Long-Term Organic Experiments in the U.S. Focus on the Iowa LTAR

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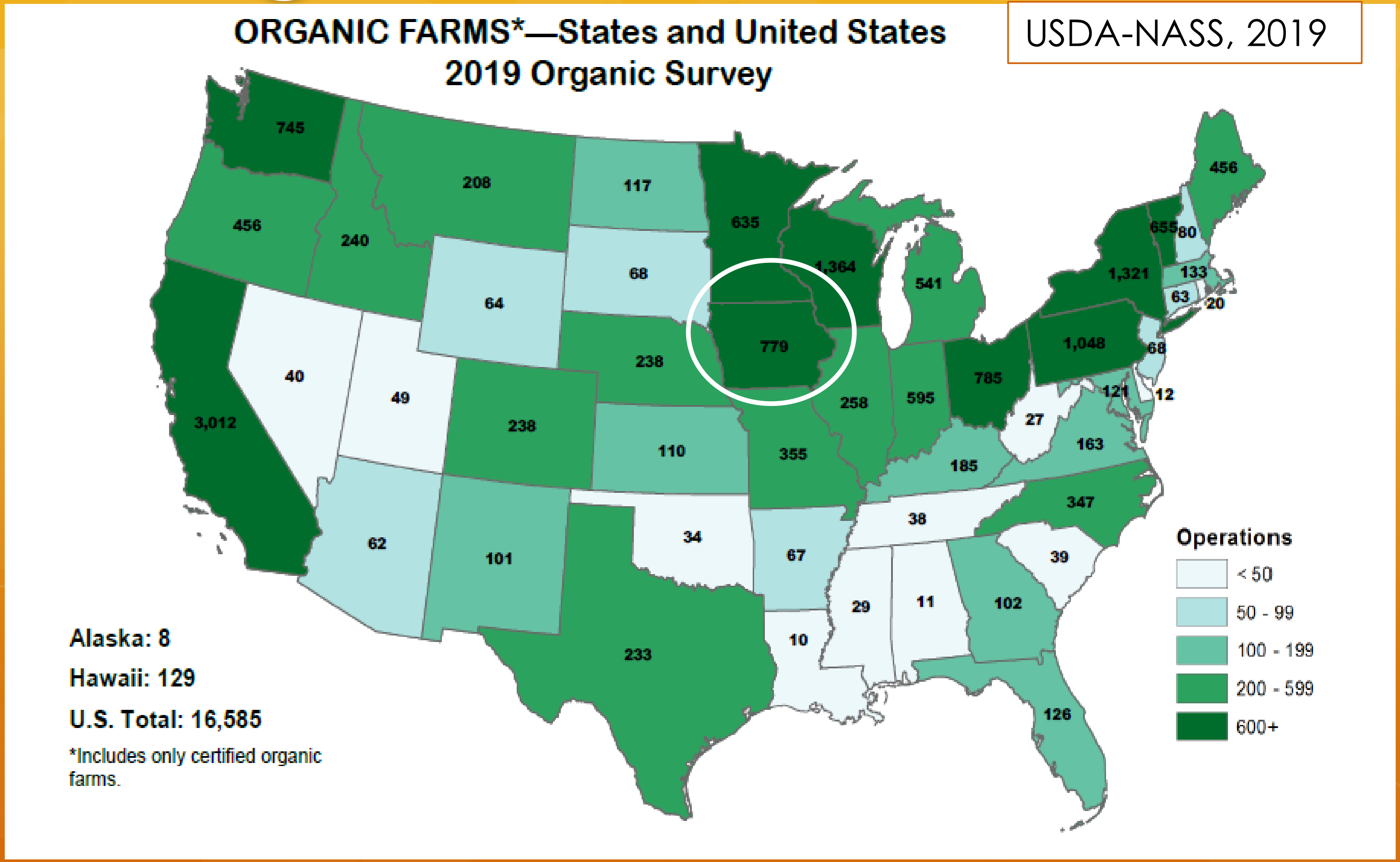
Iowa: a leader in organic farms and sales

In 2019, there were 5.5 million organic acres in the U.S. (2.2 M ha)

In Iowa, there were 779 organic farms with a US$144.6 million value.



National Agricultural Statistics Service

In 2019, there were 134,000 organic acres (54,228 ha) in Iowa

Organic Trade Assn. Organic Center
https://www.organic-center.org

COVID-19 shaped organic industry in 2020 after banner year in 2019. Importance of organic continues to rise, as sales hit $62 billion in 2020, an increase of 12.4% over previous year.

Total U.S. Organic Sales & Growth, 2011–2020

CATEGORY	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Organic Food	25,148	27,965	31,378	35,099	39,006	42,507	45,209	47,862	50,065	56,485
Growth (%)	9.5%	11.2%	12.2%	11.9%	11.1%	9.0%	6.4%	5.9%	4.6%	12.8%
% of Total Organic	**92.0%**	**91.9%**	**91.9%**	**91.8%**	**91.6%**	**91.7%**	**91.6%**	**91.3%**	**90.9%**	**91.2%**
Organic Non-Food	2,195	2,455	2,770	3,152	3,555	3,866	4,151	4,589	5,013	5,438
Growth (%)	11.2%	11.8%	12.8%	13.8%	12.8%	8.8%	7.4%	10.6%	9.2%	8.5%
% of Total Organic	**8.0%**	**8.1%**	**8.1%**	**8.2%**	**8.4%**	**8.3%**	**8.4%**	**8.7%**	**9.1%**	**8.8%**
Total Organic	**27,343**	**30,420**	**34,147**	**38,251**	**42,561**	**46,373**	**49,360**	**52,451**	**55,078**	**61,924**
Growth (%)	**9.7%**	**11.3%**	**12.3%**	**12.0%**	**11.3%**	**9.0%**	**6.4%**	**6.3%**	**5.0%**	**12.4%**

Source: Organic Trade Association's 2021 Organic Industry Survey conducted 1/13/2021–3/22/2021 ($mil., consumer sales).

Basic Rules in U.S. Organic Production

- Soil quality must be maintained or enhanced: verified by inspector
- Manure must be composted properly or applied 3 months before harvest for grain crops; 4 months before harvest for horticultural crops
- Cover crops, crop rotations with small grains/legumes, and compost: main source of N/nutrients

National Organic Program
USDA ORGANIC

https://www.ams.usda.gov/rules-regulations/organic



Sustainability determined by:

- long-term trends in yield
- profitability
- efficiency in use of limited resources (water or energy), and
- environmental impact (soil quality, leaching of nitrates and pesticides, GHG emissions)

-Kate Scow, UC-Davis

Goals of long-term ag research

- **improved understanding of agriculture** from long-term systems' perspective, such that multiple management aims can be balanced against known trade-offs;
- greater **integration of biophysical and social sciences** to provide information and insights needed to implement solutions with acceptable economic and social costs;
- improved knowledge of **geographic scalability**, to ensure solutions developed at one scale are effective at larger scales, and to allow processes that operate at larger scales to contribute to solutions at field and farm scale;
- strengthen outreach and education ties to research in agricultural ecosystems and landscapes, to **improve both relevance of research to stakeholder needs and public understanding** of these systems with their social, environmental, and management trade-offs.

Robertson et al. (2008)

Long-term organic comparisons

Name of Experiment	Date started	Comparison	Main crops	Lead entity Location
Farming Systems Trial	1981	Conv. C-S vs. Org. 3 and 4-yr rotations	Corn, soybean, wheat	Rodale Institute Pennsylvania
Sustainable Ag Farming Systems (SAFS)	1988	Conv. C, W & T vs. Org. C, W, T	Corn, tomato, wheat	University of California-Davis
Variable Input Crop Management Systems (VICMS)	1989	Conv. C-S vs. Org. 3 (dropped Org 2) and 4-yr rotations	Corn, soybean, oat, alfalfa	University of Minnesota (Lamberton, MN)
Wisconsin Integrated Cropping Systems Trials (WICST)	1989	Conv. C-S vs. Org 3 and 4-yr rotation	Corn, soybean, wheat, oats, alfalfa	University of Wisconsin-Madison (Arlington, WI)
Beltsville Farming Systems Project (FSP)	1996	Conv. C-S vs. Org 2, 3 and 6-yr rotation	Corn, soybean, wheat	USDA-ARS Beltsville, MD
Long-Term Agroecological Research (LTAR)	1998	Conv. C-S vs. Org. 3 and 4-yr rotations	Corn, soybean, oat, alfalfa	Iowa State University, (Greenfield, IA)

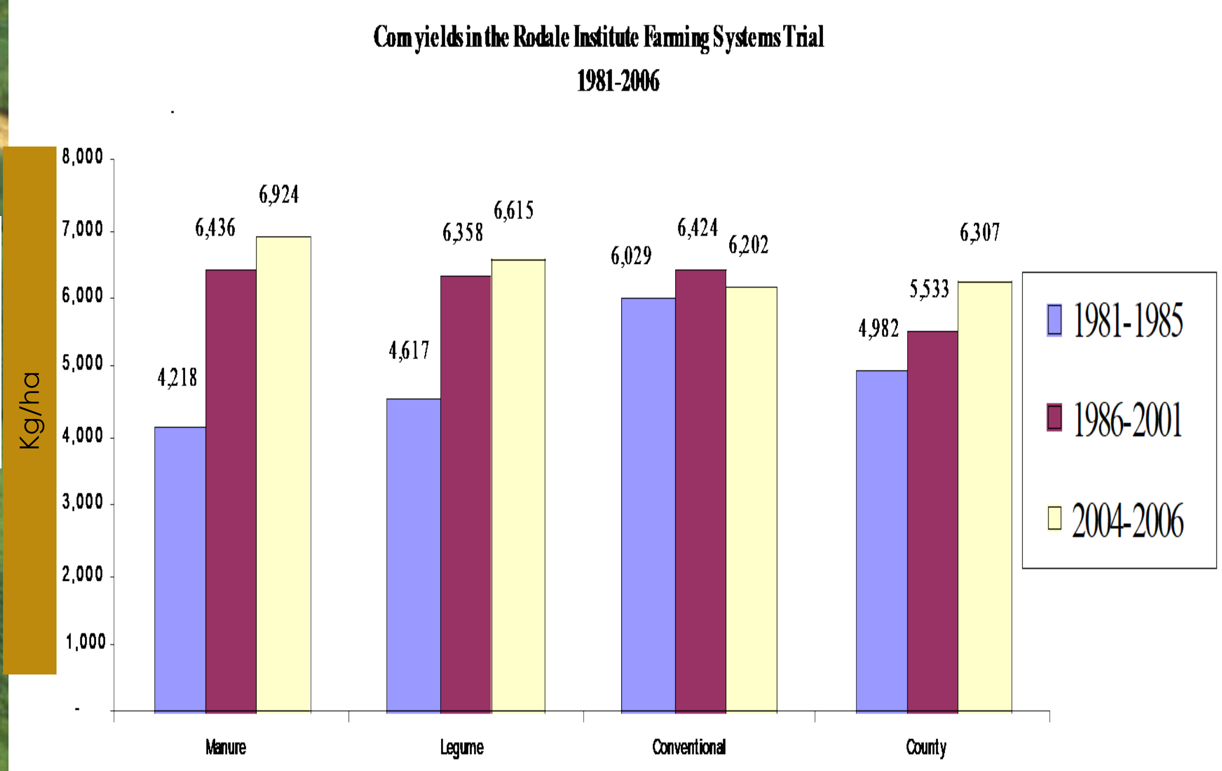
Delate, K., C. Cambardella, C. Chase, and Robert Turnbull. 2015. A review of long-term organic comparison trials in the U.S. Sustainable Agriculture Research 4(3): http://www.ccsenet.org/journal/index.php/sar/article/view/50095

