V	West Rocket Production	
V1	Landfill #6	
V2	West Rocket Roll House	
V3	East Rocket Production	
V4	West Rocket Press Houses	82
V5	East Rocket Press Houses	29
W	Southwest Corner	47
X1	Open Space	58
X2	B Nitrocellulose Line	42
X3	C Nitrocellulose Line	37
Y	E Nitrocellulose Line	68
Y1	F Line Area	33
Y2	D Nitrocellulose Line	24

Future

Relate

…care for people cannot be separated from care for the land

"Despite its profundity, 'The Land Ethic' remains principally a literary achievement; the philosophical aspiration at its core has not, as Leopold hoped, transformed society."

(Goldberg & Patz 2015 *Lancet*)

Problems

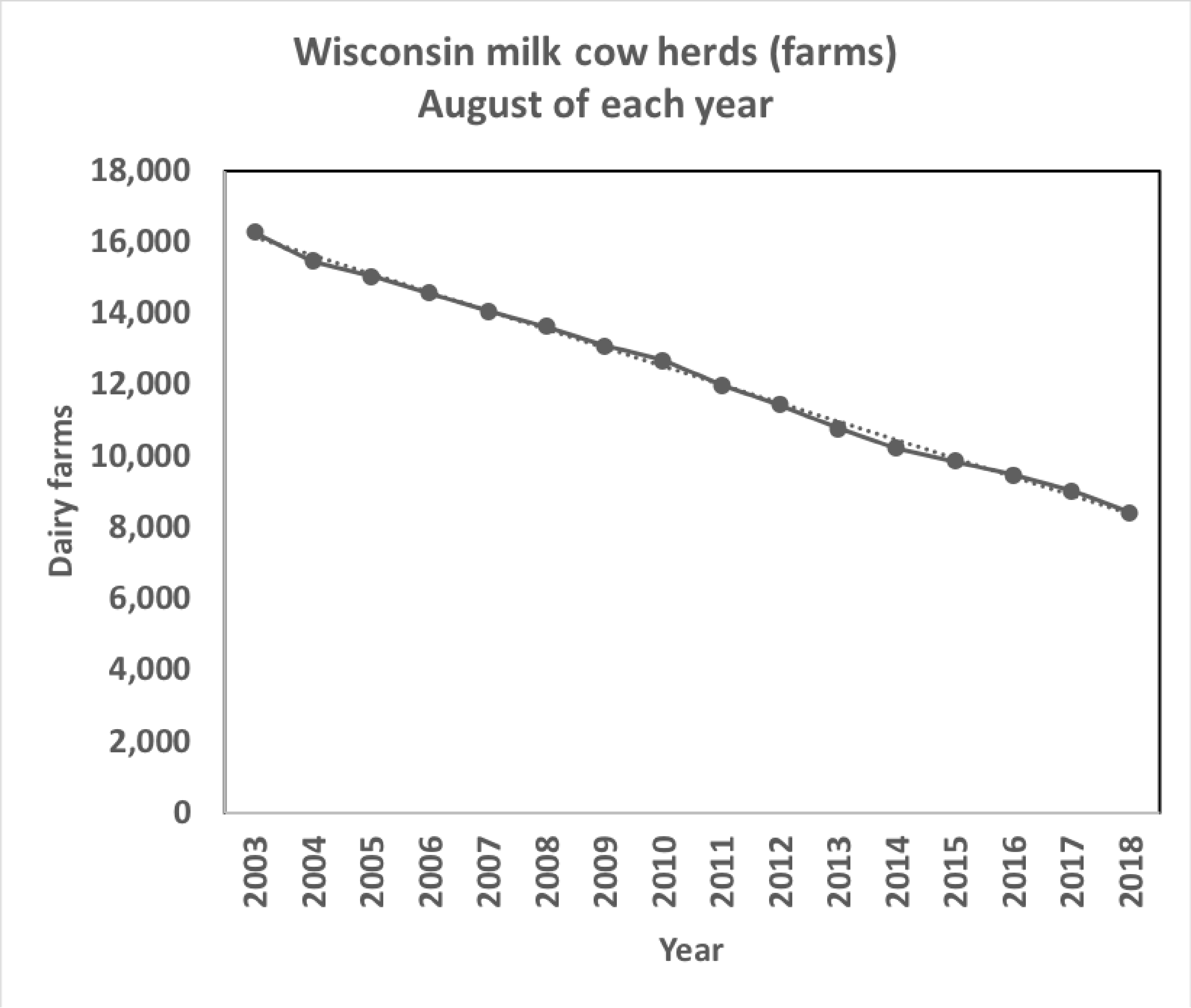
MENU WISCONSIN STATE JOURNAL News Sports Opinion Obituaries Business Lifestyles Entertainment Buy & Sell 22

TOPICAL

Scott Walker says crisis team needed to help state's crippled dairy industry

ROB SCHULTZ rschultz@madison.com Jun 6, 2018

Problems



Wisconsin milk cow herds (farms)
August of each year
Dairy farms
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Year

