Long-Term Organic Comparisons in the U.S.

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U.S. Organic Production

- Total organic acreage in 1992: 935,450
- 5.4 million acres in 2011
- 213,700 acres of organic grains: 1995
- 883,572 acres in 2011

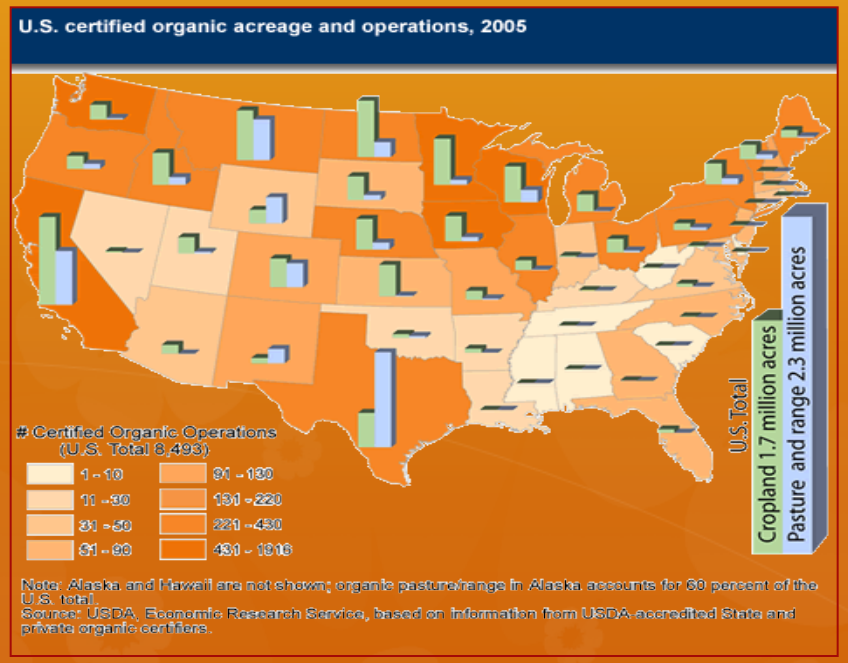
• $31.3 billion total

U.S. industry sales in 2012

-Annual growth rate

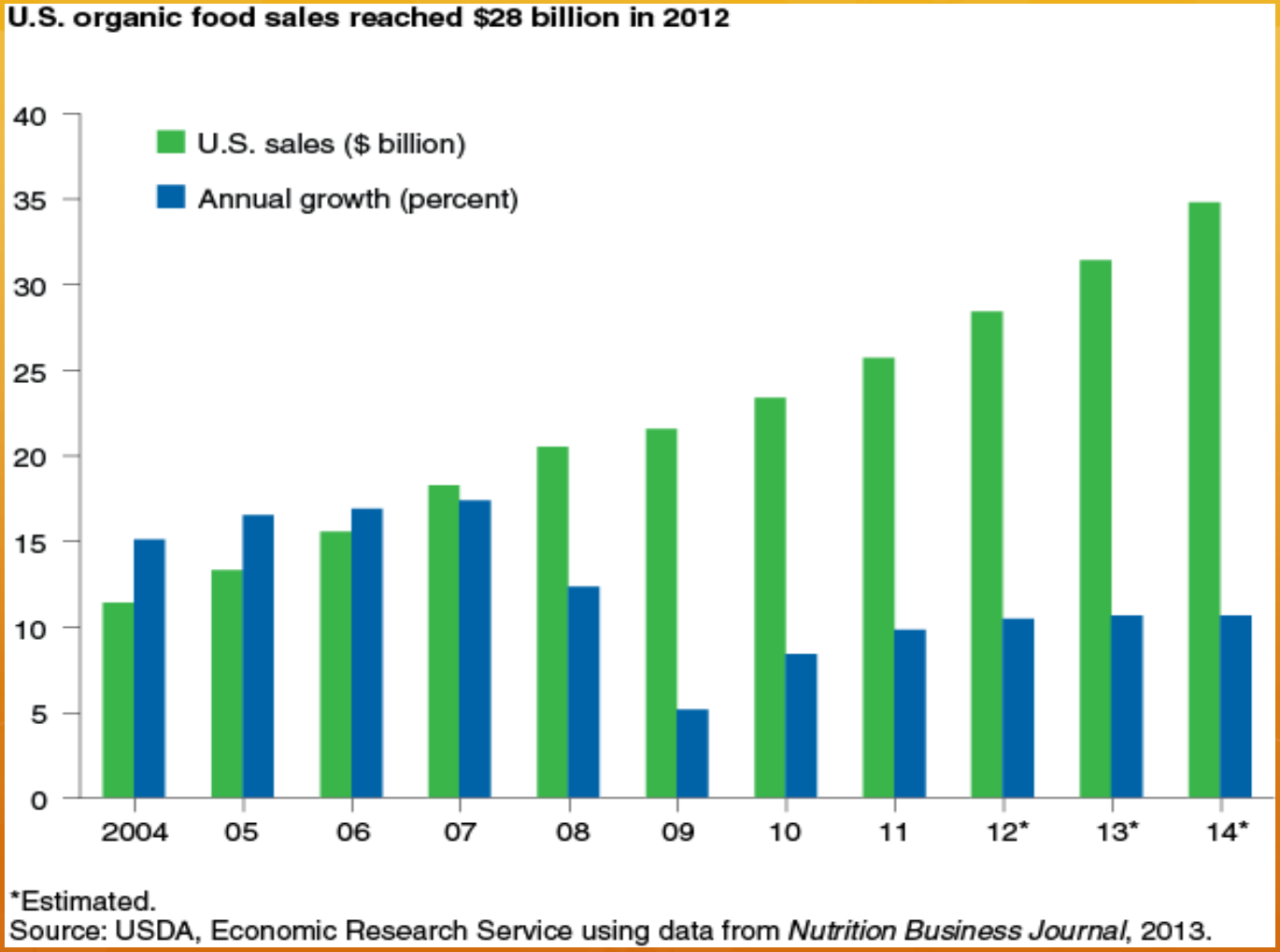
10.2% in 2012

-Iowa: 5th largest number of organic farmers in U.S.



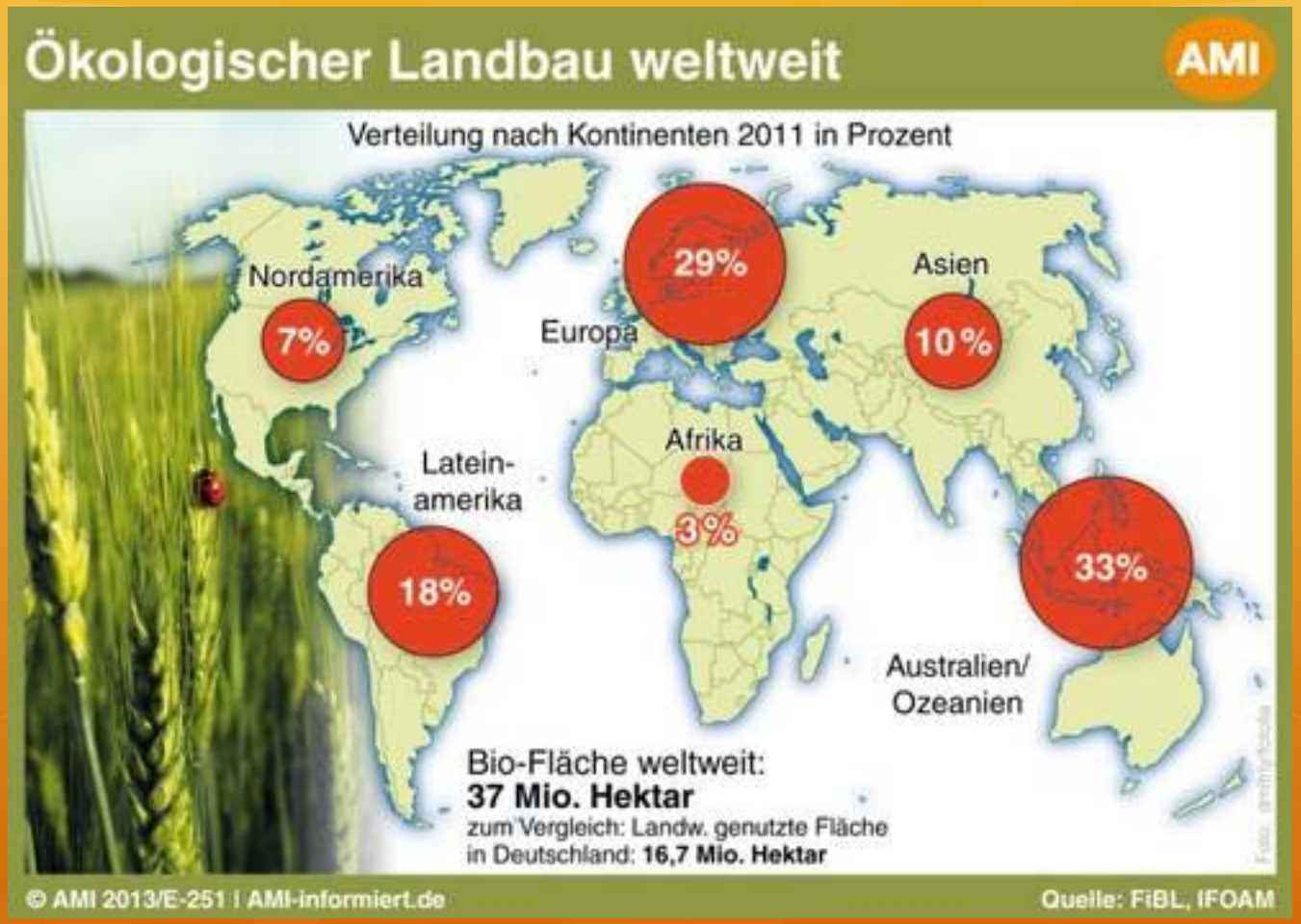
USDA-ERS website

U.S. Organic Market Size



The recession slowed but did not stop growth of organics

Europe has largest organic cropland



Organic Agriculture World-wide 2011 - Source: FiBL & IFOAM 2013; Graph: Agricultural Information Company AMI, Bonn, Germany