The Farming Systems Trial (FST)

Rodale Institute, Kutztown, PA

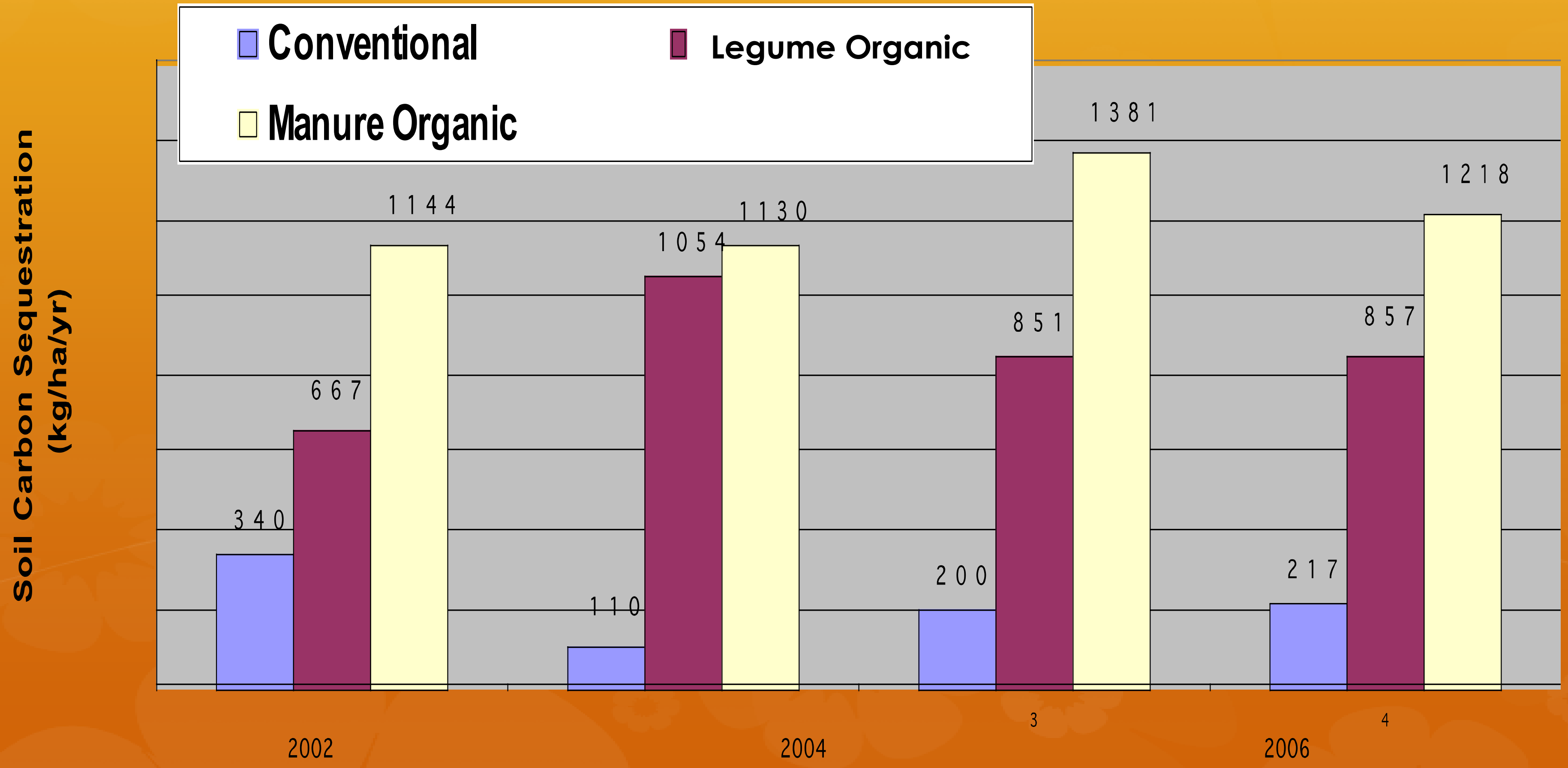
- Established in 1981, the longest running comparison of organic and conventional cropping systems in the US.
- 3 cropping systems are compared (CV, MN, LG)

-4-yr transition: org = conv
-20-yr+: org (composted manure) > conv
-Manure-based org > legume-based org



https://rodaleinstitute.org/science/farming-systems-trial/

Soil quality highest in organic rotation with composted manure



History of long-term organic comparison in Iowa

- Extension information lacking to support transition
- Farmers request long-term comparisons

Farmers develop LTAR design in Focus Group in 1997

ISU Neely-Kinyon LTAR Site (Long-Term Agroecological Research)

Close-up of 0.25 acre plots

Forty-four plots–four rotations–five crops

2022: 25–year comparison of conventional & organic crops

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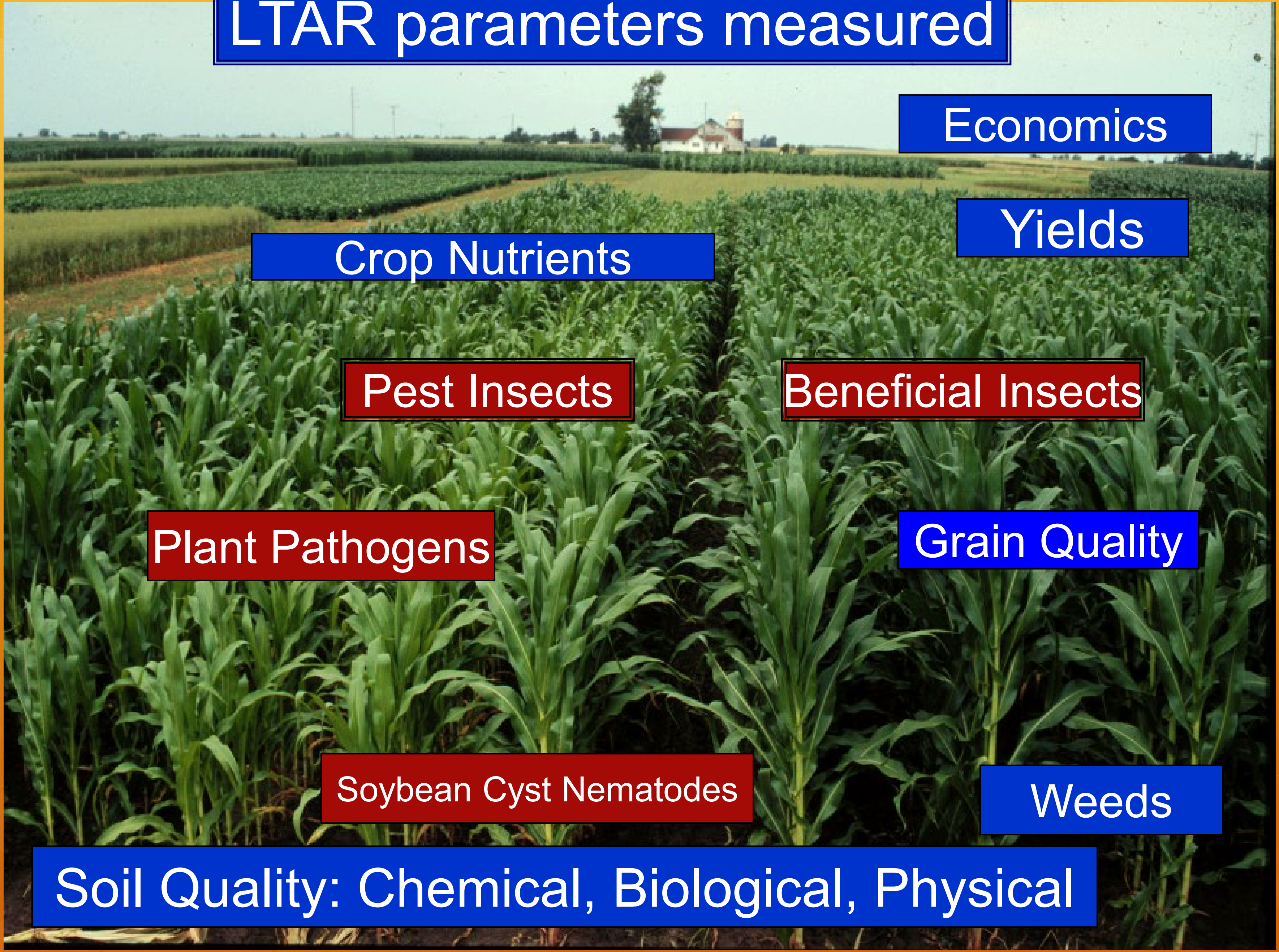
Supported by the Leopold Center for Sustainable Ag

Farmers decide treatments and provide input on results

LTAR Field Day Update with Heartland Organic Marketing Co-op and IDALS staff

- Main comparison: Conventional corn-soybean vs. longer organic rotations with small grains and legumes
- Certified organic in 3rd year by Iowa Dept. of Ag. and Land Stewardship (IDALS)
- Crops sold as certified organic