Problems

Consolidation

Credit: Mark Hoffman

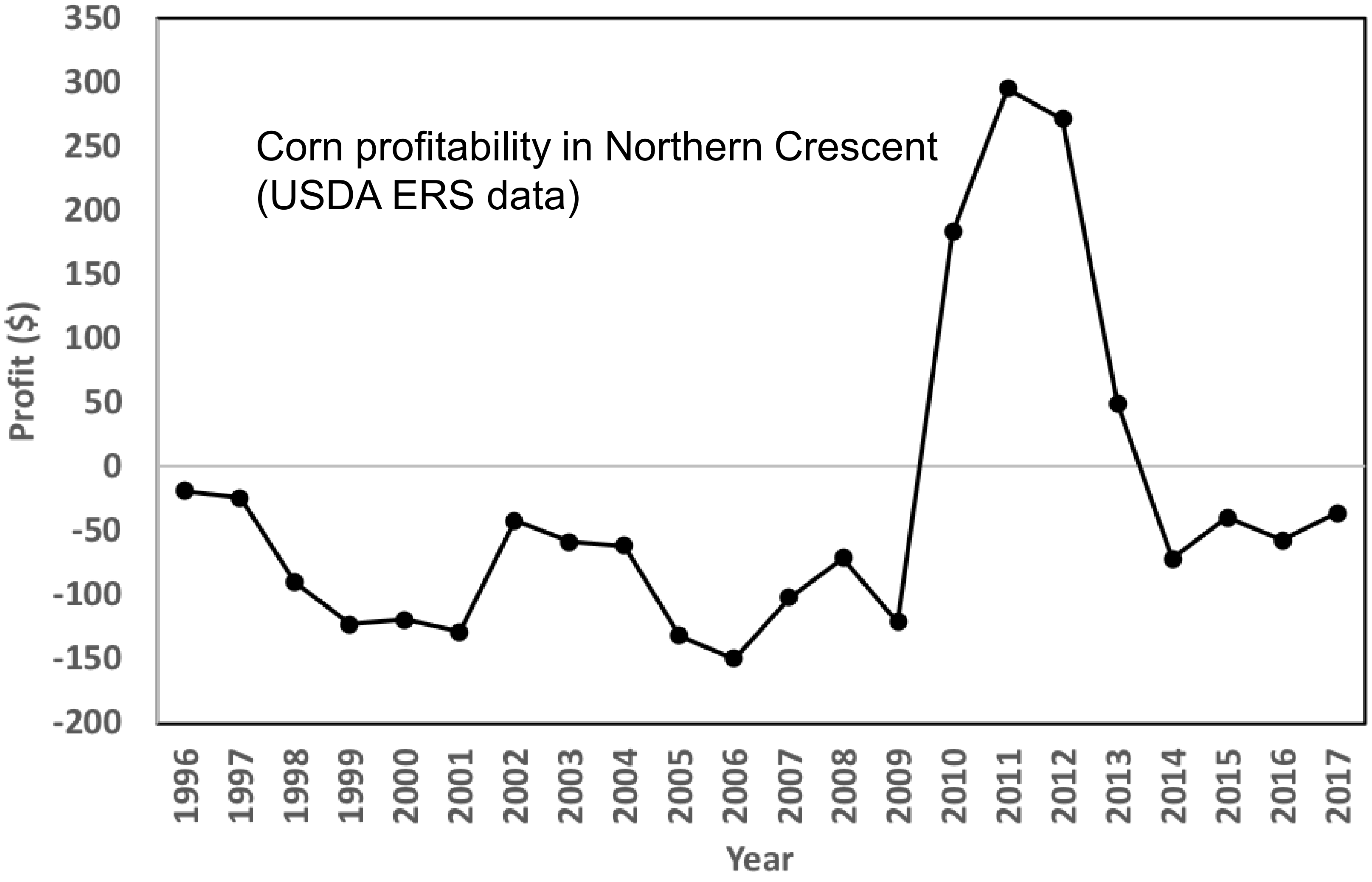
Problems

Abandonment

Credit: Alisa Chang

Problems

Credit: Alan Dooley


Corn profitability in Northern Crescent
(USDA ERS data)
Profit ($)
350
300
250
200
150
100
50
0
-50
-100
-150
-200
Year
1996
1997
1998
1999
2000
2001
2002
2003
2004
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2009
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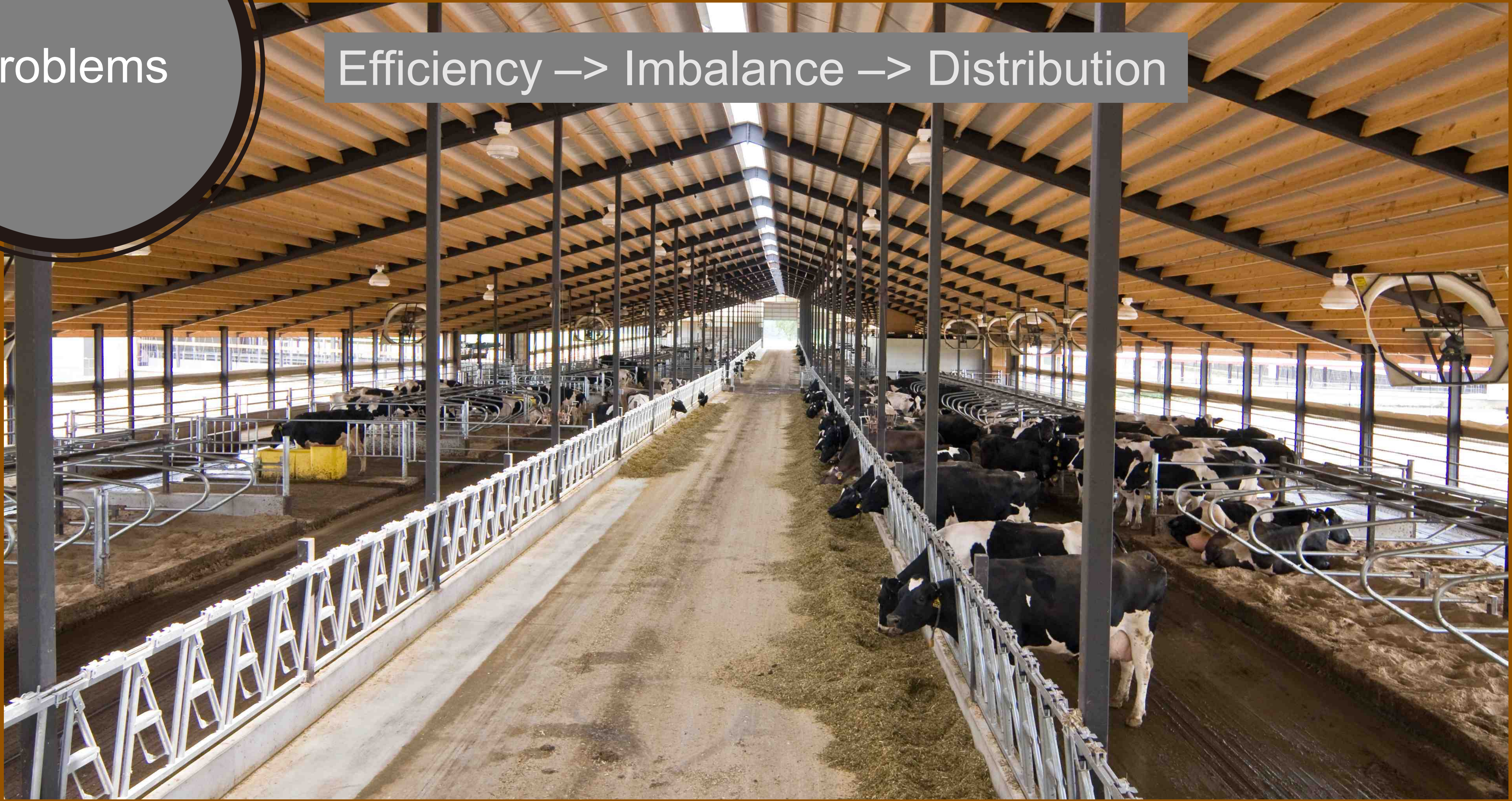
2014
2015
2016
2017

Problems

Efficiency –> Imbalance –> Distribution



Problems

Problems

Distribution

Photo credit: National Weather Service.