History of organic regulations under USDA

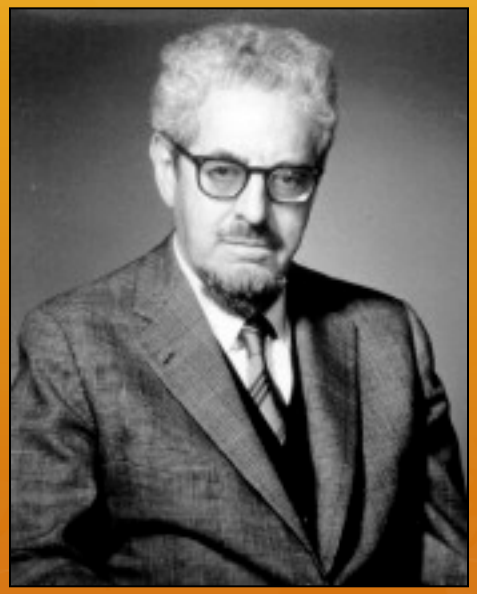
- In 1990, the Organic Foods Production Act (OFPA) was passed, establishing uniform standards for organic agriculture
- OFPA was implemented via 7 CFR Section 205 and emphasizes agroecological principles, elimination of synthetic inputs, recycling of nutrients and use of local resources
- Under the USDA-Agricultural Marketing Services-National Organic Program (NOP)

Modern Founders of Organic Ag: Offered parameters on which many of today's organic rules are based

Lady Eve Balfour
(1899-1990)

Balfour published *The Living Soil in* 1943 which was based on results from her experiments

J. I. Rodale
(1898-1971)



"Healthy Soil = Healthy Food = Healthy People®" was J.I.'s core message

Sir Albert Howard
(1873-1947)

"The maintenance of the fertility of the soil is the first condition of any permanent system of agriculture."

Need for standardization

- Prior to 1990, more that 40 organic certifiers were evaluating materials for use in organic production according to a patchwork of State and private standards.

- Organic Production (NOP definition):

"A production system that is managed in accordance with the Act and regulations… to respond to site-specific conditions by integrating cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity."

Goals of long-term ag research

- a) improved understanding of agriculture from long-term systems' perspective, such that multiple management aims can be balanced against known trade-offs;
- (b) greater integration of biophysical and social sciences to provide information and insights needed to implement solutions with acceptable economic and social costs;
- (c) 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;
- (d) strengthened 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)

Sustainability determined by:

- long-term trends in yield
- profitability
- efficiency in use of limited resources (water or energy), and
- environmental impact (e.g., leaching of nitrates and pesticides)

-Kate Scow, UC-Davis

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)

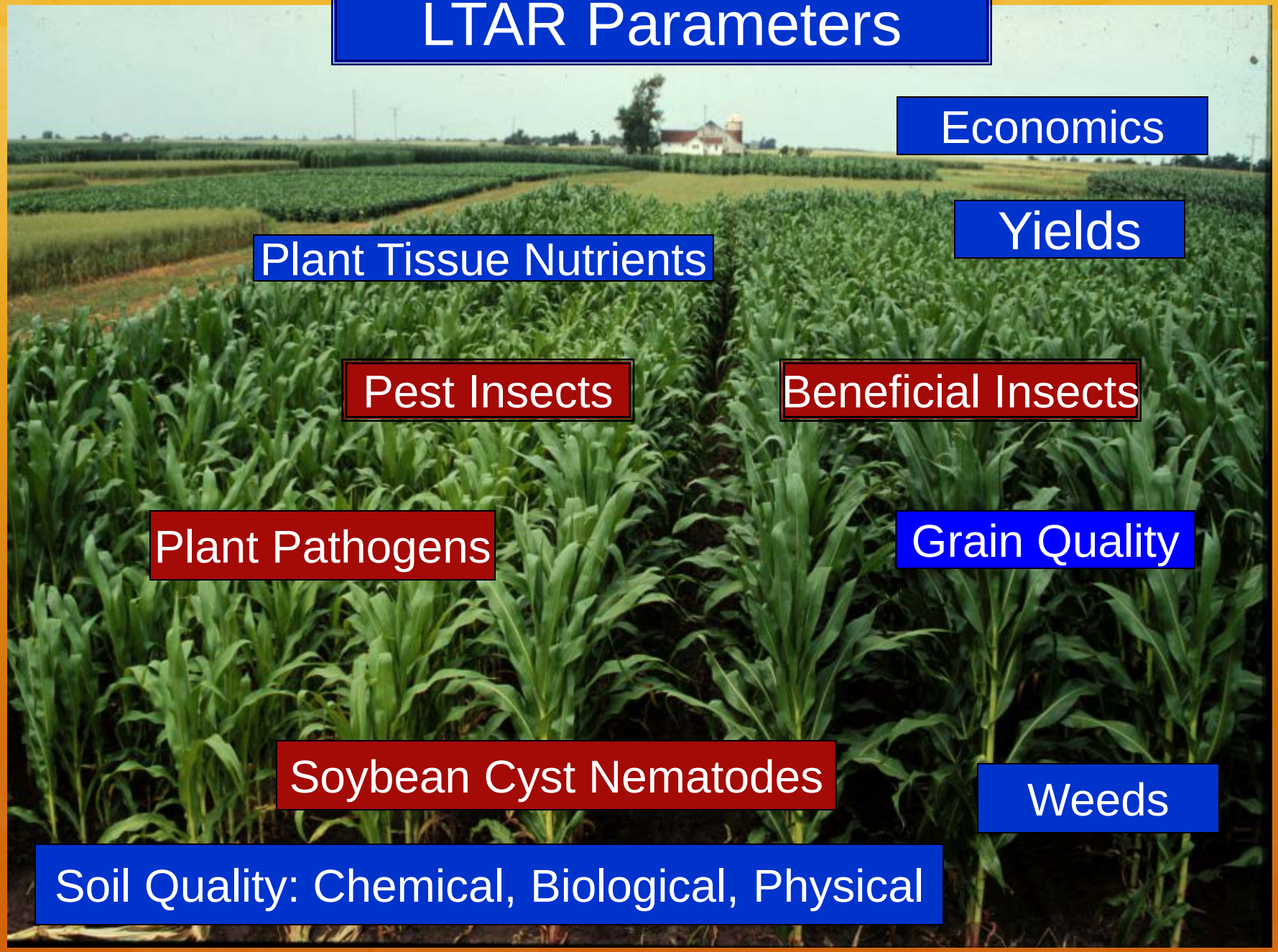
Parameters measured

- All inputs and outputs
- All field operations
- Crop yields
- Crop nutrient levels
- Soil quality
- Economic returns

- Soil biodiversity
- Greenhouse gas emissions
- Water use

Kate Scow, UC-Davis

LTAR Parameters



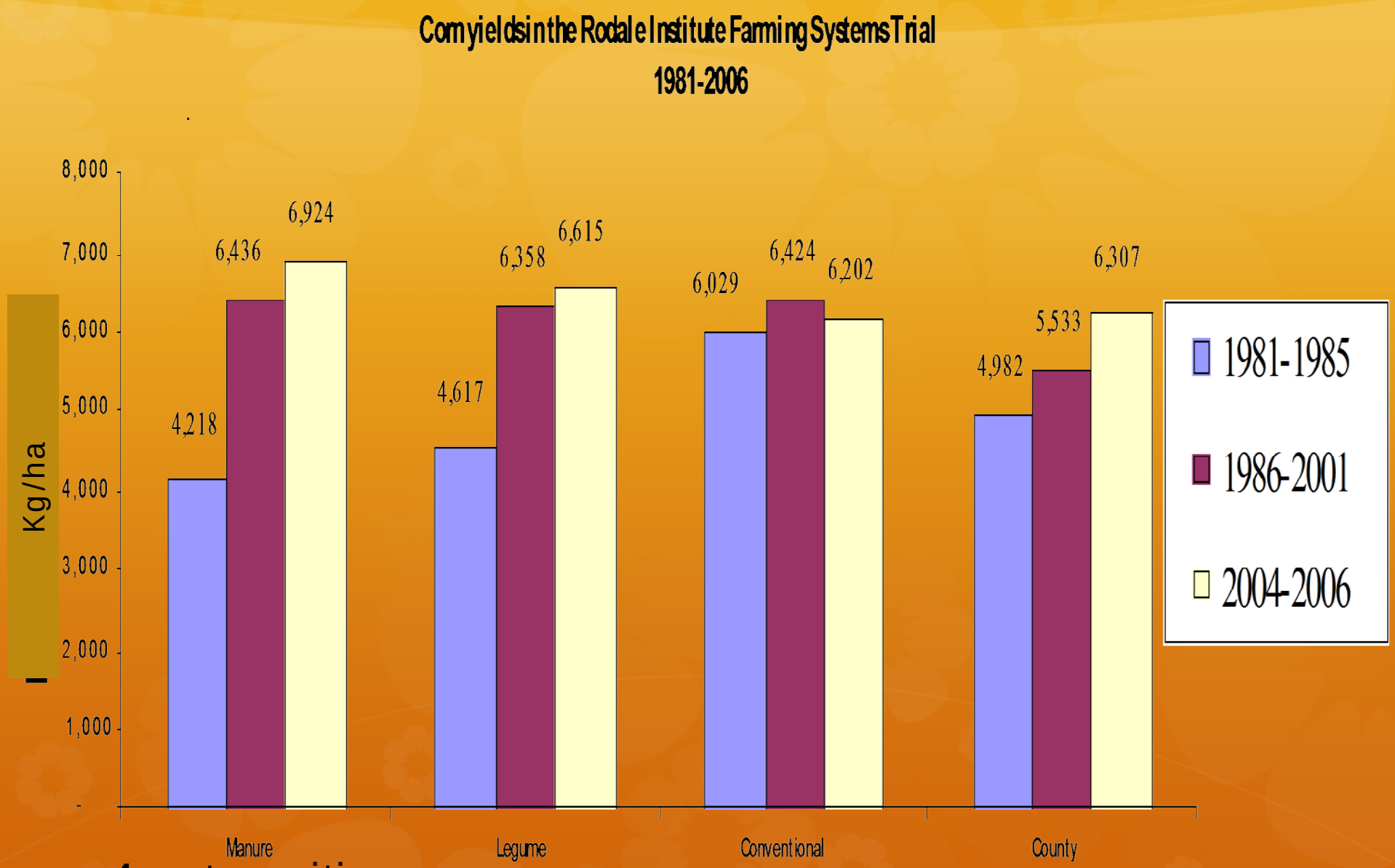
The Farming Systems Trial (FST)