LTAR parameters measured



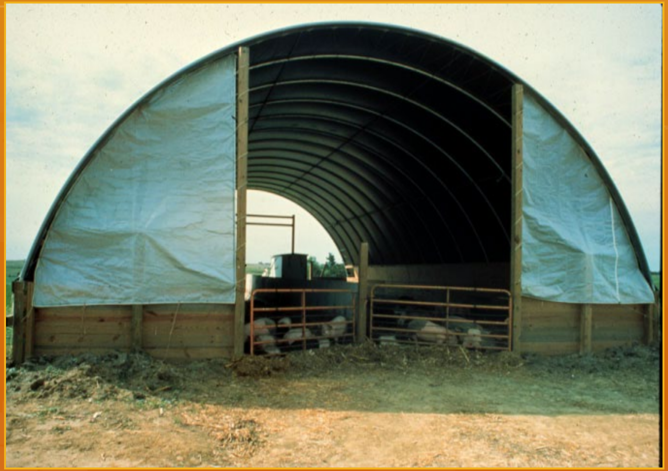
Certified Organic Practices

- Only naturally-based inputs

  (on NOP National List)

- Crop rotations (min. 3 crops)
- Soil-building compost & legumes
- 12 tons/acre of composted swine hoop house for corn every third or fourth year of rotation that provides 80-120 lb N/acre
- Compost (treated as raw manure and put on at least 3 mo. before harvest): put on in March (warm soil)
- Mixture of manure and straw/hay
- 2-3-4 N-P-K: Phosphorus not a problem but we check every year

Cover crops



Hoop-house swine

Neely-Kinyon LTAR

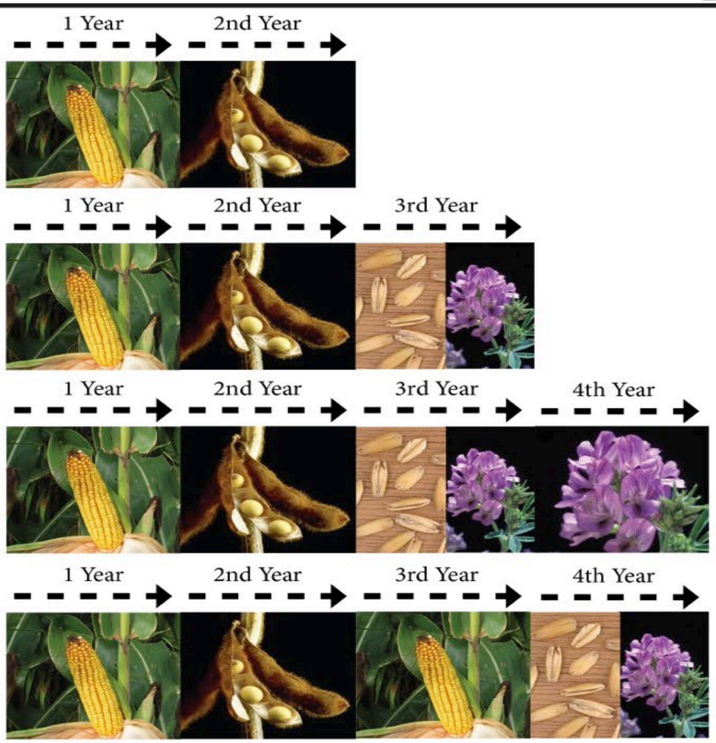
Treatments

8 Plots
Conventional C - SB

12 Plots
Organic C - SB - O/A

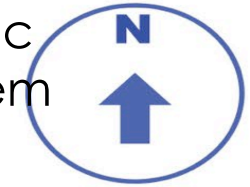
16 Plots
Organic C - SB - O/A - A

8 Plots
Organic C - SB - C - O/A
(changed from SB-W/RC in 2010)



- 44 plots total
- 4 reps of each crop in each treatment
- 70’ x 140’ plots
- 30’ borders in each direction
- Completely randomized design based on uniform slope and soil type

– Composted poultry manure (120 kg/ha N) applied before organic corn phase only
– Synthetic N in conventional corn plots
– Herbicides in conventional; multi-pronged approach in organic
– Same varieties in each system



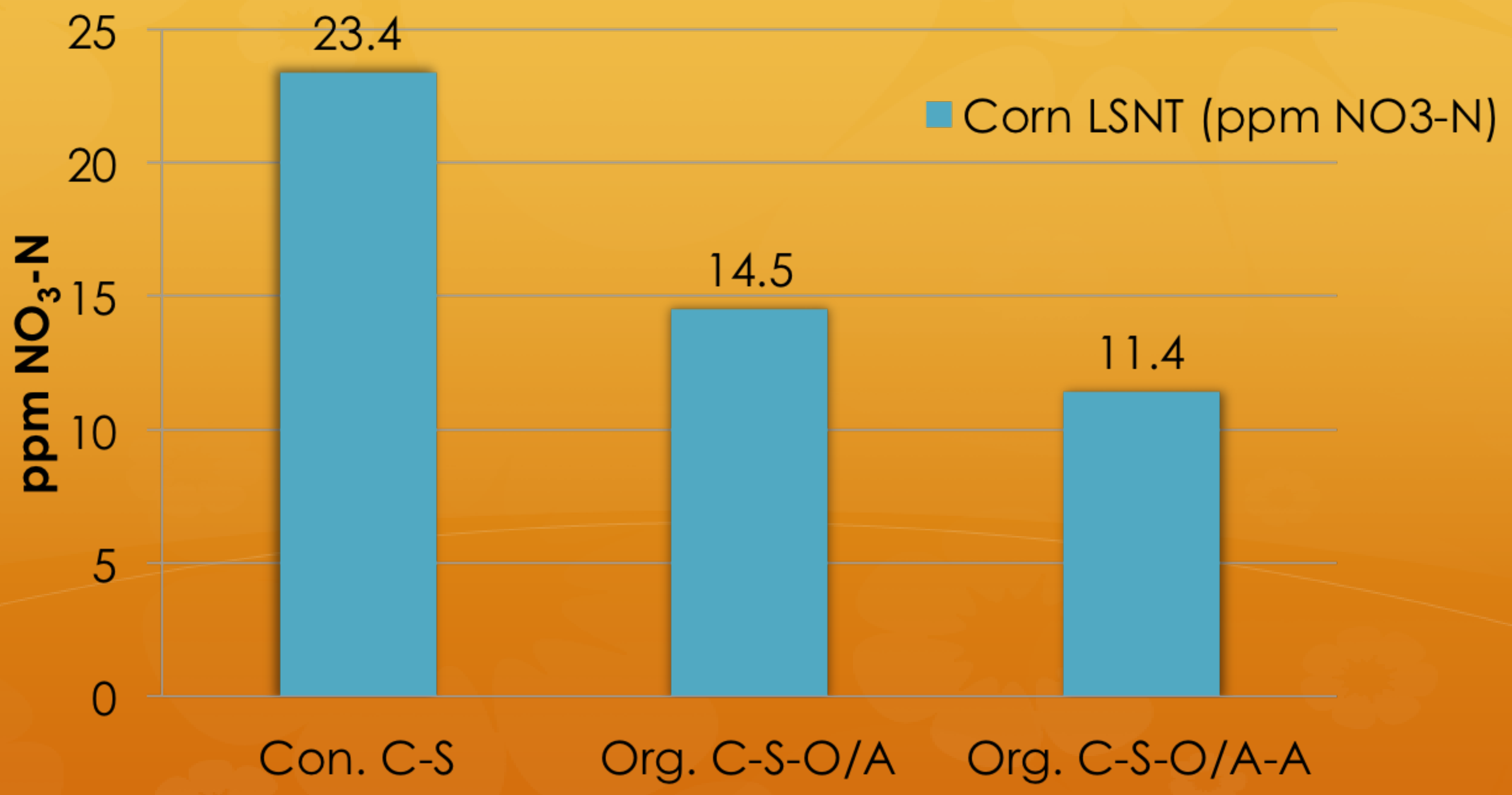
Plot Plan

Average LTAR Corn Yields 1998-2020

Rotation	Yield (bu/acre)	Yield (kg/ha)
CONV C-S	156.07	9,797
ORG C-S-O/A	146.88	9,220
ORG C-S-O/A-A	155.72	9,775
p value (0.05)	0.5331	

- Corn yields at 15.5% moisture
- No difference between organic and conventional yields

Average LTAR Corn Late-Spring Nitrate Test (LSNT)



Yields the same despite lower N at late-spring soil tests in organic plots, due to slow-release manure-based fertilizers used.

Nitrogen Loss (lb N/ac) to Tile Drainage Water

	2013	2014	2015	2016	∑ 2013-2016
Organic C-S-O/A-A	21.3	13.3	8.9	7.7	**51.2**
Conventional C-S	44.7	32.2	13.9	9.7	**100.5**
Organic Pasture	10.0	3.6	1.0	0.6	**15.2**

Tile water N loading loss (lb N/ac) from 2013-2016 from organic C-S-O/A-A was 50% lower than conventional C-S

Pasture was the lowest, showing its importance in longer rotations, and integrated systems.

Cambardella, C.A., K. Delate, and D.B. Jaynes. 2015. Water quality in organic systems. Sustainable Agriculture Research 4(3): http://www.ccsenet.org/journal/index.php/sar/article/view/50106

Average LTAR Soybean Yields 1998-2020

Rotation	Yield (bu/acre)	Yield (kg/ha)
CONV C-S	47.40	3,188
ORG C-S-O/A	46.04	3,096
ORG C-S-O/A-A	47.83	3,217
p value (0.05)	0.7597	

- Soybean at 13% moisture
- No difference between organic and conventional yields

Organic Weed Management

- **Use preventive measures: cover crops, esp. rye (allelopathy)**
- **Crop rotations:** Solid cover of small grain crop important in rotation for weed management
- **Manage when weeds are first emerging and at appropriate intervals to prevent establishment /weed seed production**
- High planting rate
- **Rotary hoe, row cultivator**
- **Flame-weeder when wet**
- “Walking” soybeans, esp. for any ‘staining’ weeds (nightshade)

Author	State	Weed control	Corn Yield (% of CV)	Soybean Yield (% of CV)	Sm. Grain Yield (% of CV)
Liebhardt	PA	poor	84	---	---
		good	112	---	---
		unrated	---	103	90w
Porter	MN	poor	---	64	---
		good	---	98	---
		unrated	92	100o	---
Delate and Cambardella	IA	good	114	111	---
Smith and Gross	MI	poor	72	---	---
WICST	WI	poor	75	79	---
		poor	98	94	---
		unrated	---	---	93w

Posner et al., 2008

Weed management:
A key component of optimal yields.