Problems

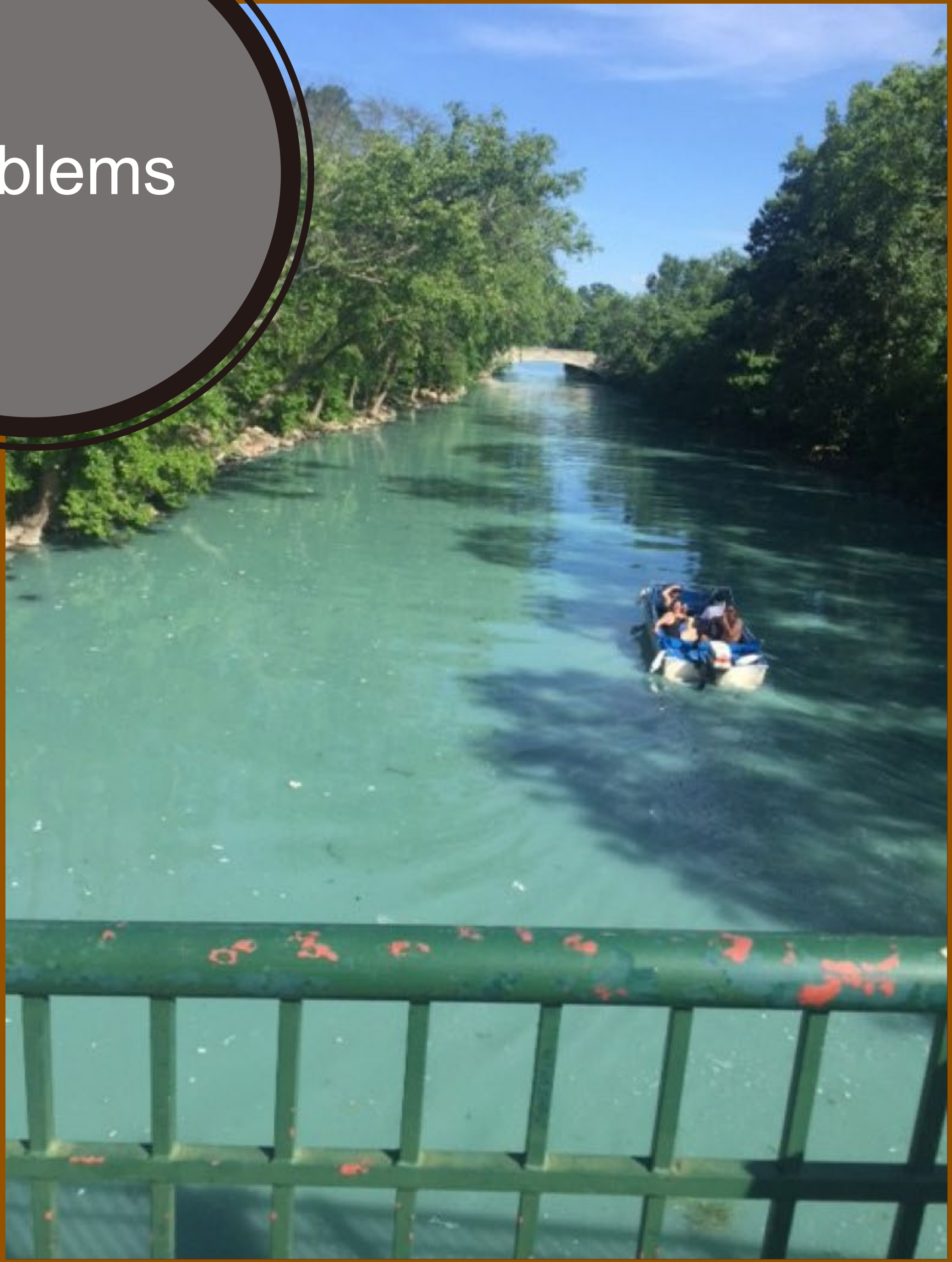


Photo: Katie Rice

Eutrophication