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)
- 3 crops in each system; 8 replications

The Farming Systems Trial (FST)

	Organic		
	Manure (MNR)	Legume (LEG)	Conventional (CNV)
Nitrogen source	Composted manure	Legume cover crops	Ammonium nitrate and Urea
Weed control	Cultivation	Cultivation	Herbicides
Primary tillage	Moldboard plow	Moldboard plow	Chisel plow
Planting date	Late	Late	Early
Cover crops	Rye	Rye, Hairy vetch	None
Cash crops that function as cover crops	Winter wheat, red clover/alfalfa hay		

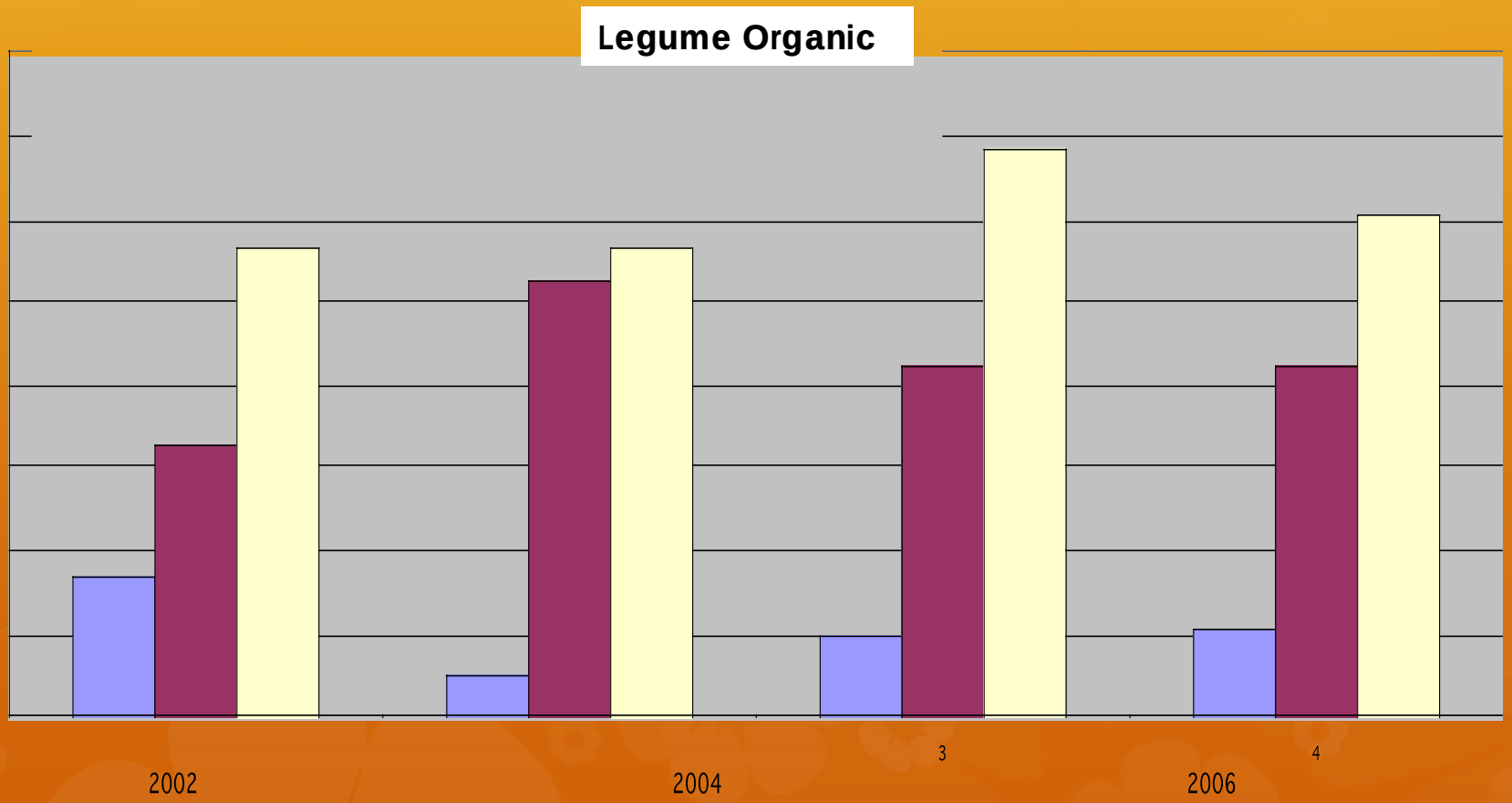


-4-yr transition: org = conv

-20-yr+: org (composted manure) > conv

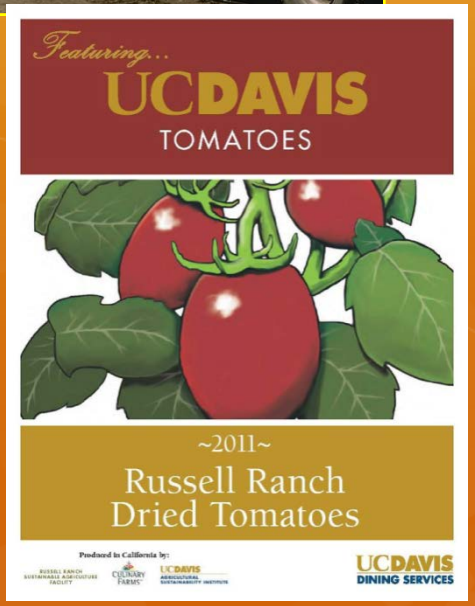
The RODALE INSTITUTE

Soil quality highest in organic with composted manure



Cali med crops: wheat & tomatoes

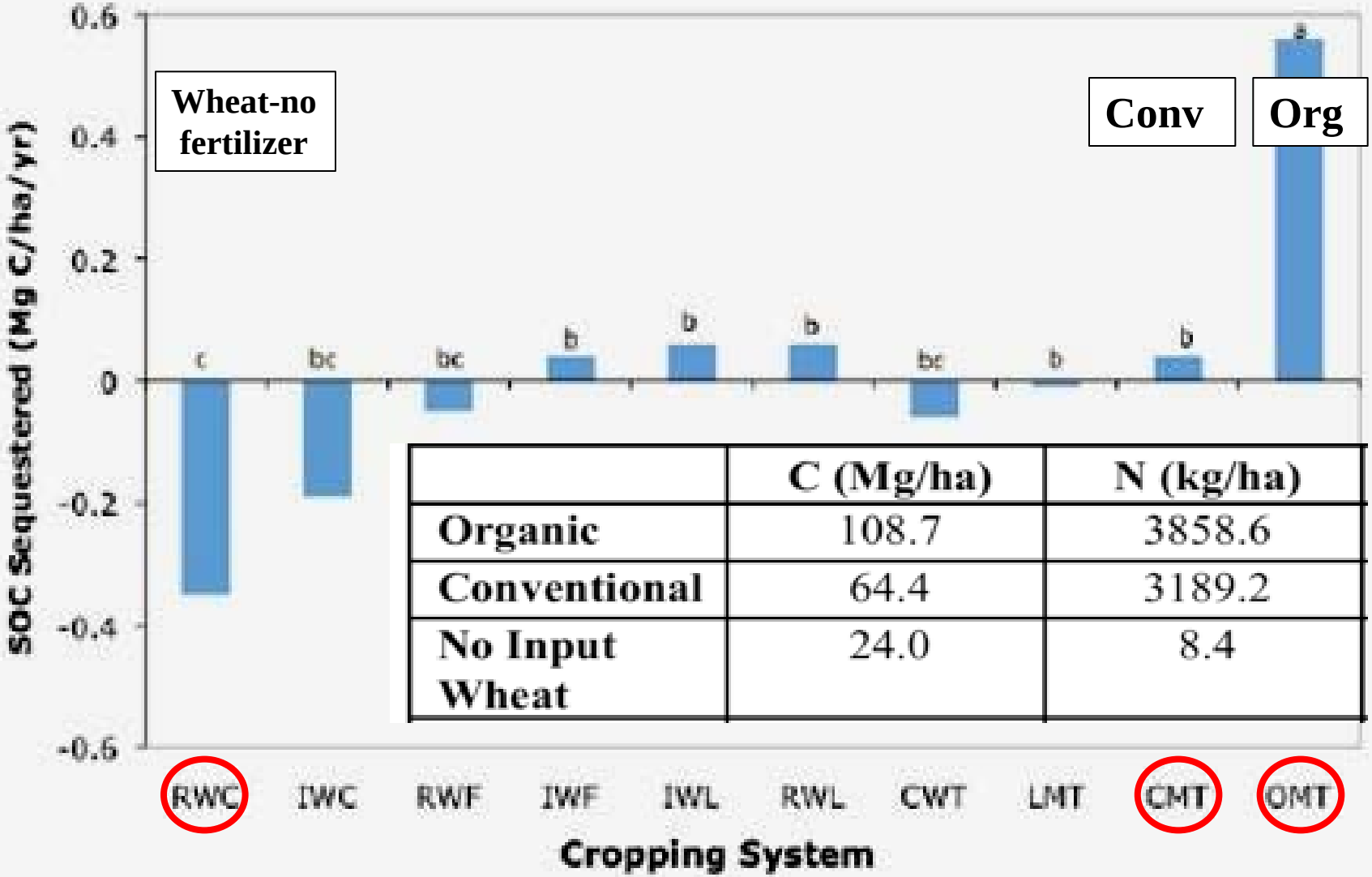
Sustainable Ag Farming Systems (SAFS), UC-Davis