When weather was not conducive to early weed management, yields suffered.

Average Weed Populations 1998-2020

Rotation	Total weeds/m² Corn
CONV C-S	4.64a
ORG C-S-O/A	12.46b
ORG C-S-O/A-A	13.66c
p value (0.05)	0.0265*

Rotation	Total weeds/m² Soybean
CONV C-S	4.70
ORG C-S-O/A	10.15
ORG C-S-O/A-A	10.26
p value	0.1363

Weed populations lower where herbicides used, but weeds not significantly greater in organic soybean plots. No additional benefit with weed control observed with second year of alfalfa.

Average LTAR Corn Grain Quality 1998-2020

Rotation	Oil (%)	Protein (%)	Starch (%)
CONV C-S	3.80	8.04	65.49
ORG C-SB-O/A	3.83	7.92	65.75
ORG C-SB-O/A-A	3.86	8.09	65.56
p value (0.05)	0.9198	0.8773	0.9901

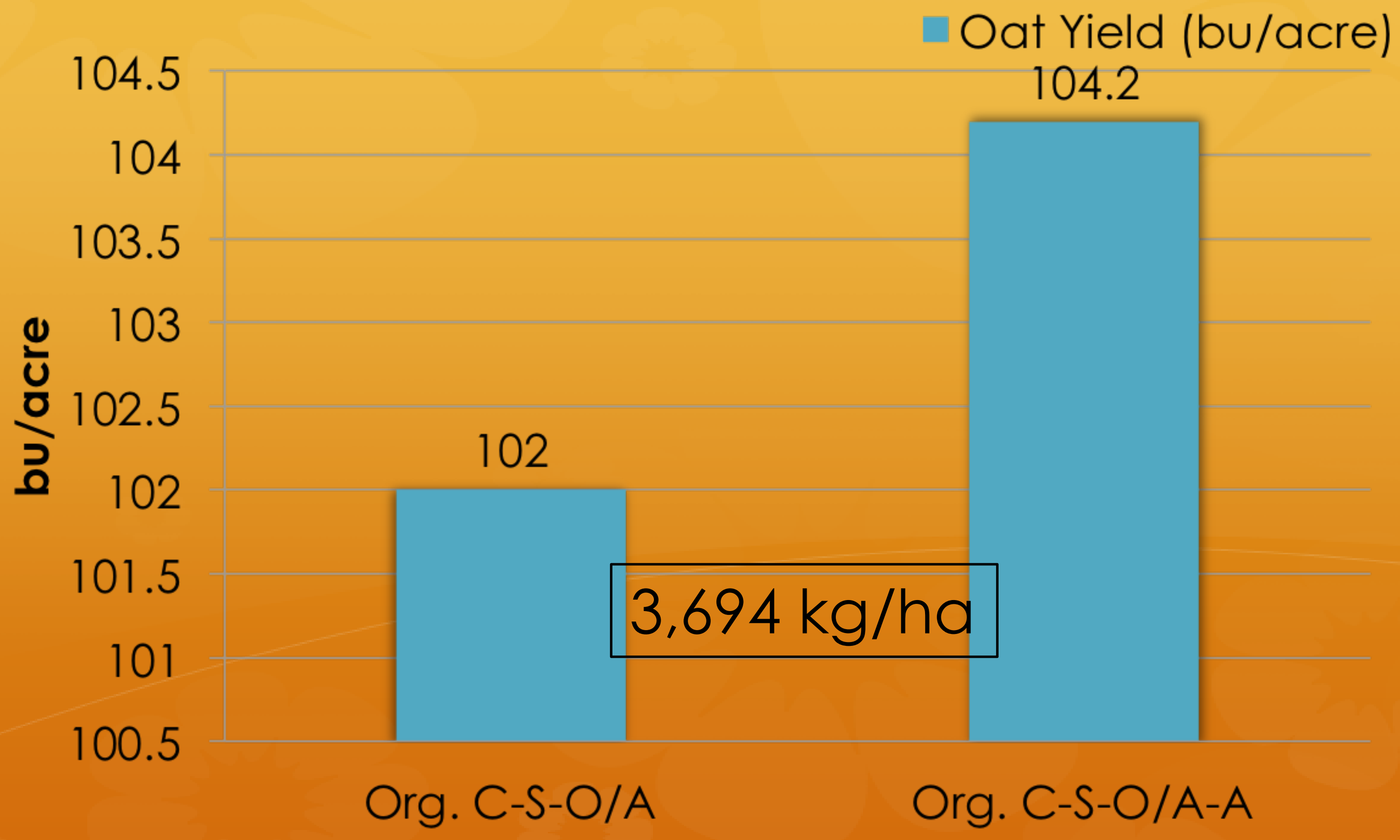
No difference between conventional and organic corn grain quality.

Average LTAR Soybean Grain Quality: 1998-2020

Rotation	Carbo-hydrates (%)	Oil (%)	Protein (%)	Fiber (%)
CONV C-S	23.22	18.45	35.48	4.78
ORG C-SB-O/A	23.14	18.50	35.65	4.75
ORG C-SB-O/A-A	23.10	18.39	35.81	4.74
p value (0.05)	0.9474	0.9505	0.8555	0.8081

No difference between conventional and organic corn grain quality.

Average Organic Oat and Alfalfa Yields



Average alfalfa yield: 3.49 ton/acre (7.82 tonnes/ha)

Only numerical difference in yield increase with extra year of alfalfa

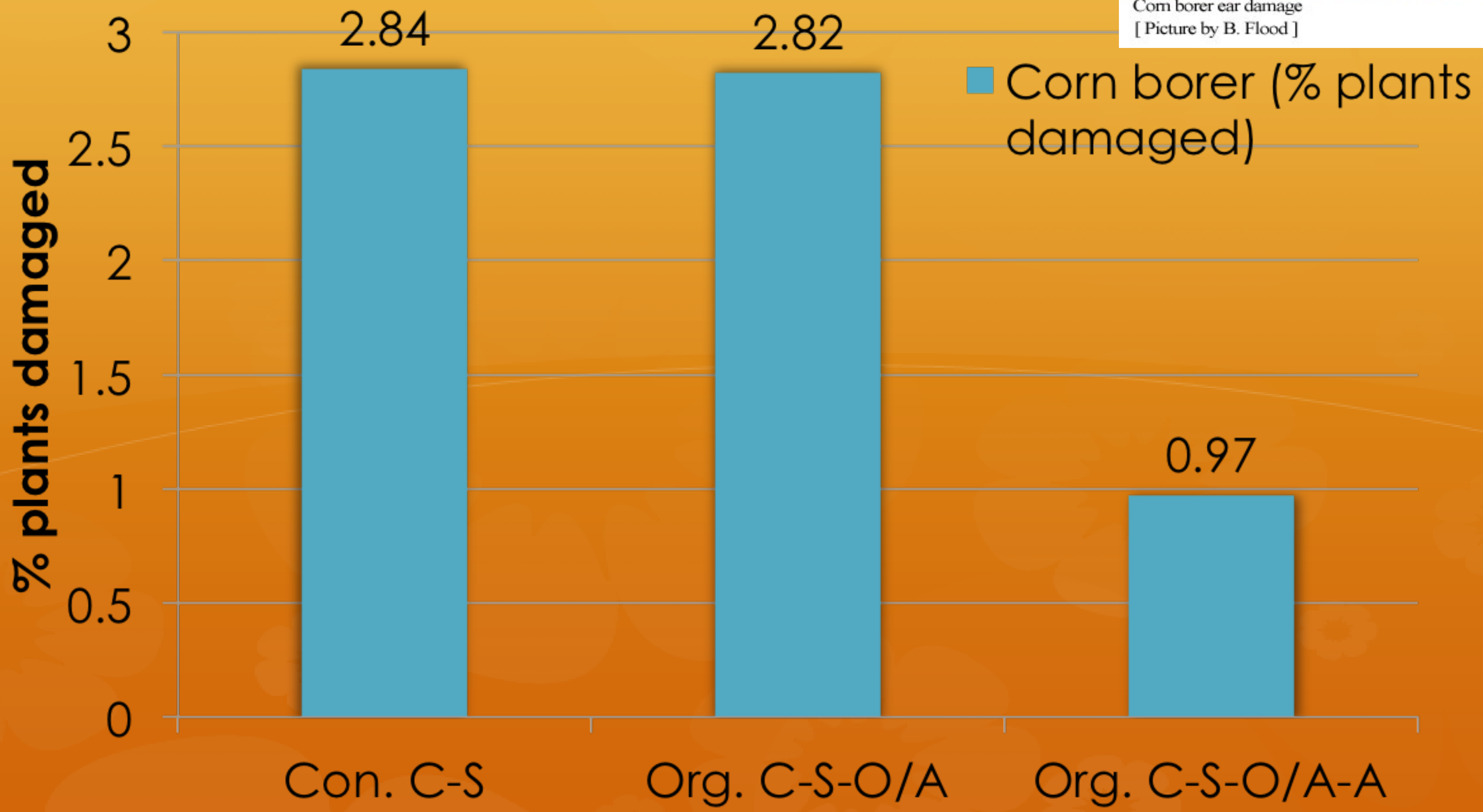
Organic Pest Management

- Bio-diversity on farm
- Conservation of beneficial insects
- Preventative (resistant varieties)
- Least toxic organic-compliant pesticides (used once in 24 years)