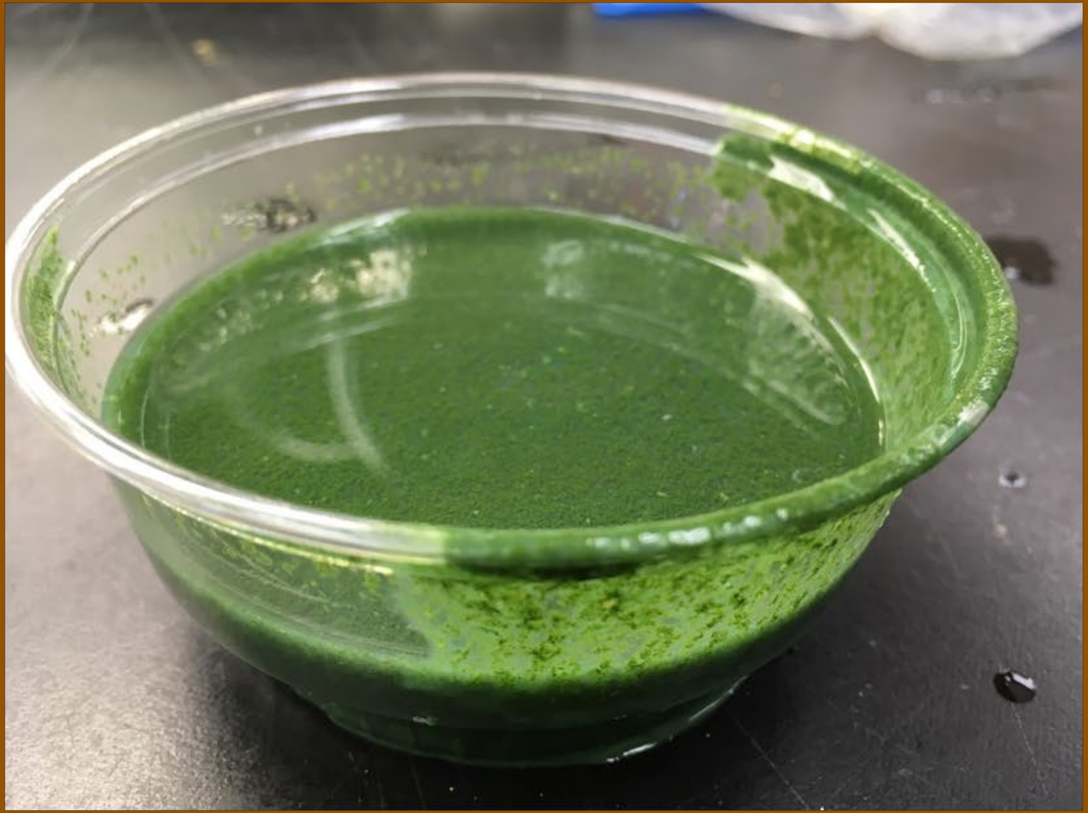
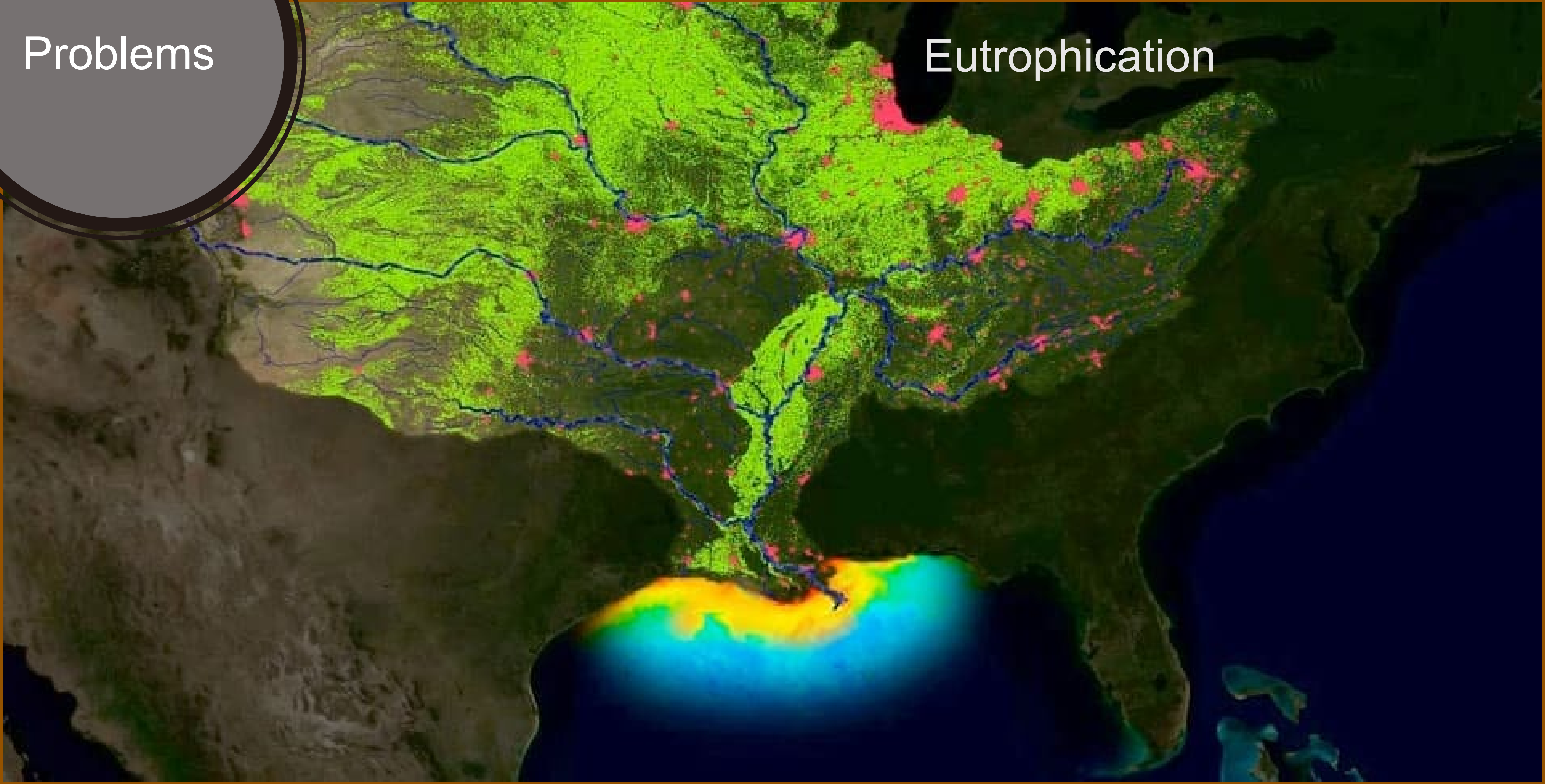