- Crops sold commercially with detailed economic analysis (K. Klonsky)
- Food quality analysis (A. Mitchell)

-Photos: K. Scow

Higher soil organic carbon sequestered over 12 yrs of farming



	C (Mg/ha)	N (kg/ha)
Organic	108.7	3858.6
Conventional	64.4	3189.2
No Input Wheat	24.0	8.4

Kong et al., 2005

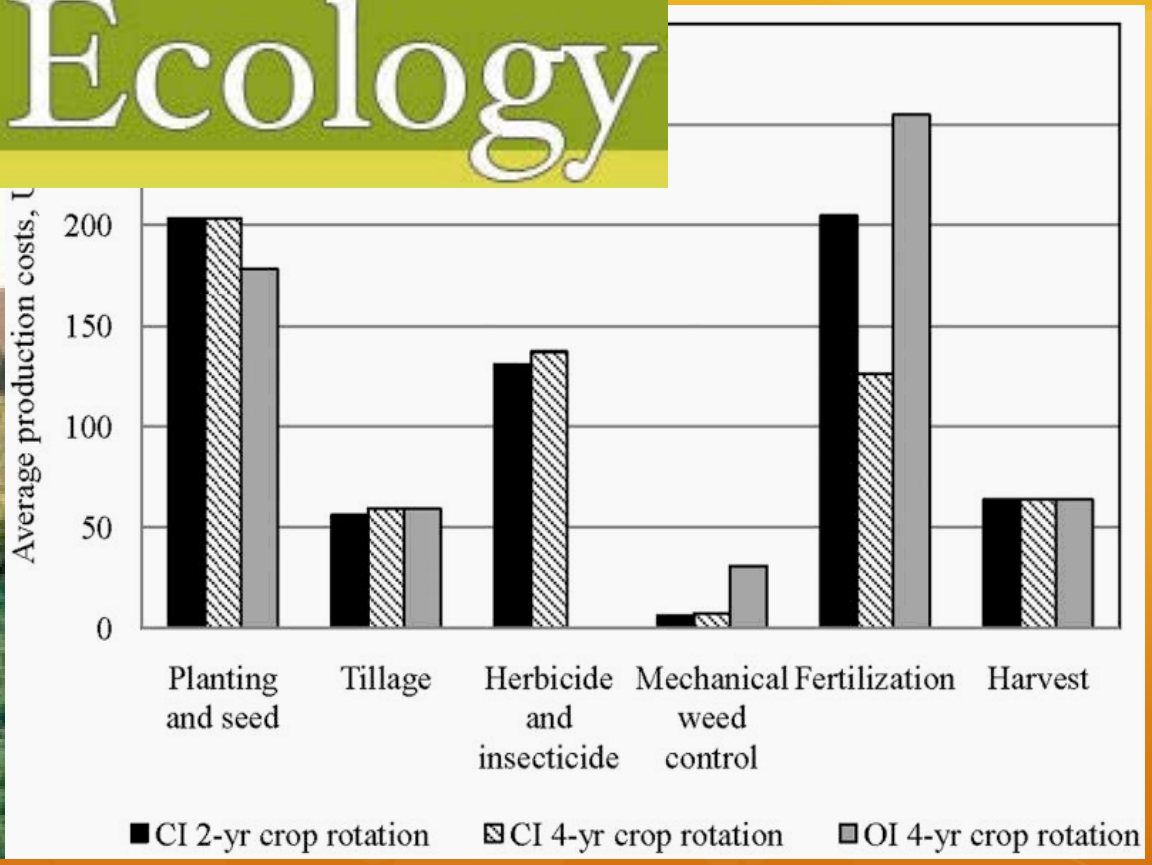
Differences in tomato nutritional quality under different management systems

- **Significant differences in 3 flavonoids (Kaempferol, Quercitin, and Naringenin) in dried fruit samples from processing tomatoes grown in conventional and organic systems**
- **Flavonoids higher in organic than conventional samples and differences increased with time**
- **Differences due to different pattern of N availability in organic?**

Mitchell, A. E.; Hong, Y.-J.; Koh, E.; Barrett, D. M.; Bryant, D. E.; Denison, R. F.; Kaffka, (2007). Ten-Year Comparison of the Influence of Organic and Conventional Crop Management Practices on the Content of Flavonoids in Tomatoes. J. Agric Food Chem 55:6154

Variable Input Crop Management Systems

UNIVERSITY OF MINNESOTA
Organic Ecology



-Inputs lower in organic rotation

-Mahoney, Olson, & Porter

-Even without price premiums,
organic returns not lower than conventional

-Variability of net returns similar in conventional & organic

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	90 w
Porter	MN	poor	---	64	---
		good	---	98	---
		unrated	92	---	100 o
Delate and Cambardella	IA	good	114	111	---
Smith and Gross	MI	poor	72	---	---
WICST	WI	poor	75	79	---
		poor	98	94	---
		unrated	---	---	93 w

Posner et al., 2008

UW: Effect of weed pressure on corn yield

Rotation	Wet springs (May + June >10" rain)		Normal springs	
	ARS	LAC	ARS	LAC
	|----------bu/a----------|			
Conventional (corn-soybean)	160	137	173	132
Organic (3-yr grain)	115	103	167	124
Org: conv	72%	76%	96%	94%

Janet Hedtcke
UW-Madison, Agronomy Dept

UW: Effect of weed pressure on soybean yield

Rotation	Wet springs (May + June > 10” rain)		Normal springs	
	ARS	LAC	ARS	LAC
	|----------bu/a----------|			
Conventional (corn-soybean)	48	57	57	53
Organic (3-yr grain)	38	44	54	49
Org:conv	79%	76%	95%	92%

Janet Hedtcke
UW-Madison, Agronomy Dept

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

2014: 17–year comparison of conventional & organic crops

LEOPOLD CENTER
FOR SUSTAINABLE AGRICULTURE

Supported by the Leopold Center for Sustainable Ag

Farmers decide treatments and provide input on results

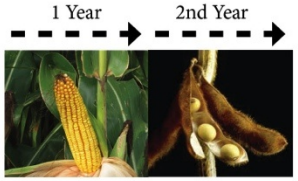
1998 LTAR Field Day Update with Heartland Organic Marketing Co-op and IDALS staff

- 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

Neely-Kinyon LTAR

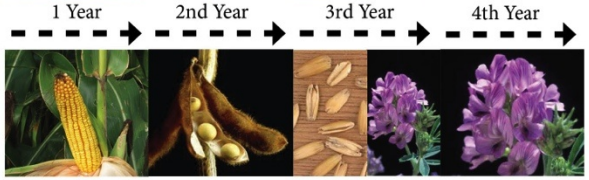
Treatments

8 Plots
Conventional C - SB

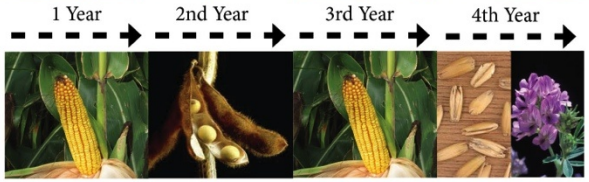


12 Plots
Organic C - SB - O/A

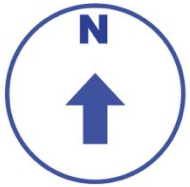
16 Plots
Organic C - SB - O/A - A



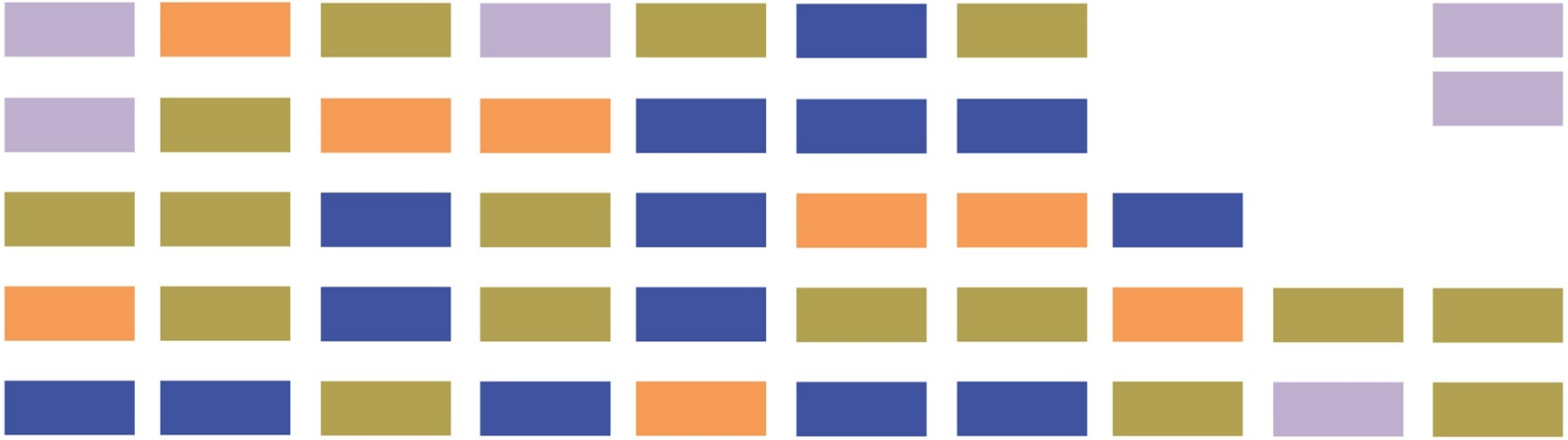
8 Plots
Organic C - SB - C - O/A
(changed from SB-W/RC in 2010)



-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



Plot Plan



Annual Field Days every August encourage local farmer feedback and interest in transitioning