http://www.ento.vt.edu/Fruitfiles/orius.html, Douglas Pfieffer

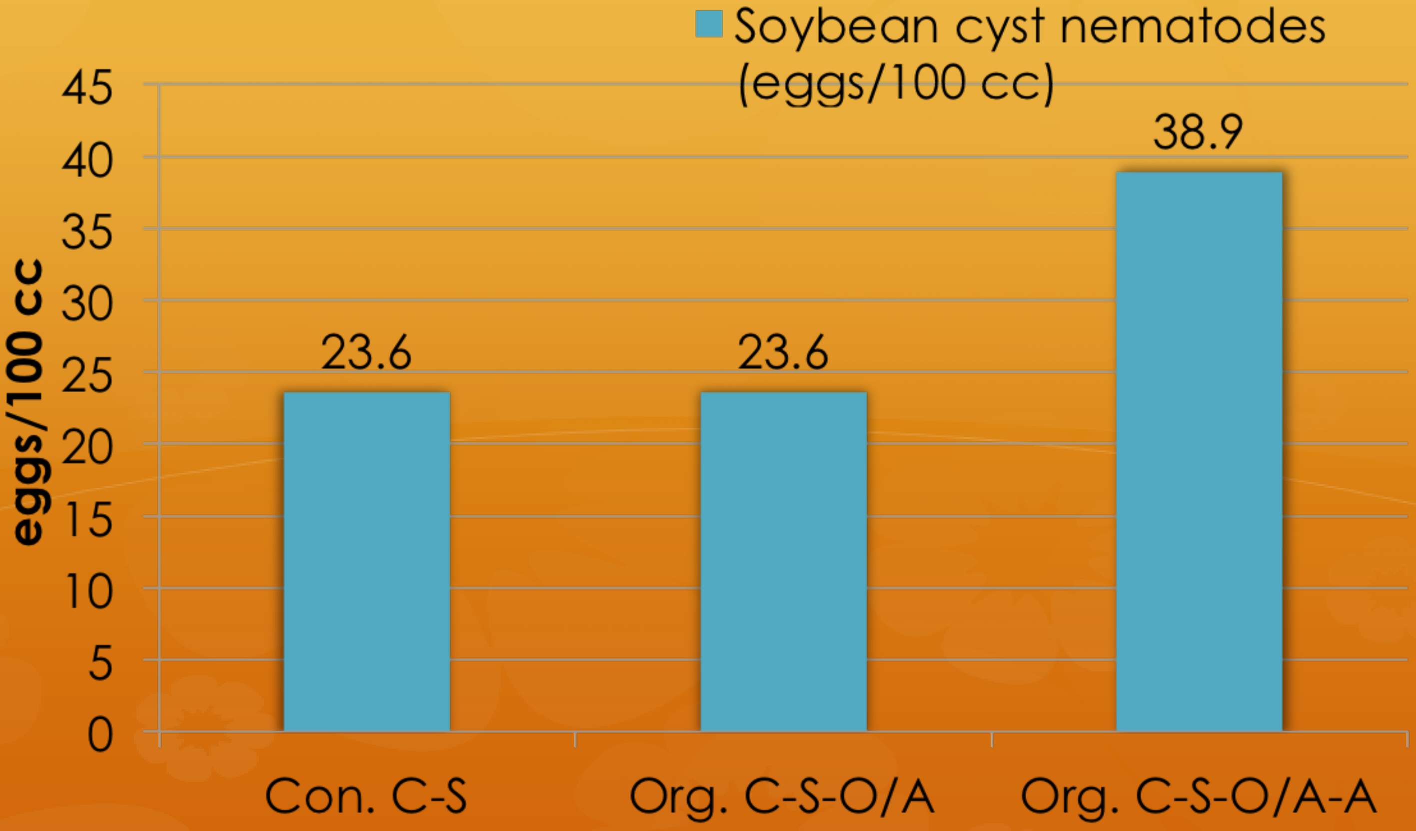
Average LTAR Corn Borer

Corn borer ear damage
[Picture by B. Flood]



No difference between conventional and organic.
Low damage overall due to CB-tolerant varieties used.

Average LTAR Soybean Cyst Nematodes



No difference between conventional and organic.

Soil Quality

- Dr. Cynthia Cambardella (1953-2020)
- Marcio Nunes, USDA-ARS, National Lab for Ag. and the Environment, Ames, IA
- Soil sampling each fall in each plot
- Five randomly-located soil cores (0-15 cm) from each plot every fall after harvest but before tillage for cover crops

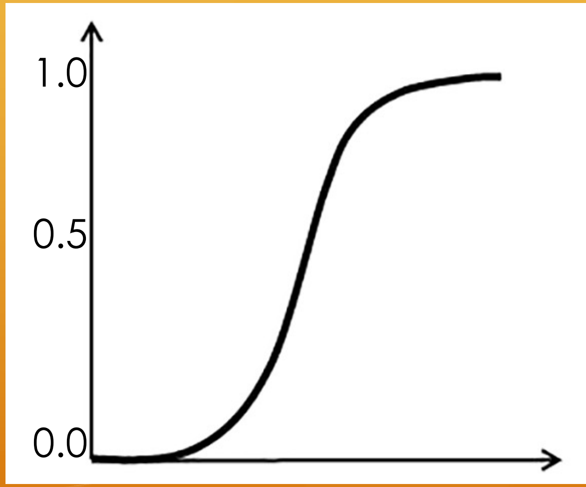
Using a SMAF (Soil Management Assessment Framework)

Susan Andrews, C. Cambardella and D. Karlen 2004: https://doi.org/10.2136/sssaj2004.1945

A tool that uses non-linear scoring curves to interpret how each inherent + dynamic soil **property relates** to **soil function -> SOIL HEALTH**

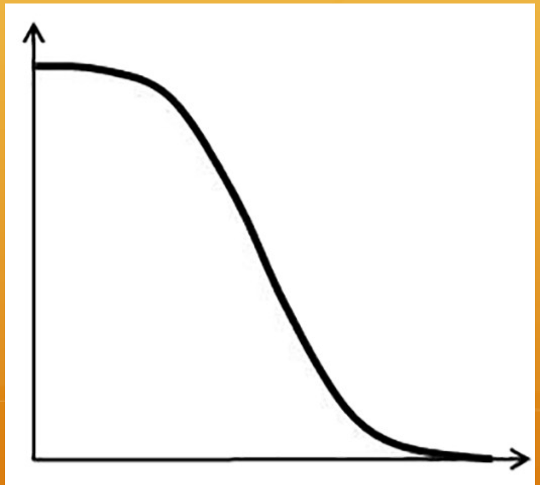
Soil Function

SMAF Score



'more is better'

- Organic C
- Microbial Biomass C
- Agg. Stability
- Potential mineralizable N
- Soil K



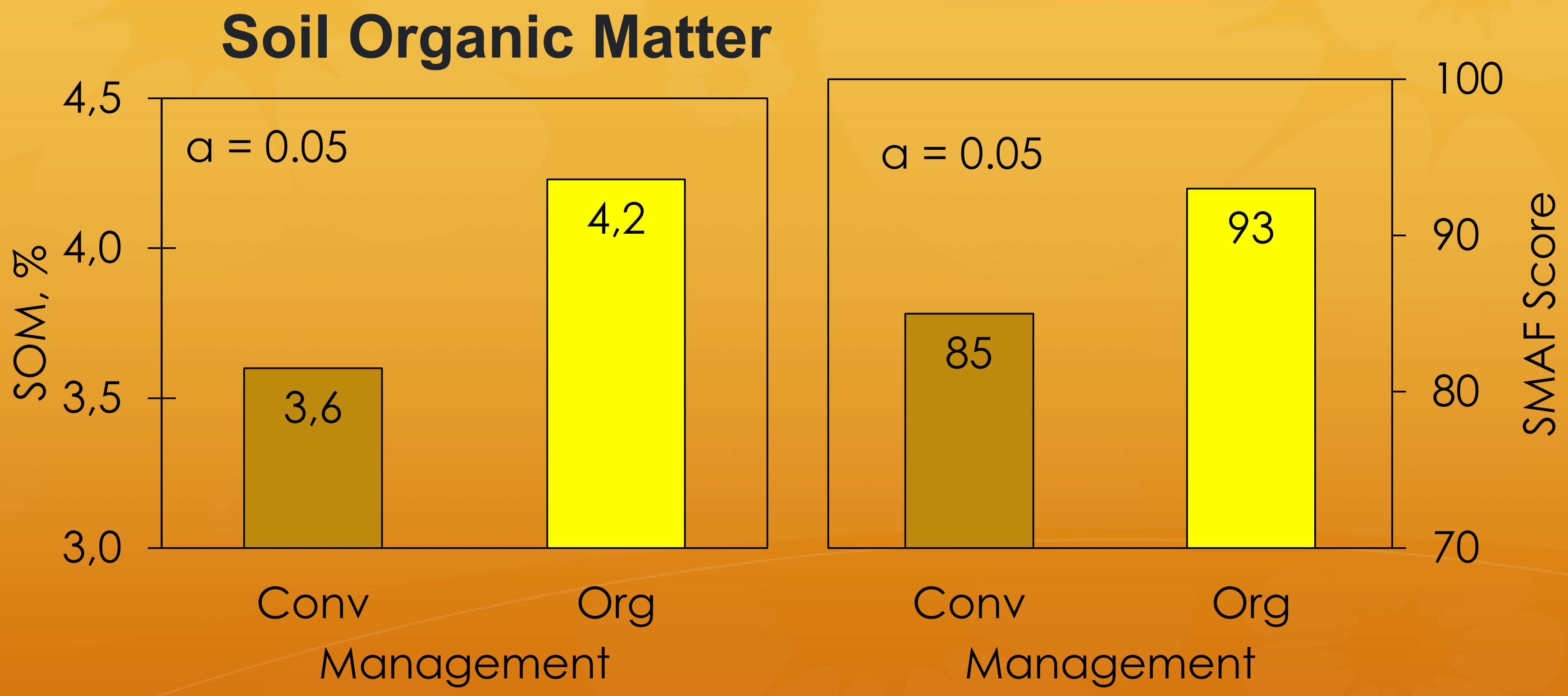
'less is better'