Photo: Emily Stanley

Problems

Eutrophication



Problems

Drainage

http://cbbel-in.com

Photo: Gary Sands

Problems

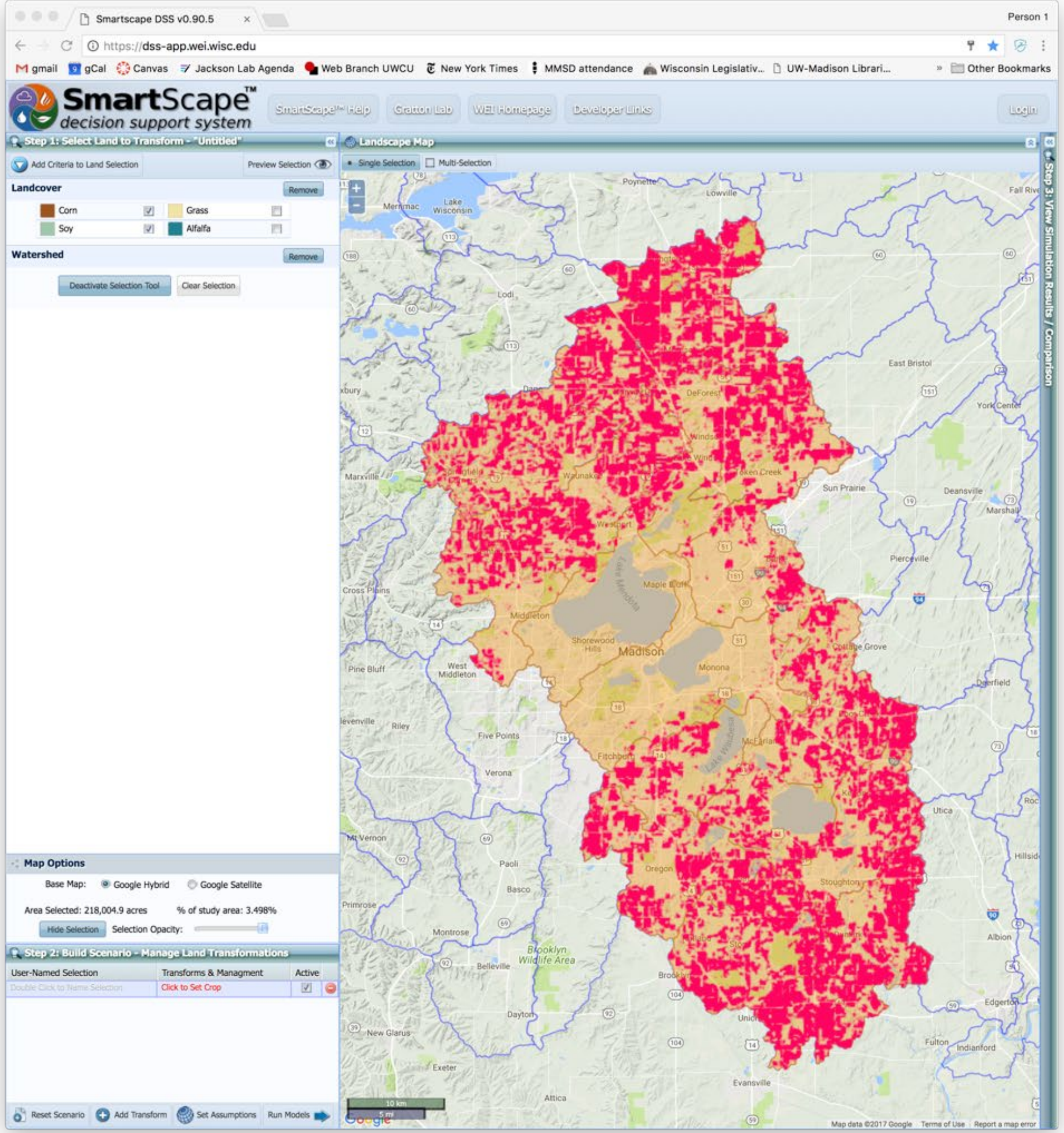
Flooding

Problems

Problems

Photo: University of Wisconsin-Madison

Solutions

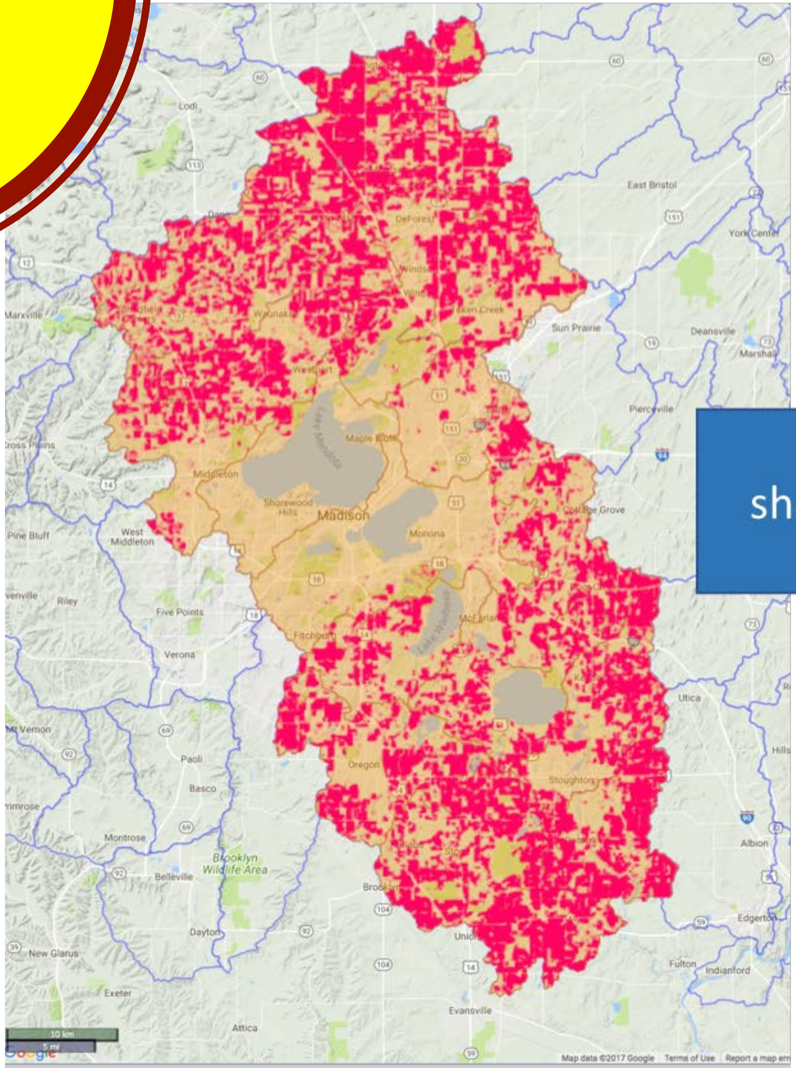


Yahara River watershed

Corn & soybean cover

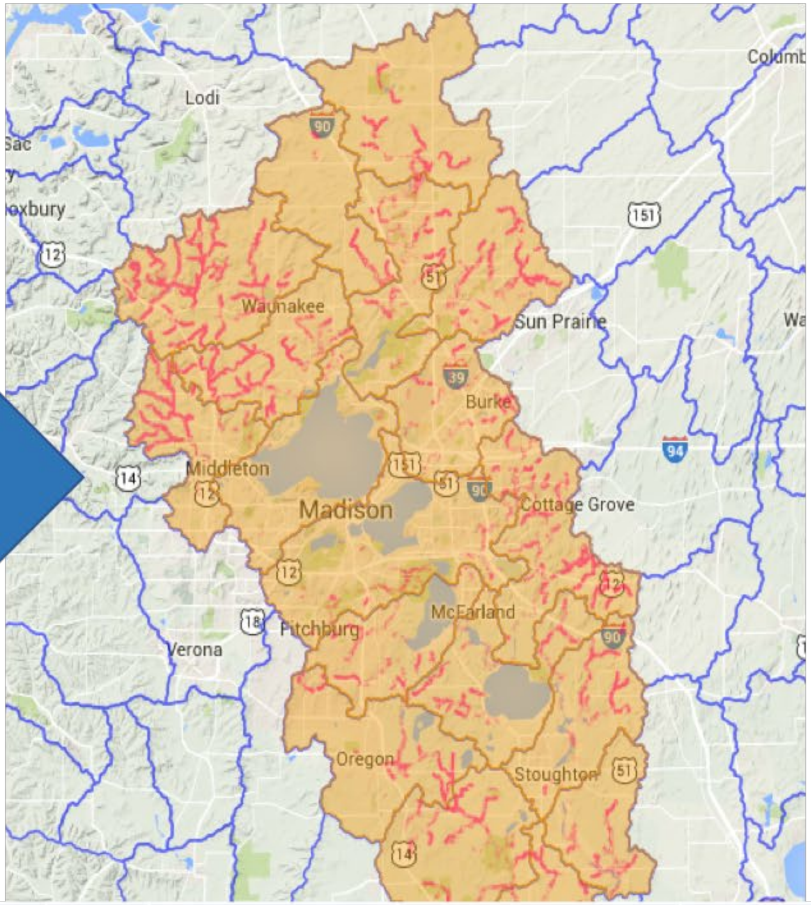