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

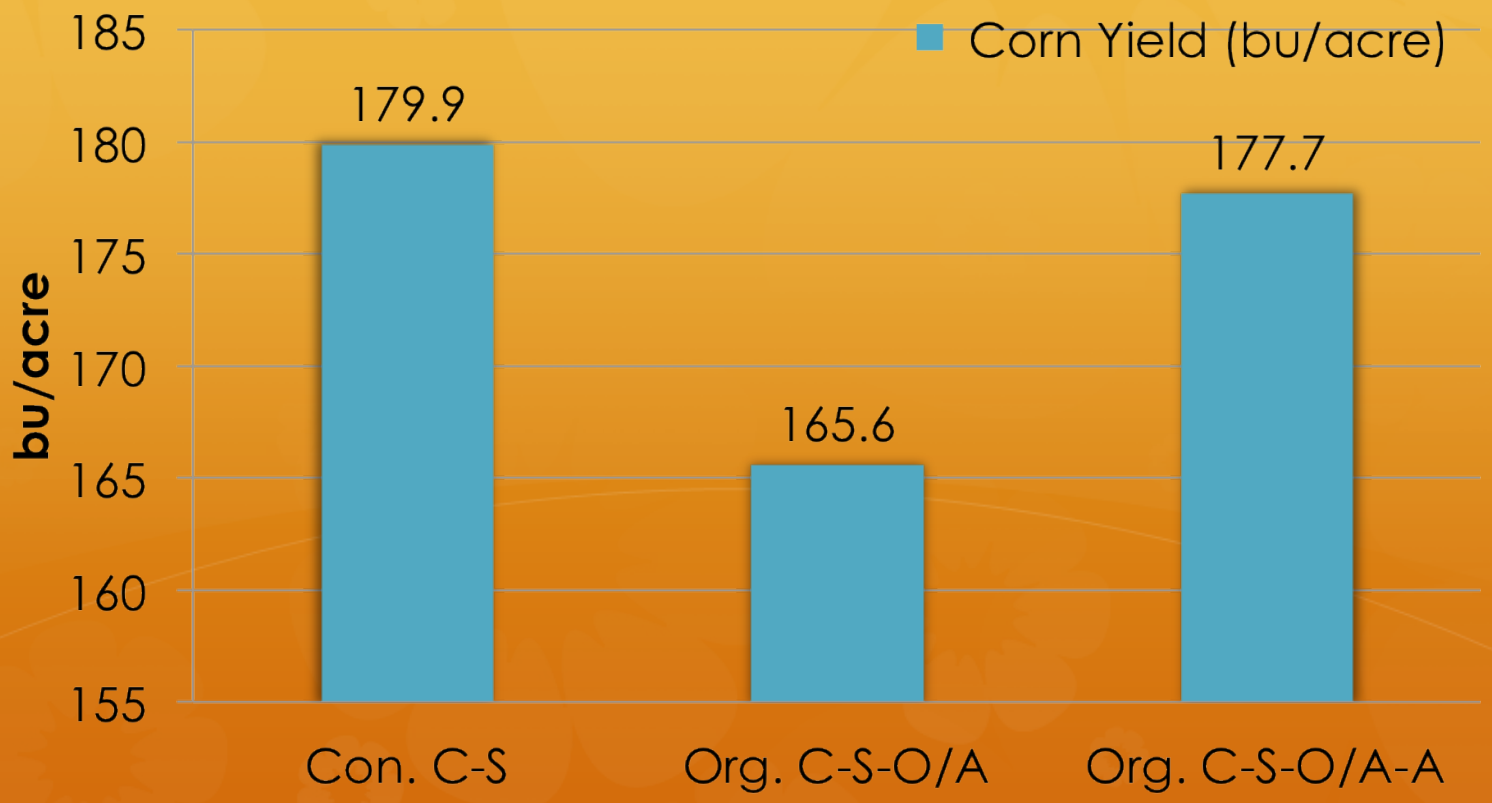
- Compost (treated as raw manure and put on at least 3 mo. before harvest): put on in March (warm soil)

- Mixture of manure and straw/hay

- 2-3-4 N-P-K: Phosphorus not a problem but we check every year

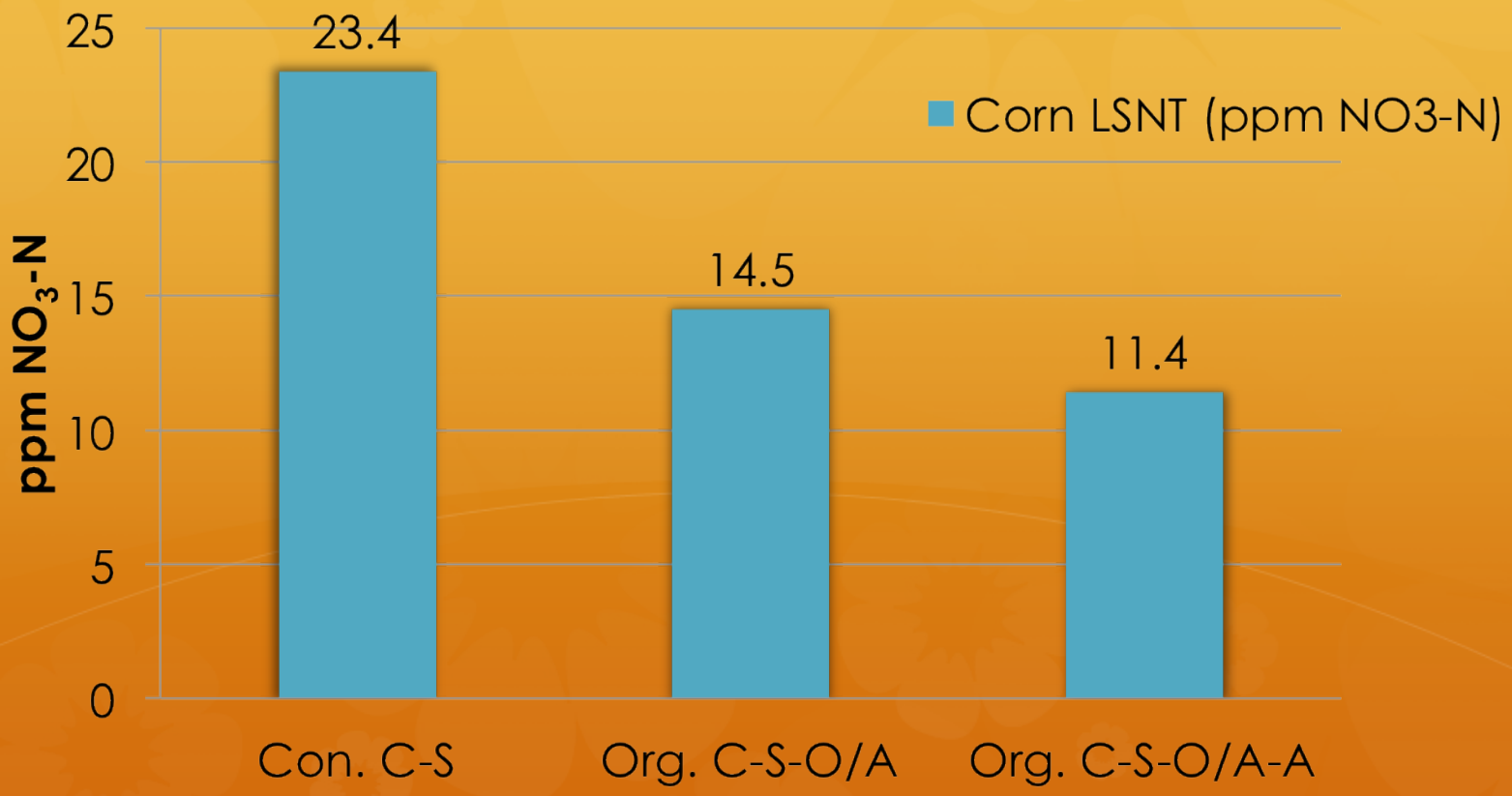
Hoop-house swine

Average Corn Yields
LTAR–2002-2010



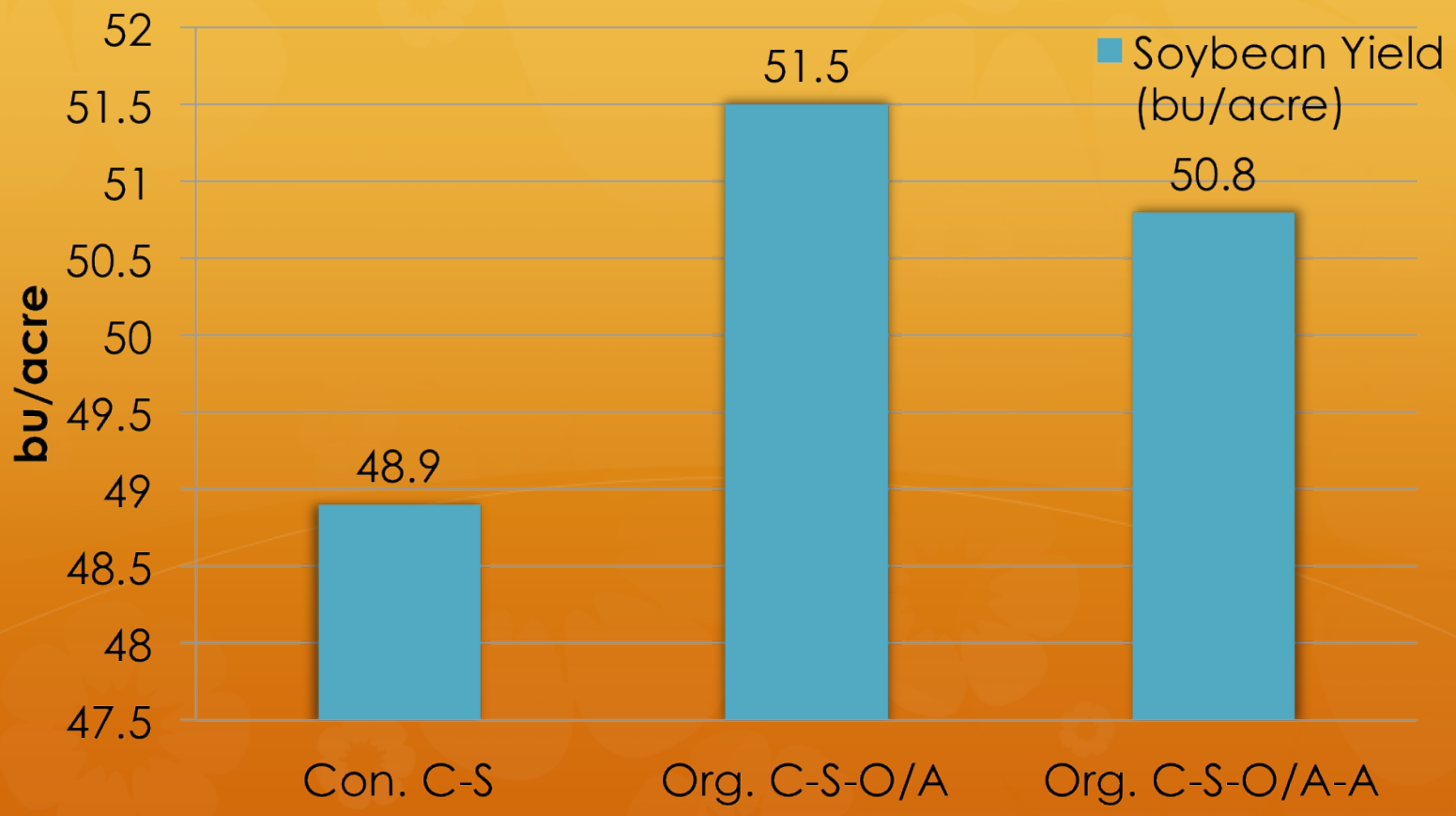
- Corn yields at 15.5% moisture
- No difference between organic and conventional yields