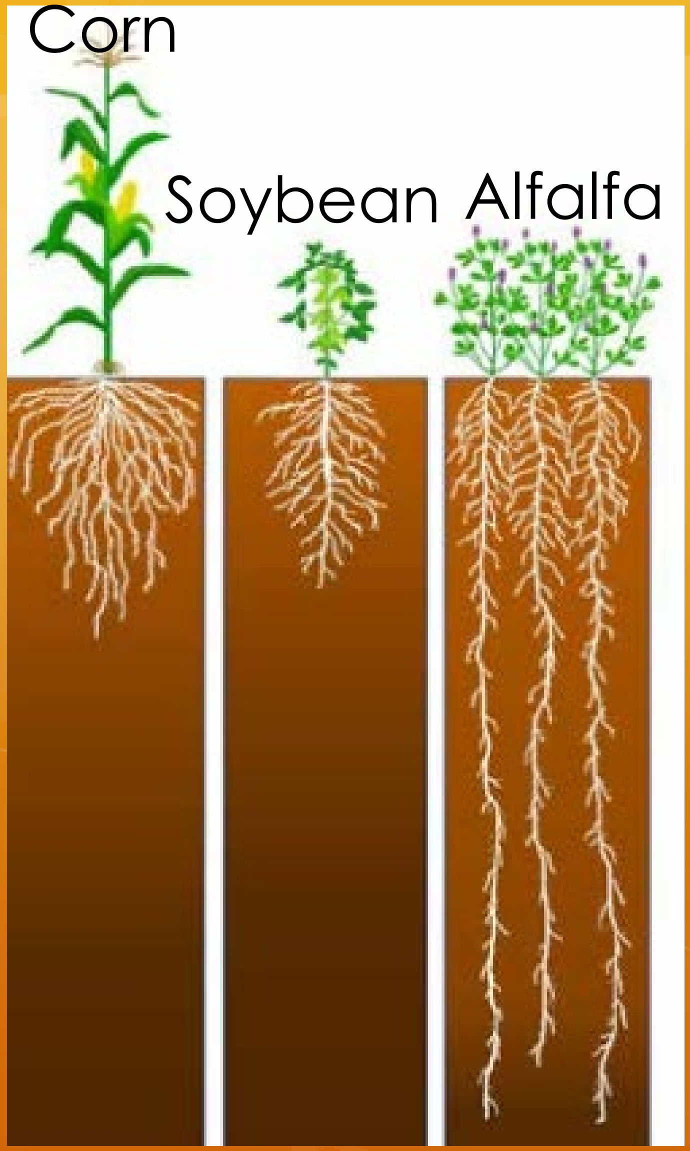
- Bulk density
- Electrical conductivity
- Sodium adsorption ratio

'mid-point optimum'

- Soil pH
- Soil P

20-yr organic farming effects on SOM



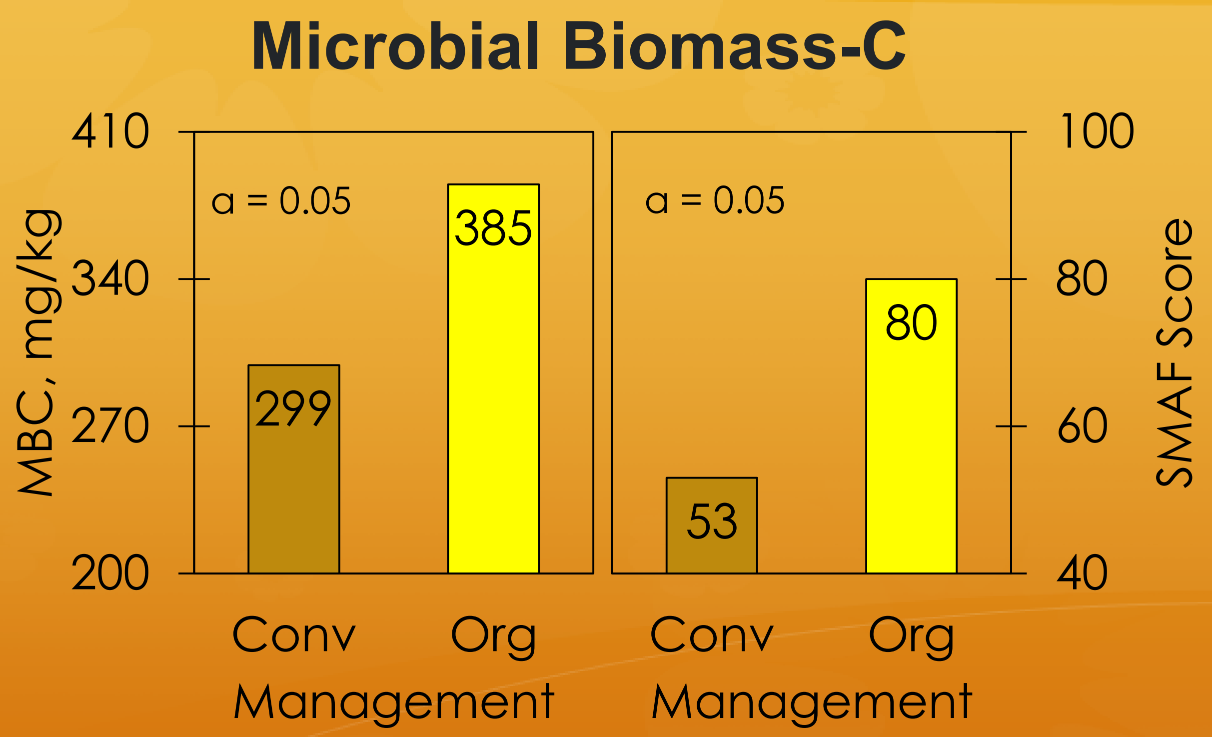


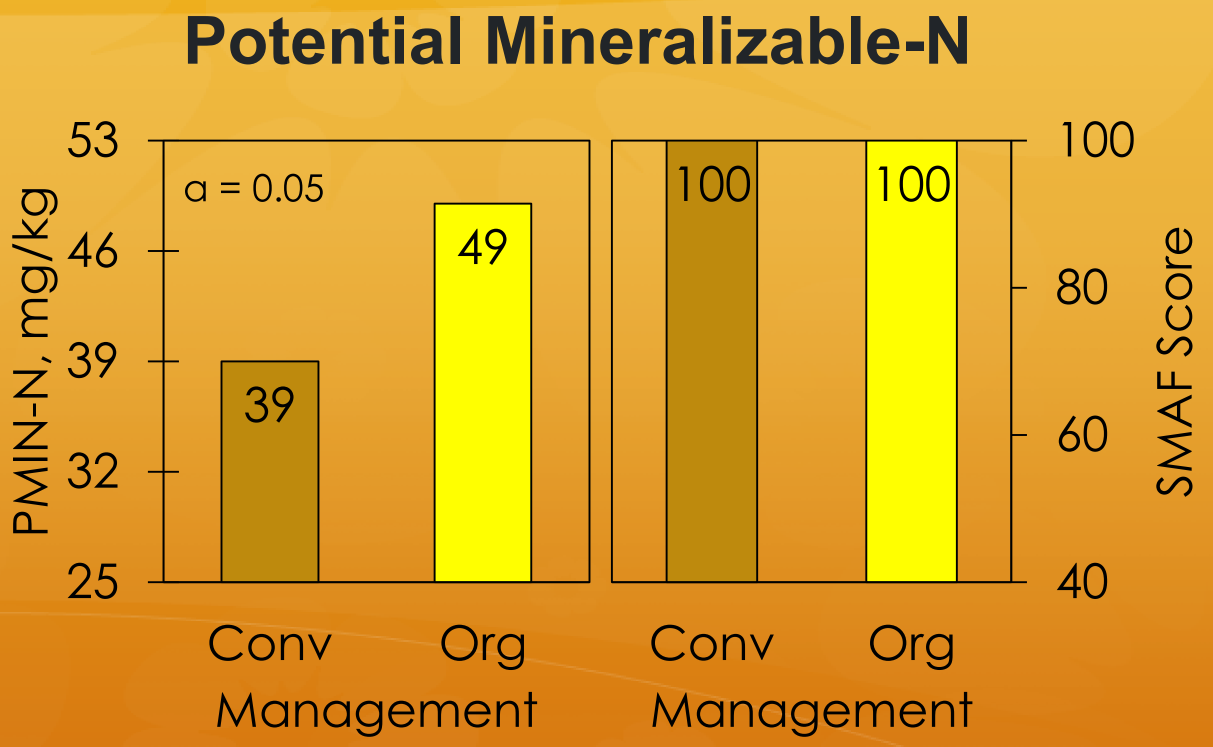
Adapted from: Fernandez et al. 2019

Higher SOM -> better soil functioning in organic systems

- Increased resistance and resilience
- Increased nutrient cycling
- Increased structure stability