Cover	Acres	Percent of area	P Loading (lbs/yr)
Corn	1,464,328	23.5	1,160,062
Soybean	455,204	7.3	188,518
Total	1,919,532	30.8	1,348,580

Solutions



show me

Corn & soybean cover **500 ft. from stream**



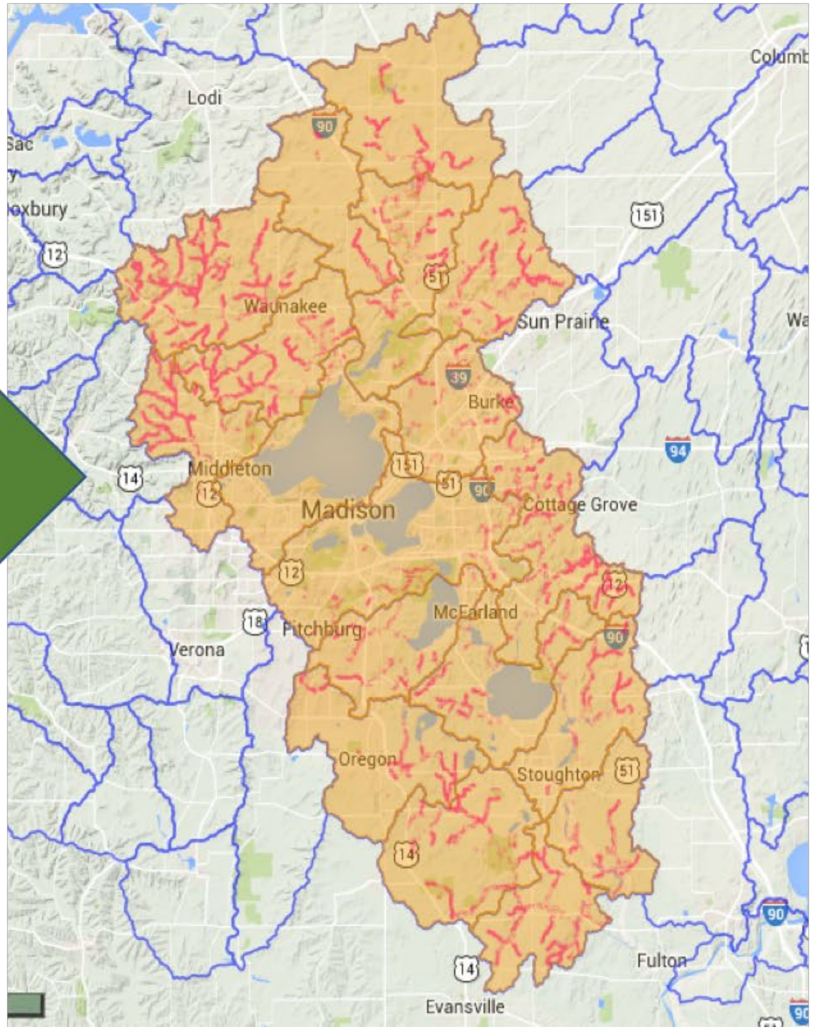
Cover	Acres	Percent of corn & soybeans	P Loading (lbs/yr)	Percent of P loading
Corn	282,511	19	870,627	69%
Soybean	78,490	17	145,555	62%
Total	361,000	19	1,016,182	68%