Average Corn LSNT LTAR–2002-2010



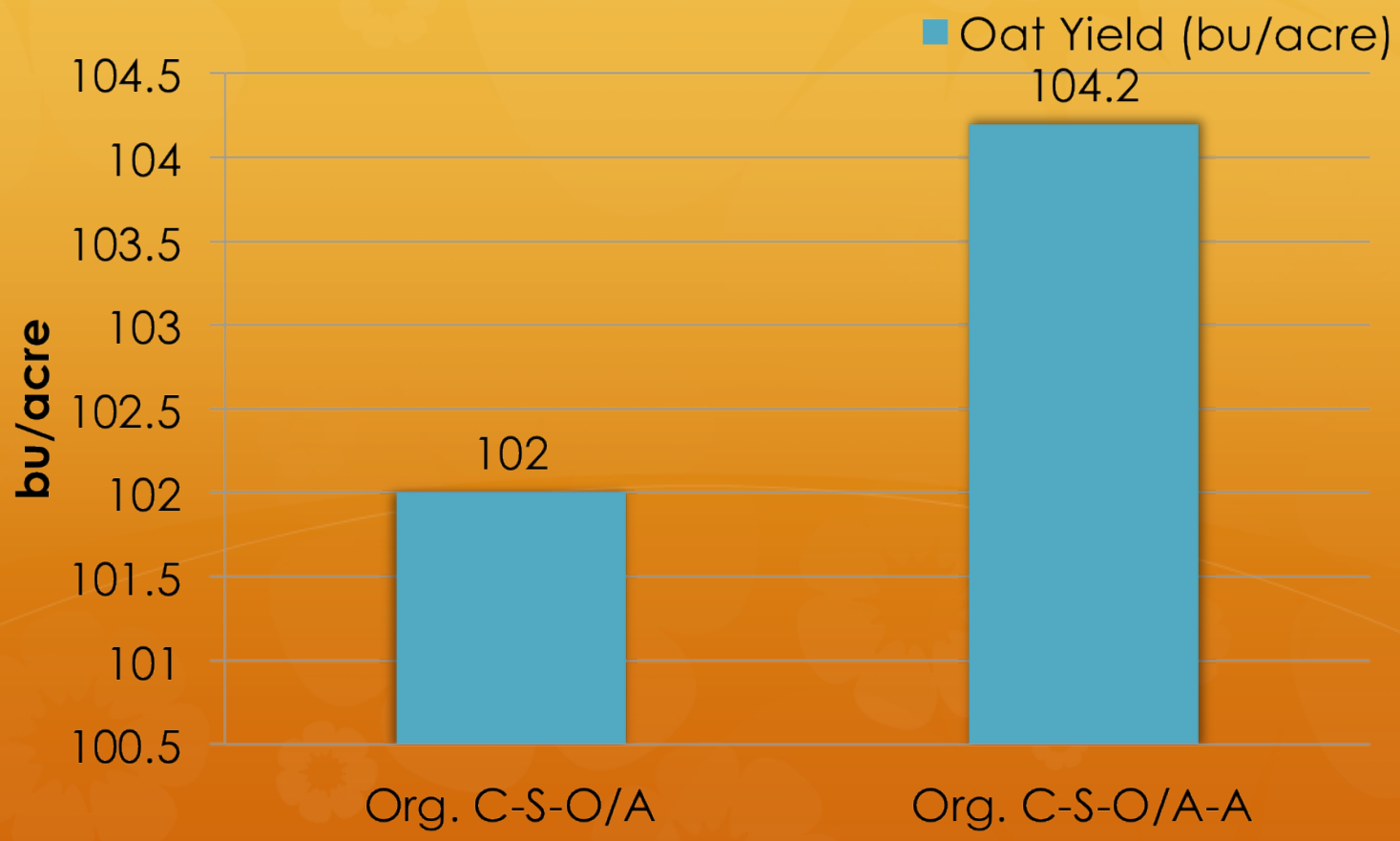
Yields the same despite lower N at late spring testing in organic, due to slow-release manure-based fertilizers used.

Average Soybean Yields
LTAR–2002-2010



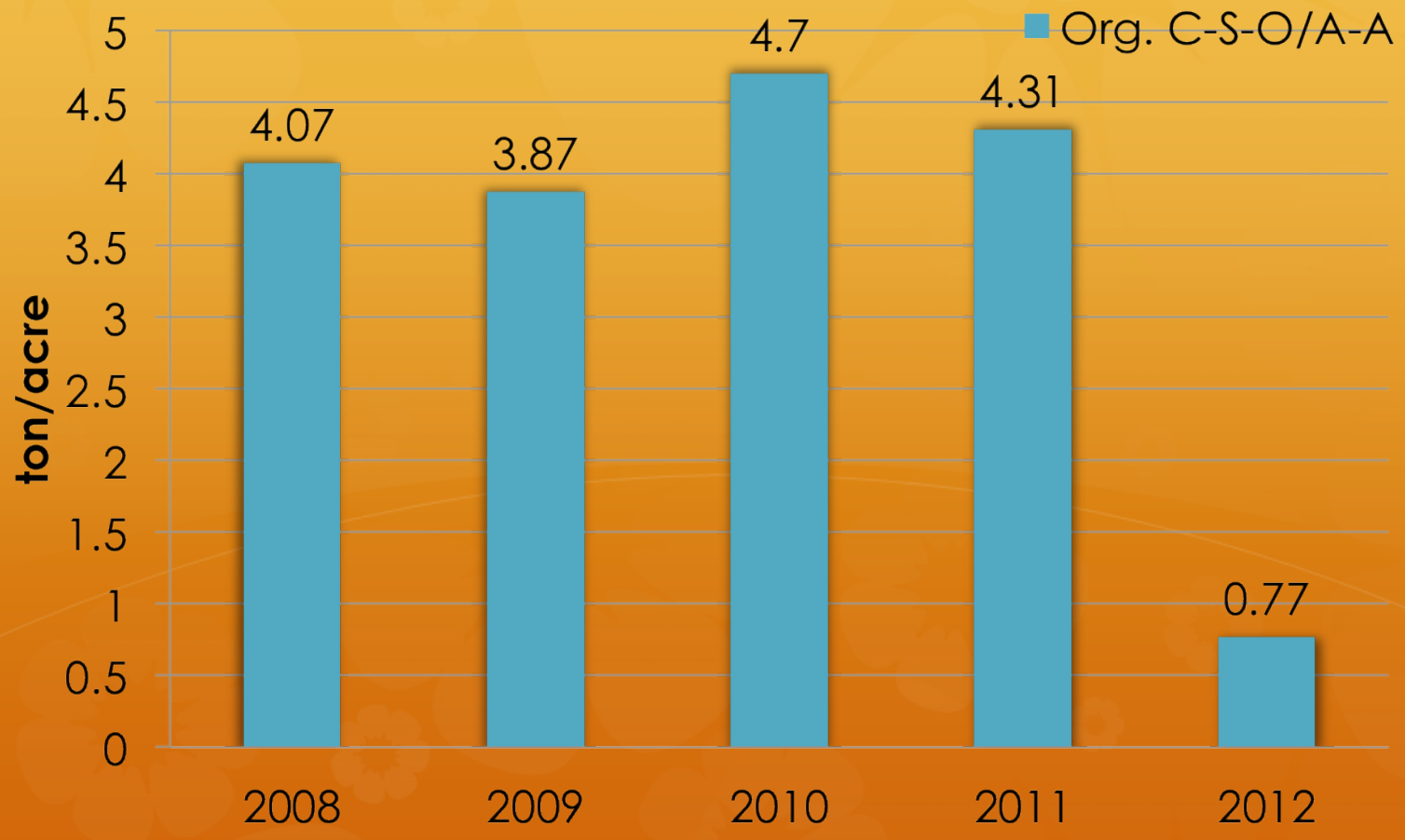
- Soybean at 13% moisture
- No difference between organic and conventional yields

Average Organic Oat Yields
LTAR–2002-2010



Only numerical difference in yield increase with extra year of alfalfa

Average Alfalfa Yields LTAR–2008-2012



Yields averaging 4 tons/acre until drought in 2102.