20-yr organic farming on MBC & PMN



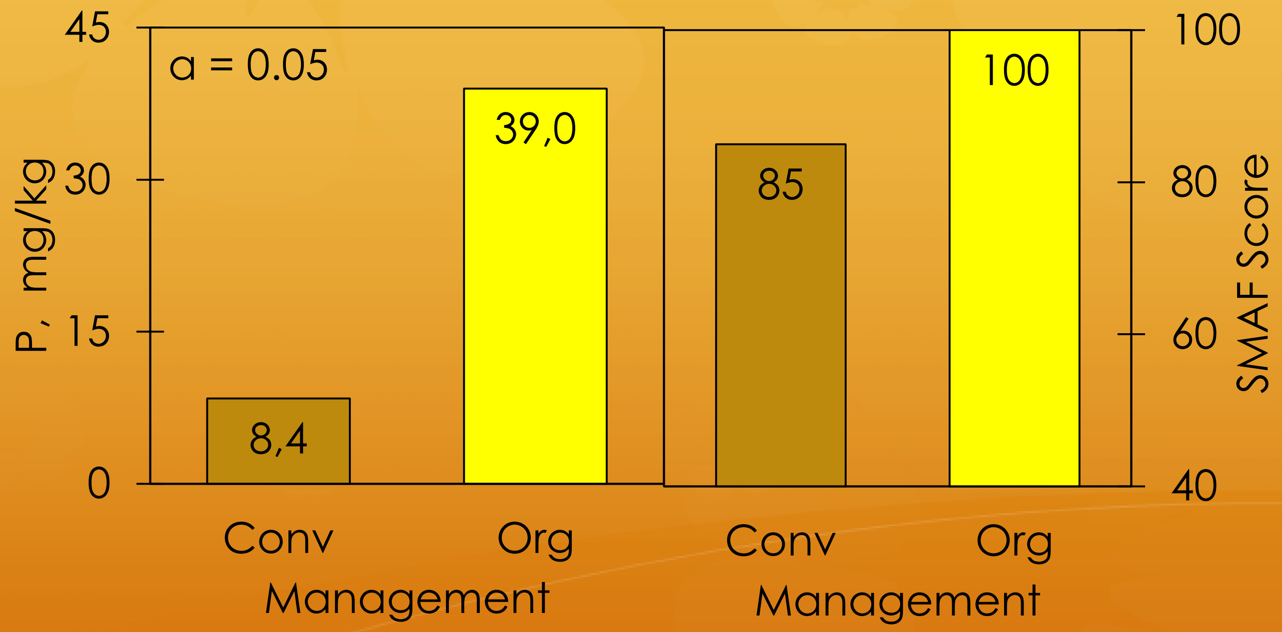


Higher MBC and PMN -> better soil functioning in organic systems

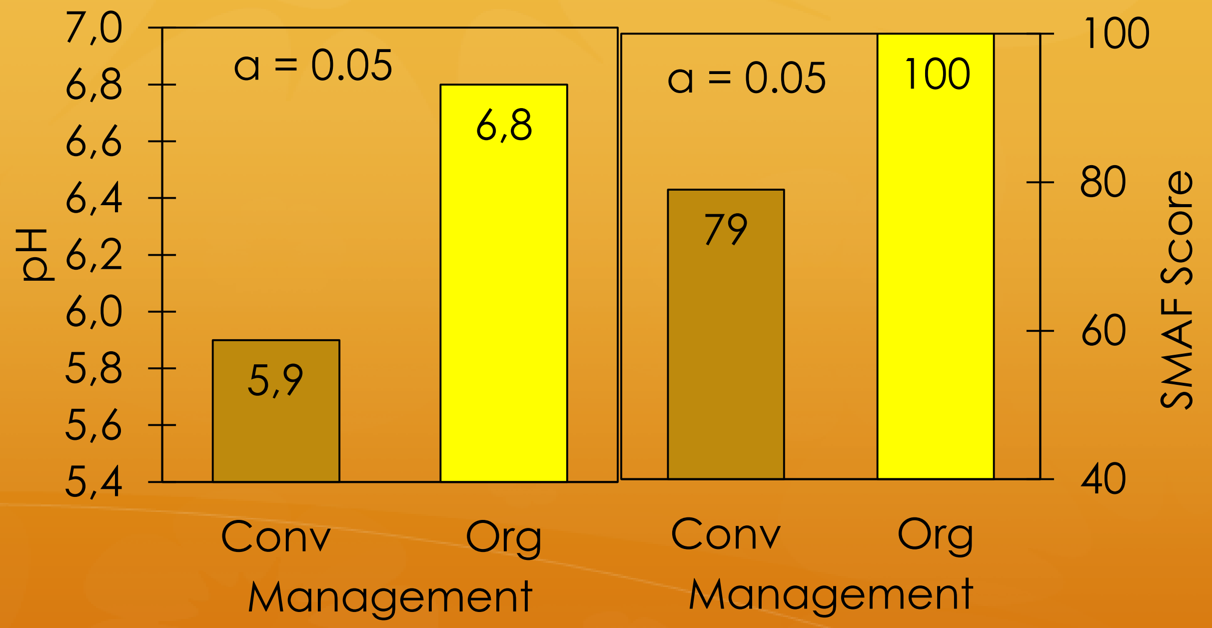
- Increased microbiology (bacteria, fungi)
- Increased cycling and release of nutrients

20-yr organic farming on soil **chemical indicators**

Soil P



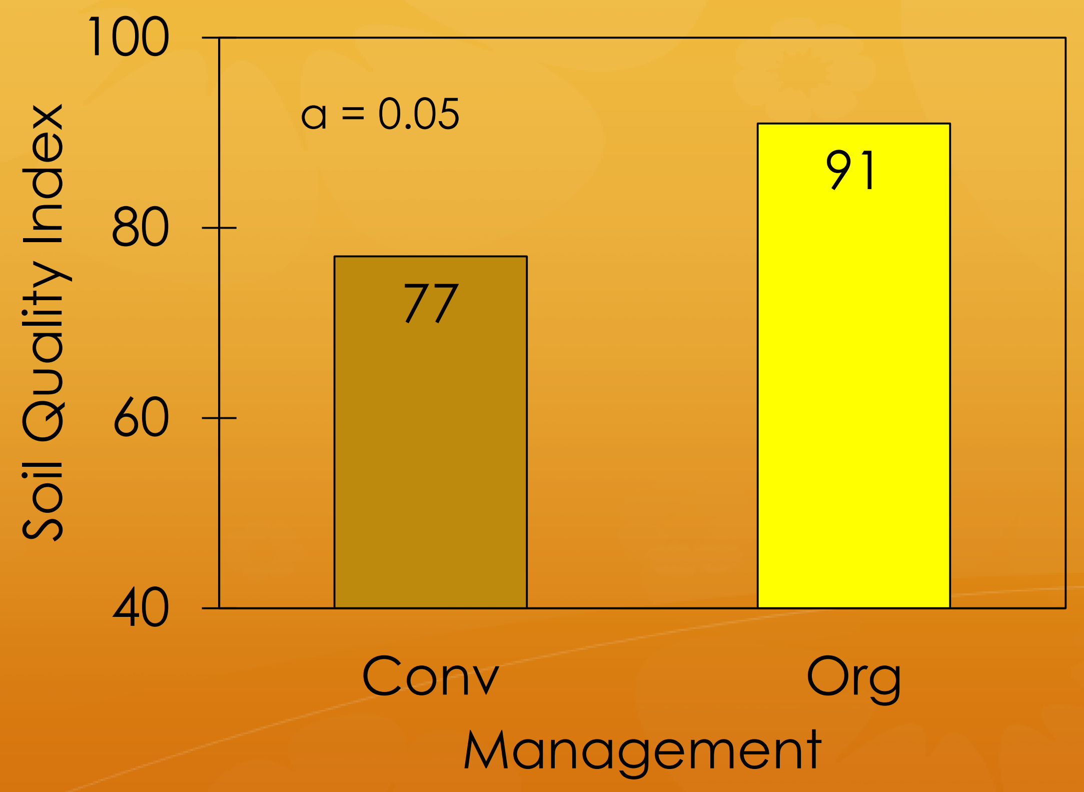
Soil pH



More balanced soil chemical functioning in organic systems

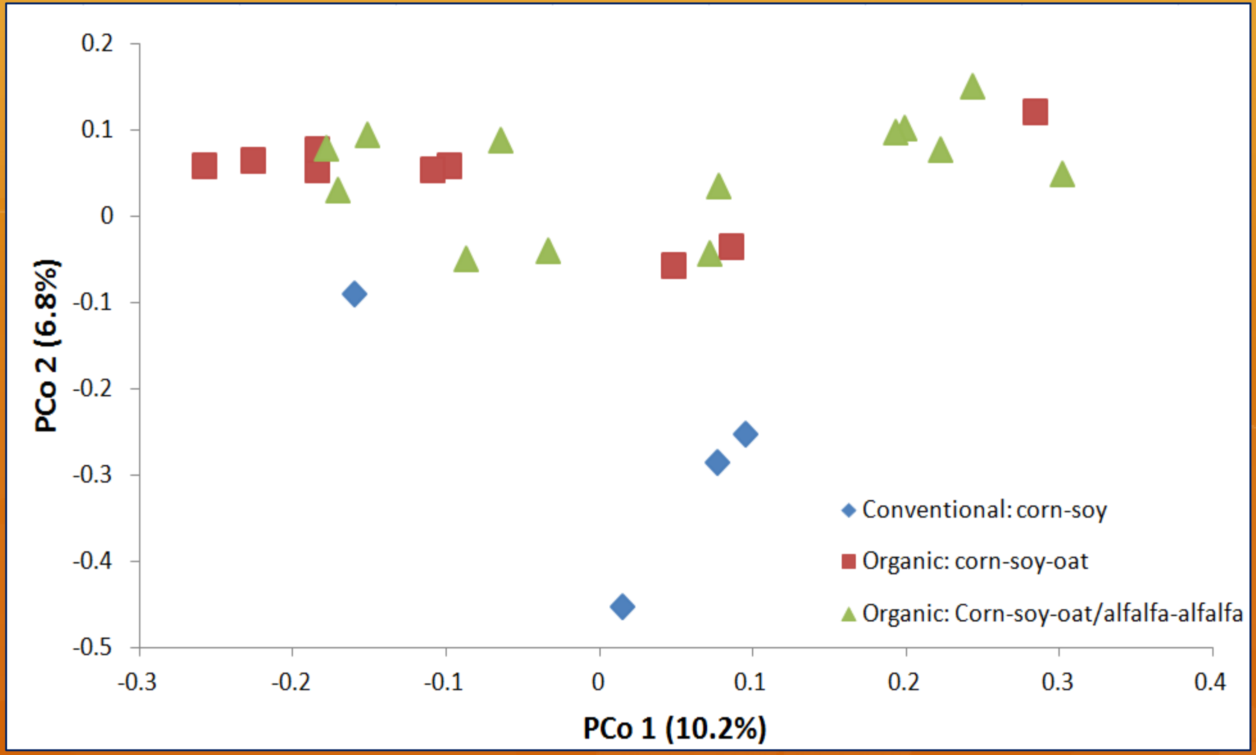
- Synthetic fertilizers increased soil acidification
- Organic fertilizers, associated with higher biological activity, increase plant available nutrients

20-yr organic farming on **soil quality/health**



Overall analysis:

Long-term **organic systems** improve biological, physical, and chemical soil health. Differences observed in bacterial community.



Bakker, M.G., T. Looft, D.P. Alt, K. Delate, and C.A. Cambardella. 2018. Bulk soil bacterial community structure and function respond to long-term organic and conventional agricultural management. Canadian Journal of Microbiology 64 (12): 901-914. http//doi.org/10.1139/cjm-2018-0134.