Solutions

Perennial grasslands should reduce P-loading

Corn & soybean cover **500 ft. from stream**

transform corn & soybeans to perennial grass

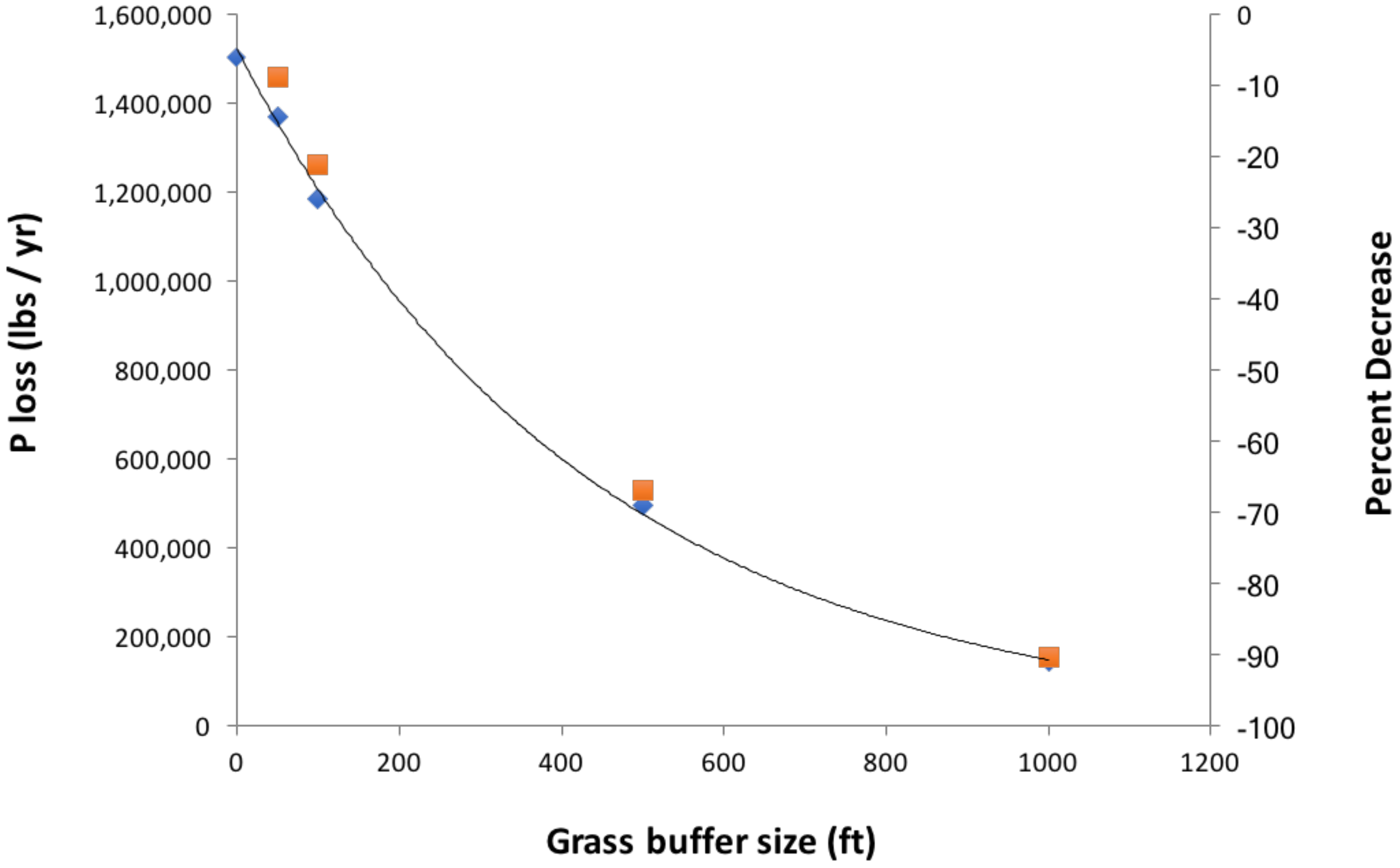


Cover	Acres	Percent of former corn & soybean land	P Loading (lbs/yr)	Percent reduction across all current & former corn & soybean land
Corn –> Grass	282,511	19	9,440	68%
Soybean –> Grass	78,490	17	2,270	61%
Corn+Soybean –> Grass	361,000	19	11,710	67%

Solutions

Yahara River watershed

Buffer size	Total Area	Percent of Corn/Soy land	P loss from buffer	Total P	% decrease
0	0	0		1,500,583	
50	30,839.70	2%	7,239	1,368,770	-8.8
100	82,272.60	4%	9,658	1,183,730	-21.1
500	361,000.10	18.8%	11,710	496,111	-66.9
1000	696,844.30	36.3%	11,715	145,586	-90.3



Solutions

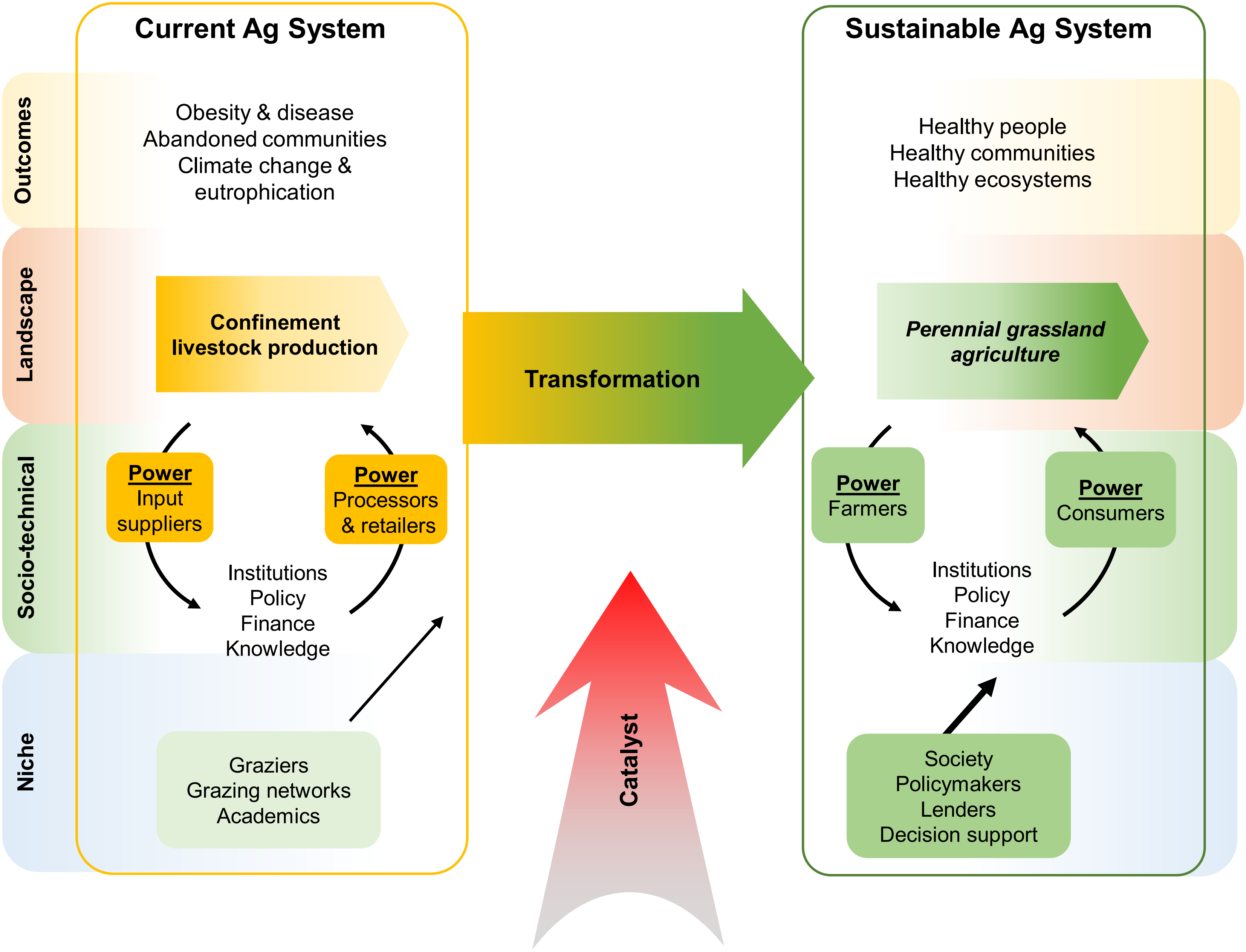
destabilizing climate change
polluting lakes & streams
reducing biodiversity