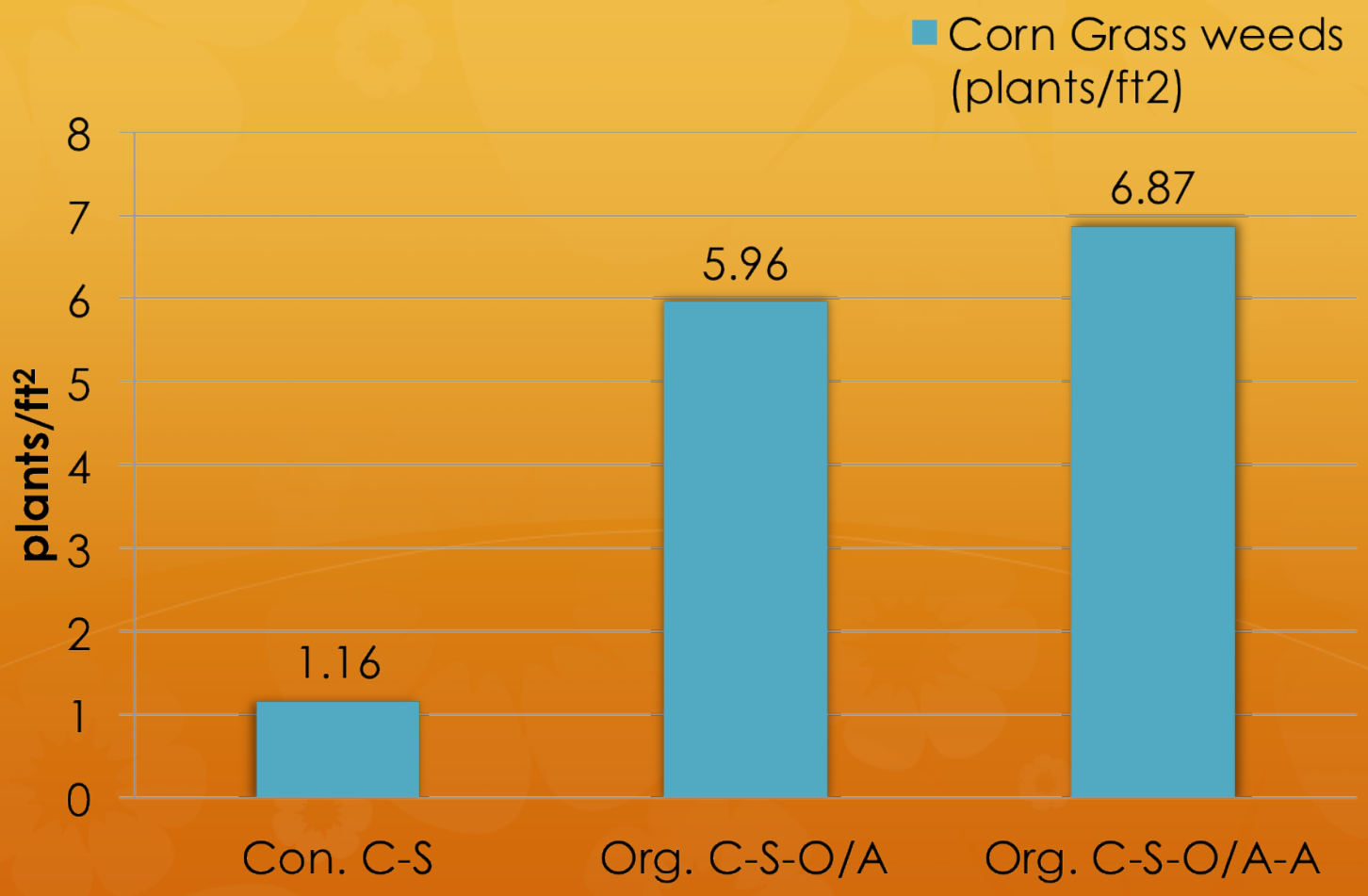
Weed Management

- Use preventive measures: cover crops, esp. rye (allelopathy)
- Crop rotations
- Manage when weeds are first emerging ("white thread stage") and at appropriate intervals to prevent establishment /weed seed production
- Rotary hoe, row cultivator
- Flame-weeder when wet

Weed management

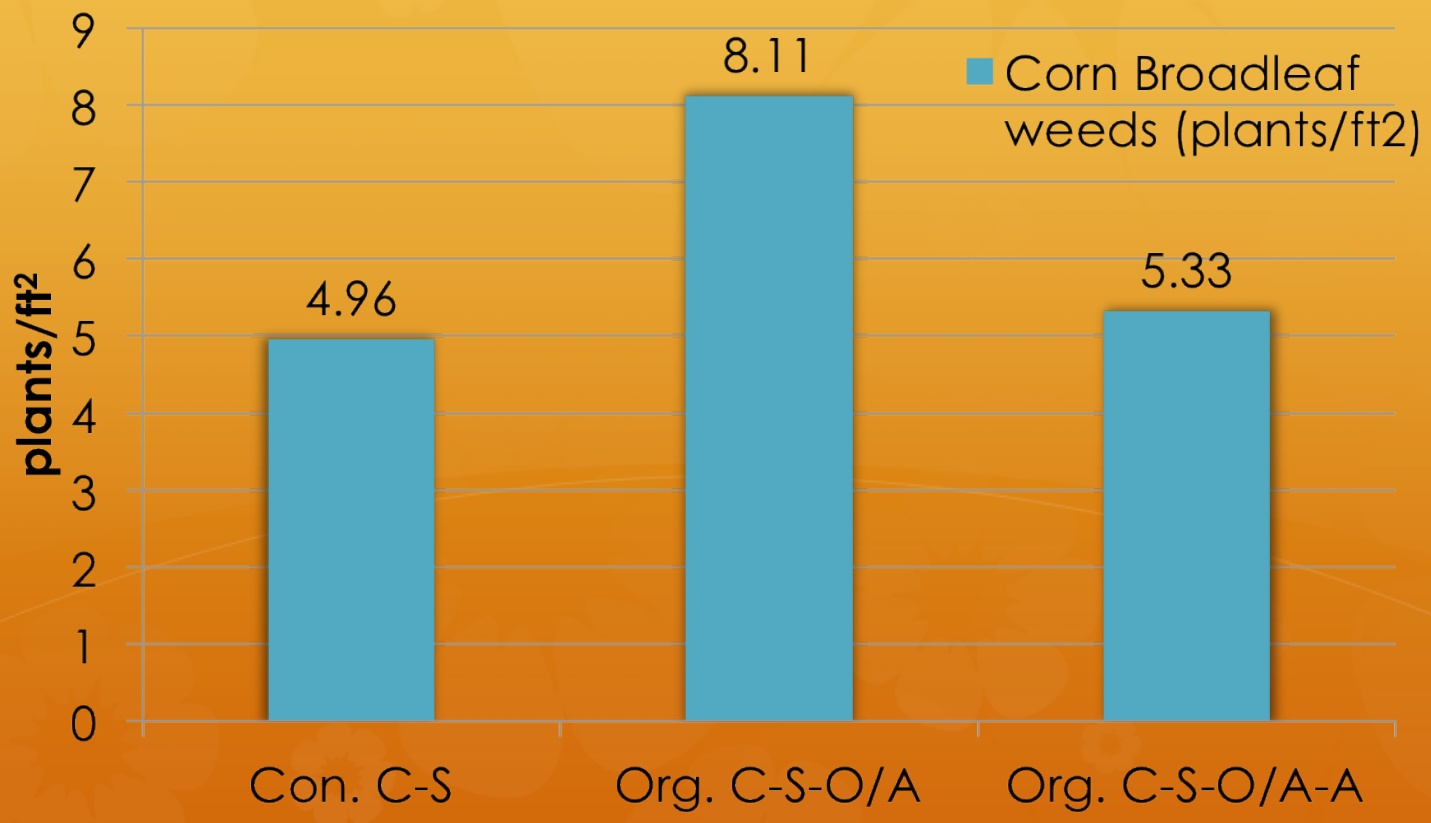
- High planting rate (175,000–220,000 seeds/acre)
- “Walking” soybeans, esp. for any ‘staining’ weeds (nightshade)
- Solid cover of small grain crop important in rotation for weed management

Average Corn Grass Weeds
LTAR – 2002-2010



Grass weeds lower where herbicides used,
but weeds not significantly greater in organic plots.

Average Broadleaf Weeds in Corn
LTAR – 2002-2010



Broadleaf weeds lower where herbicides used, but weeds not significantly greater in organic plots.