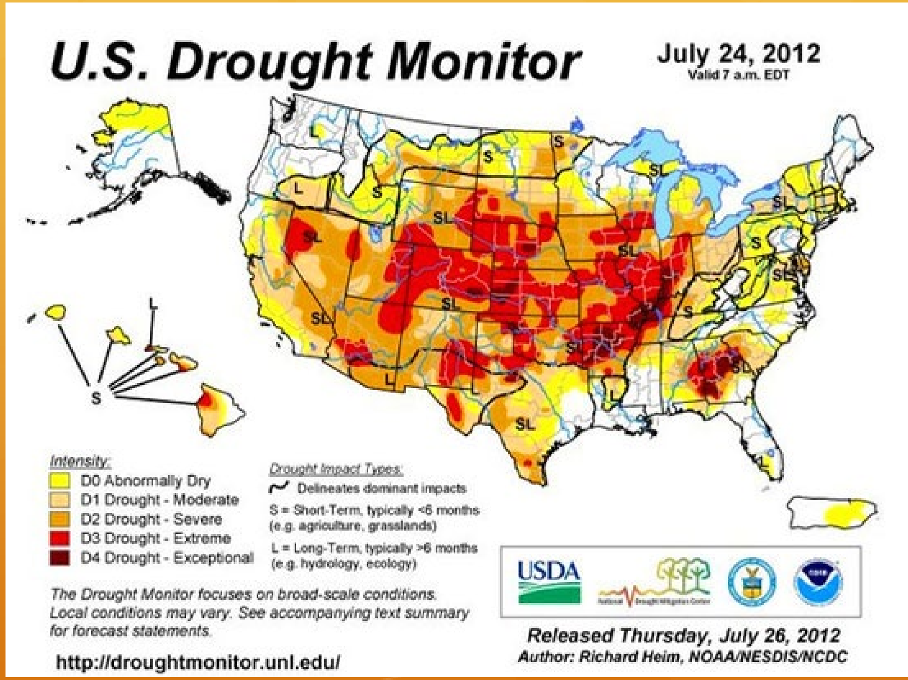
Neely-Kinyon Economics – Conventional vs. Organic

Conventional Rotation	2014-2018	2018
Total Revenue	$476.47	$438.16
Total Costs	$534.73	$489.68
Return to Management	-$58.26	-$51.52

Organic Rotation	2014-2018	2018
Total Revenue	$814.43	$923.76
Total Costs	$429.45	$482.48
Return to Management	$384.98	$441.28

Costs average about $50–100/acre less in organic; even during transition, costs lower in organic: no pesticide or fertilizer costs. Premium prices = greater revenue. *-Craig Chase, ISU*

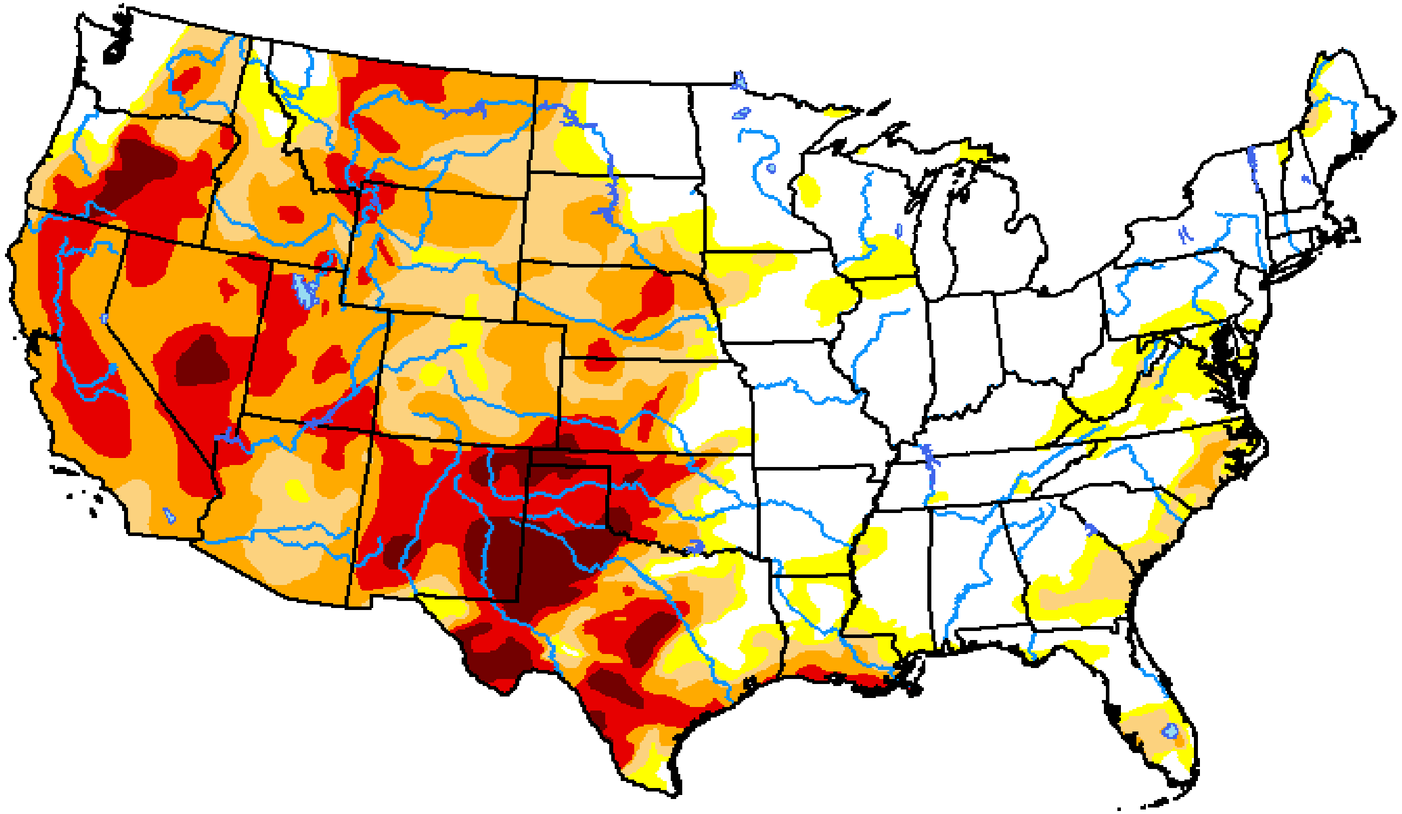
Droughts becoming more common



May 3, 2022 Drought Map

Yellow = Dry

Red and Brown = Extreme to Exceptional drought

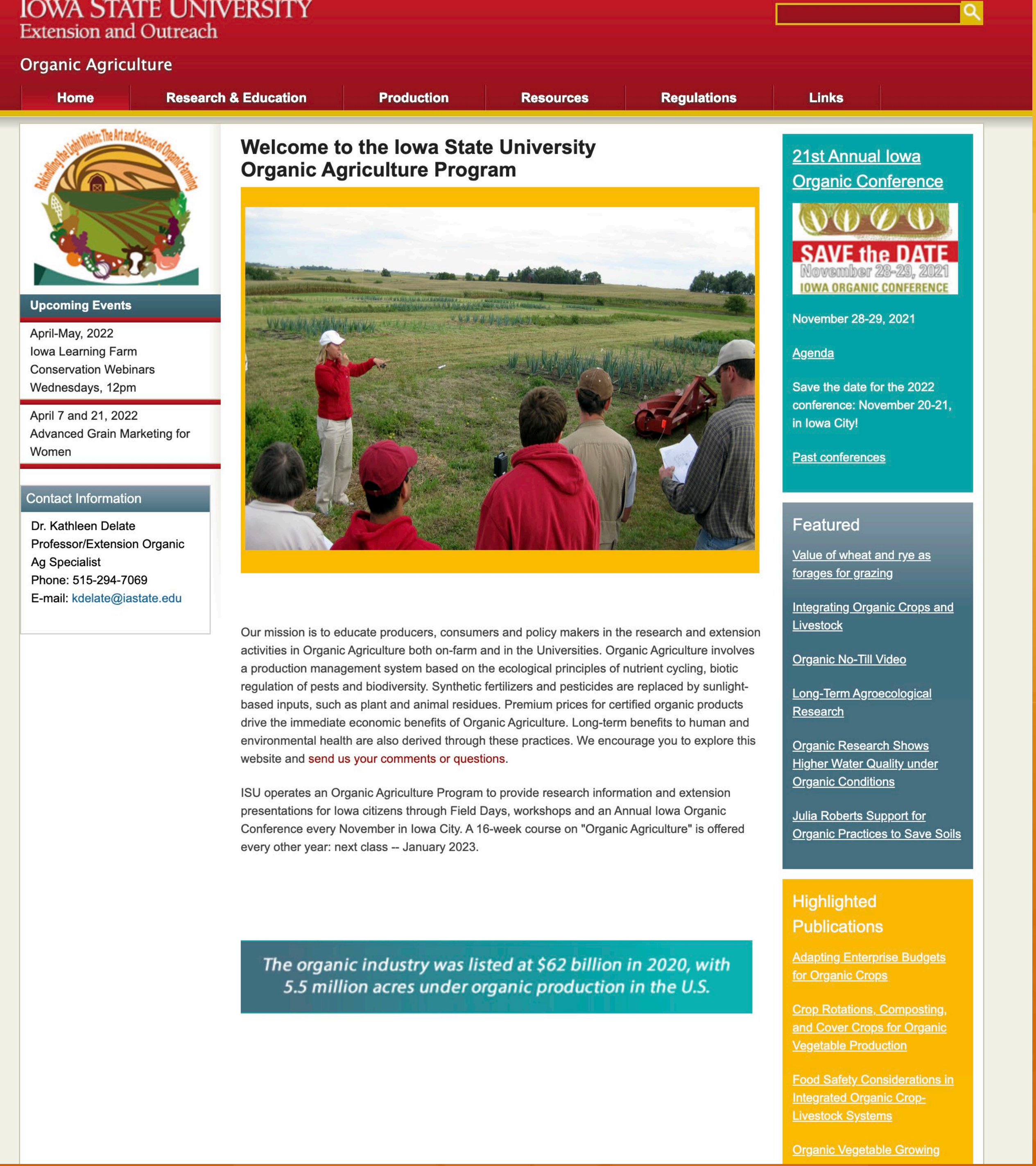


Extension and outreach: Critical components

Annual Field Days encourage local farmer feedback and interest in transitioning to organic ag

- Support for LTE organic sites crtical as both research and demonstration sites to encourage organic transition
- Local farmer support is key to continuation/new ideas
- Organic sites show greater soil organic carbon; higher profitability; and equal yields under normal rainfall/timely weed management
- The next frontier: fine-tuning nutrient & water mng't
  - From other U.S. LTEs, N mineralization potential of the organic system was 34% greater than conventional NT after 14 years
  - N availability increased with longer rotation

Area third-graders learn about soils at the LTAR



Thank you for the invitation – look forward to working together to support LTEs worldwide!

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