stabilizing climate
purifying water
mitigating floods
providing habitat

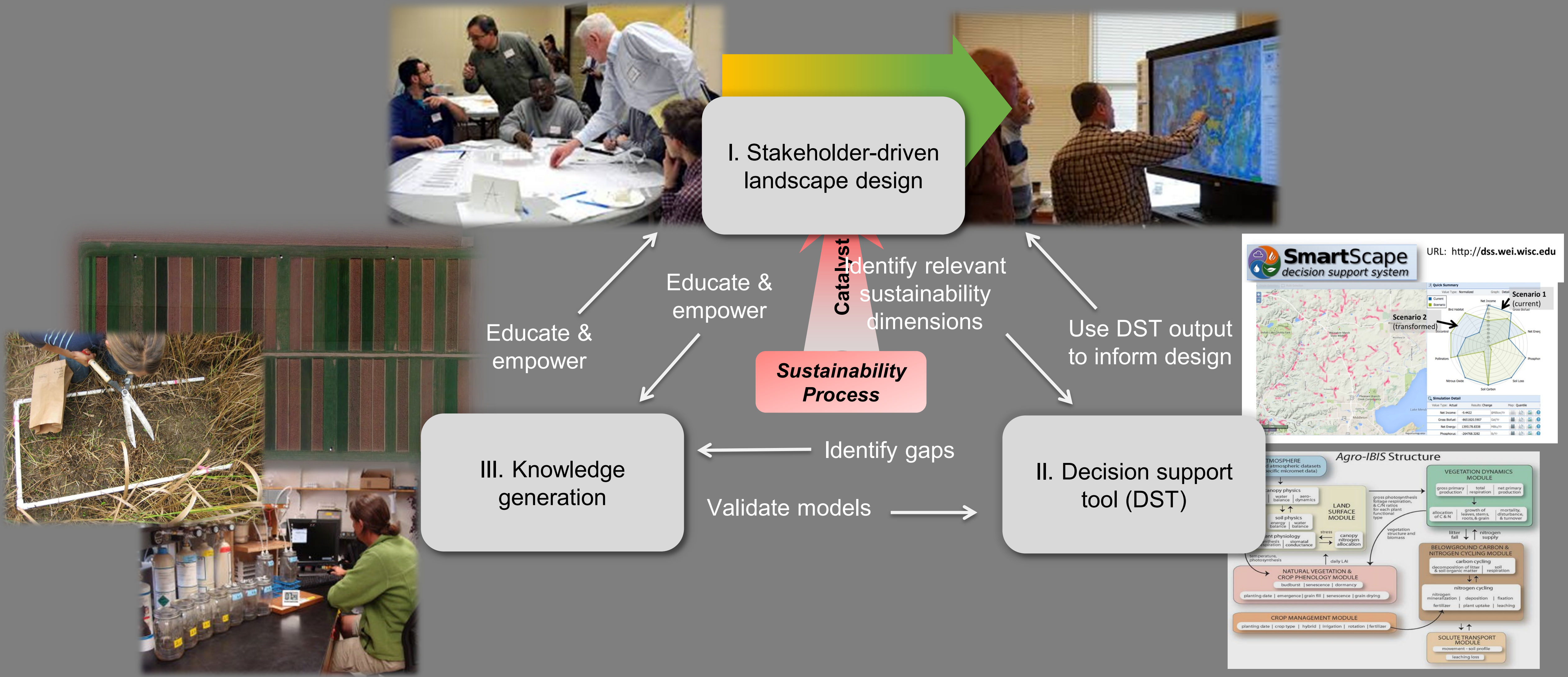
Solutions

Solutions

Solutions



Current Ag System
Sustainable Ag System
Outcomes
Landscape
Socio-technical
Niche
Obesity & disease
Abandoned communities
Climate change &
eutrophication
Confinement
livestock production
Power
Input
suppliers
Power
Processors
& retailers
Institutions
Policy
Finance
Knowledge
Graziers
Grazing networks
Academics
Transformation
Catalyst
Healthy people
Healthy communities
Healthy ecosystems
Perennial grassland
agriculture
Power
Farmers
Power
Consumers
Institutions
Policy
Finance
Knowledge
Society
Policymakers
Lenders
Decision support



I. Stakeholder-driven landscape design
Catalyst
Identify relevant sustainability dimensions
Sustainability Process
Educate & empower
Educate & empower
Use DST output to inform design
III. Knowledge generation
Identify gaps
Validate models
II. Decision support tool (DST)
SmartScape decision support system
URL: http://dss.wei.wisc.edu
Scenario 1 (current)
Scenario 2 (transformed)
Agro-IBIS Structure

Grassland 2.0!