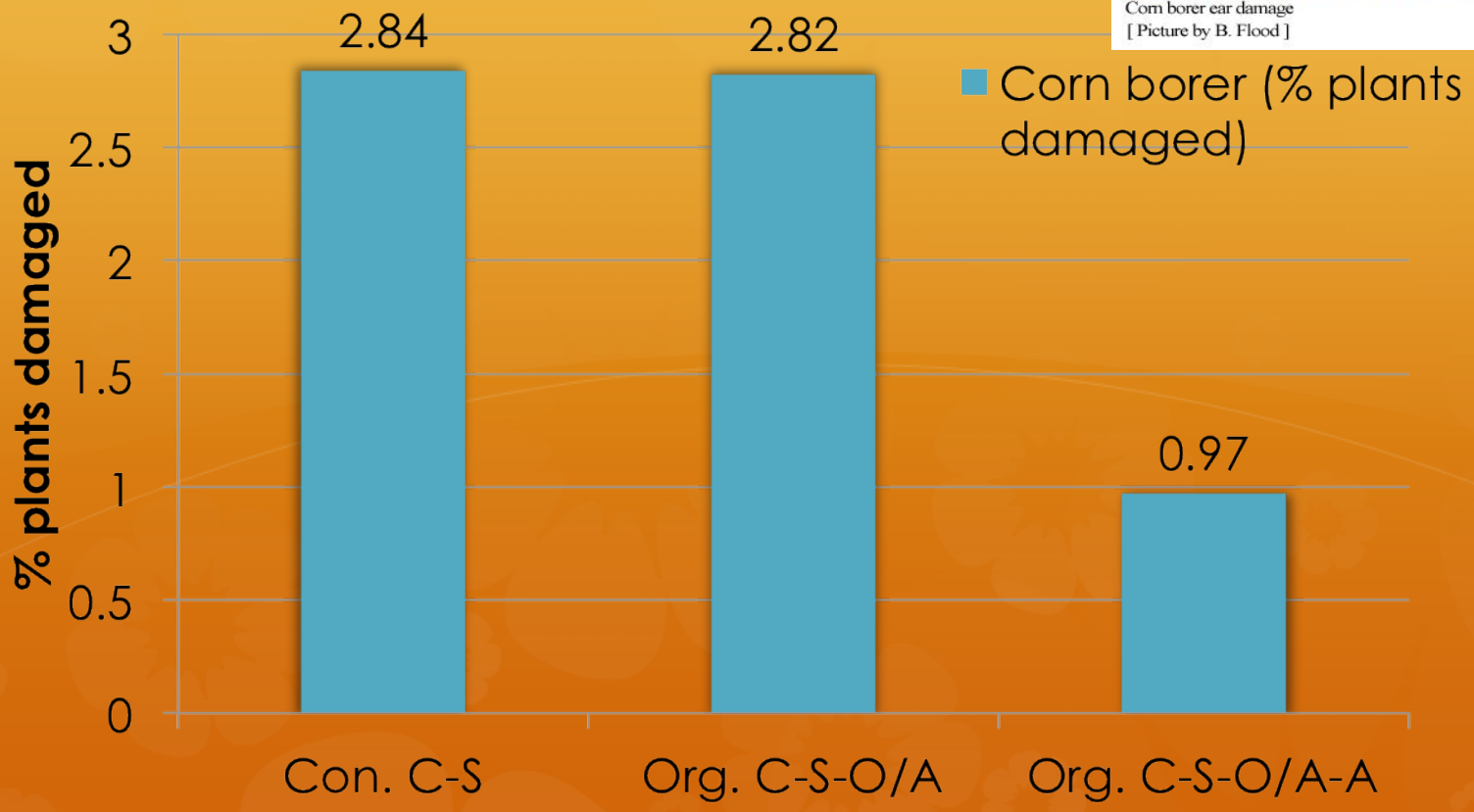
Organic Pest Management

- Bio-diversity on farm
- Conservation of beneficial insects
- Preventative (resistant varieties)
- Least toxic organic-compliant pesticides (used once in 17 years)

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

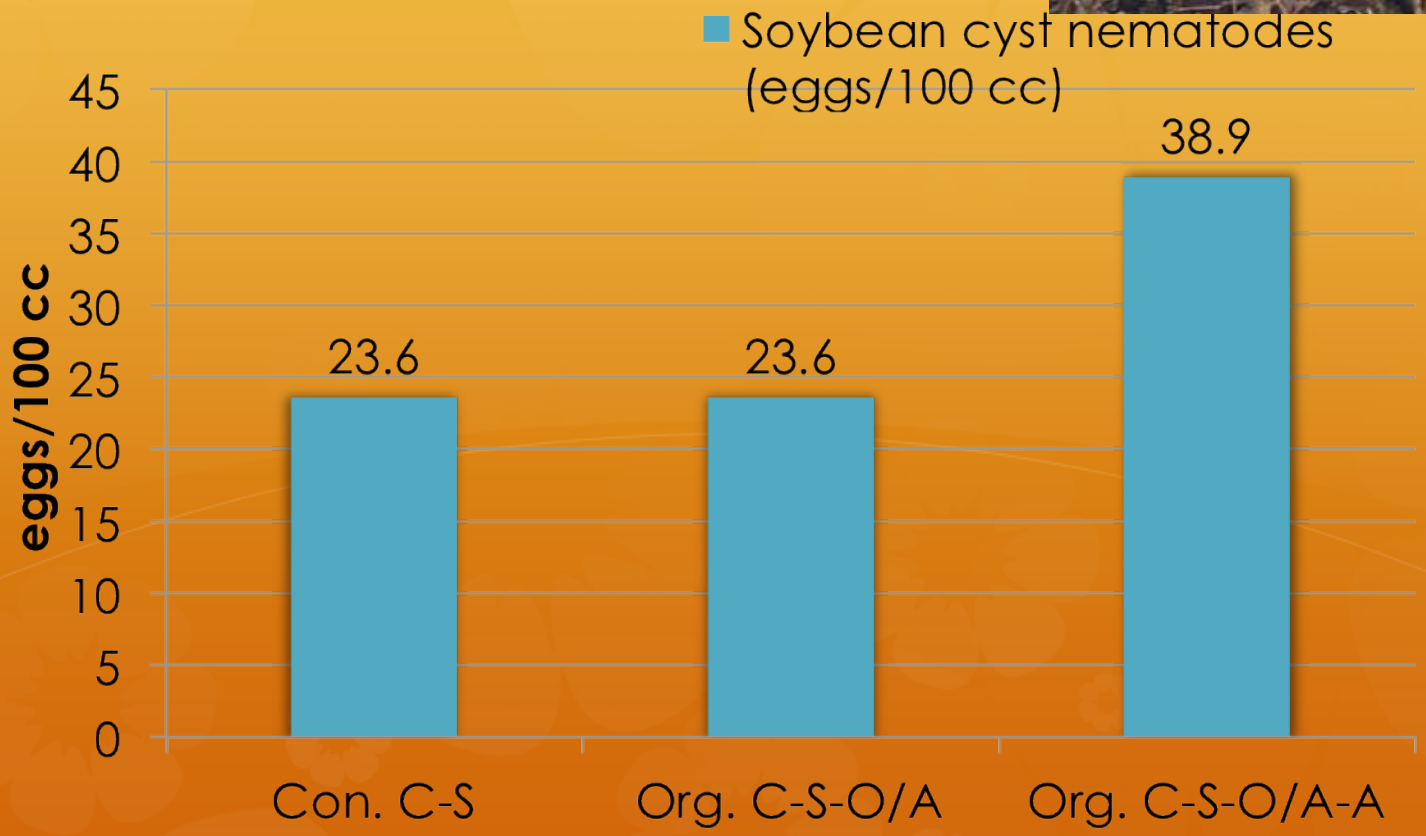
Average Corn Borer
LTAR – 2002-2010

Corn borer ear damage
[Picture by B. Flood]



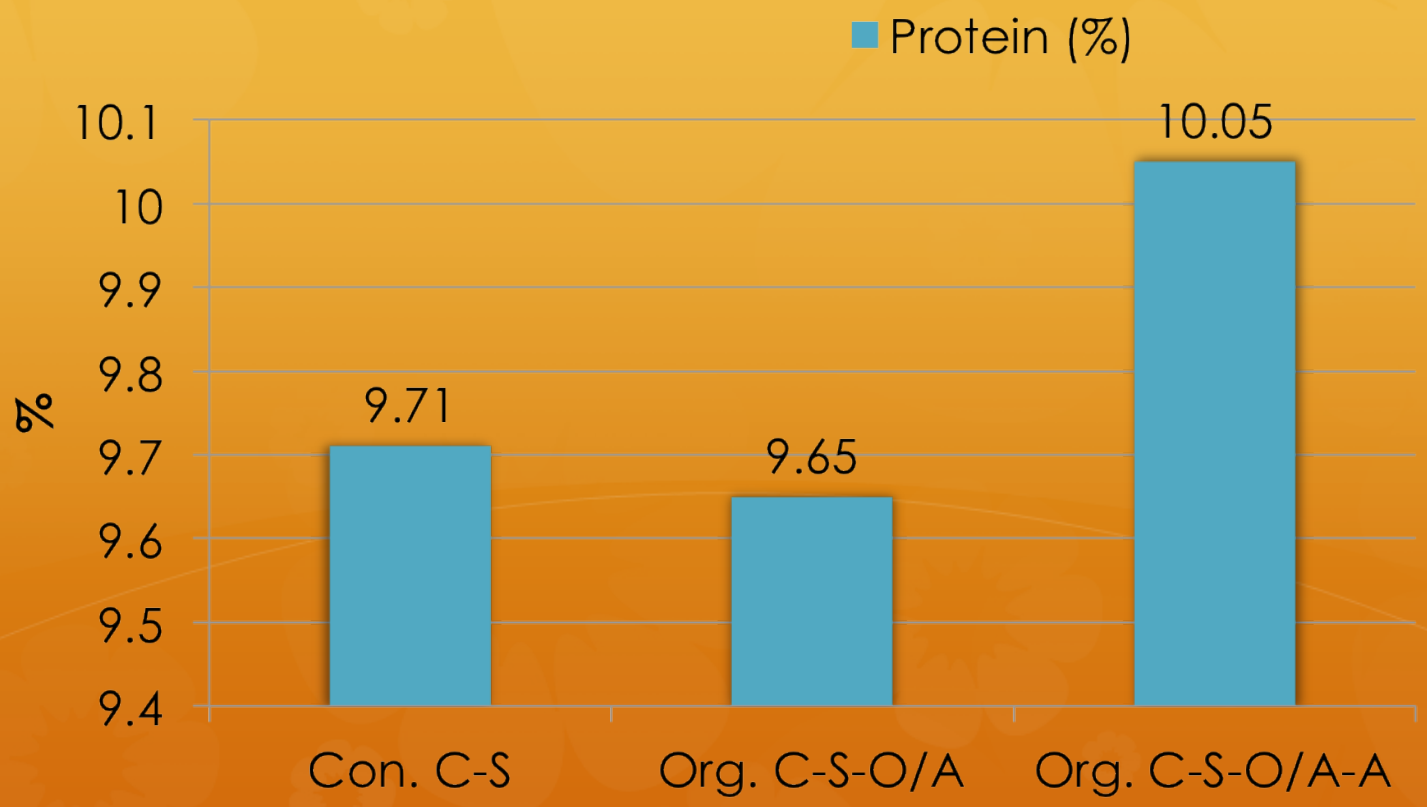
No difference between conventional and organic.
Low damage overall due to CB-tolerant varieties used.

Average Soybean Cyst Nematodes
LTAR – 2002-2010



No difference between conventional and organic.

Average Corn Protein
LTAR – 2002-2010

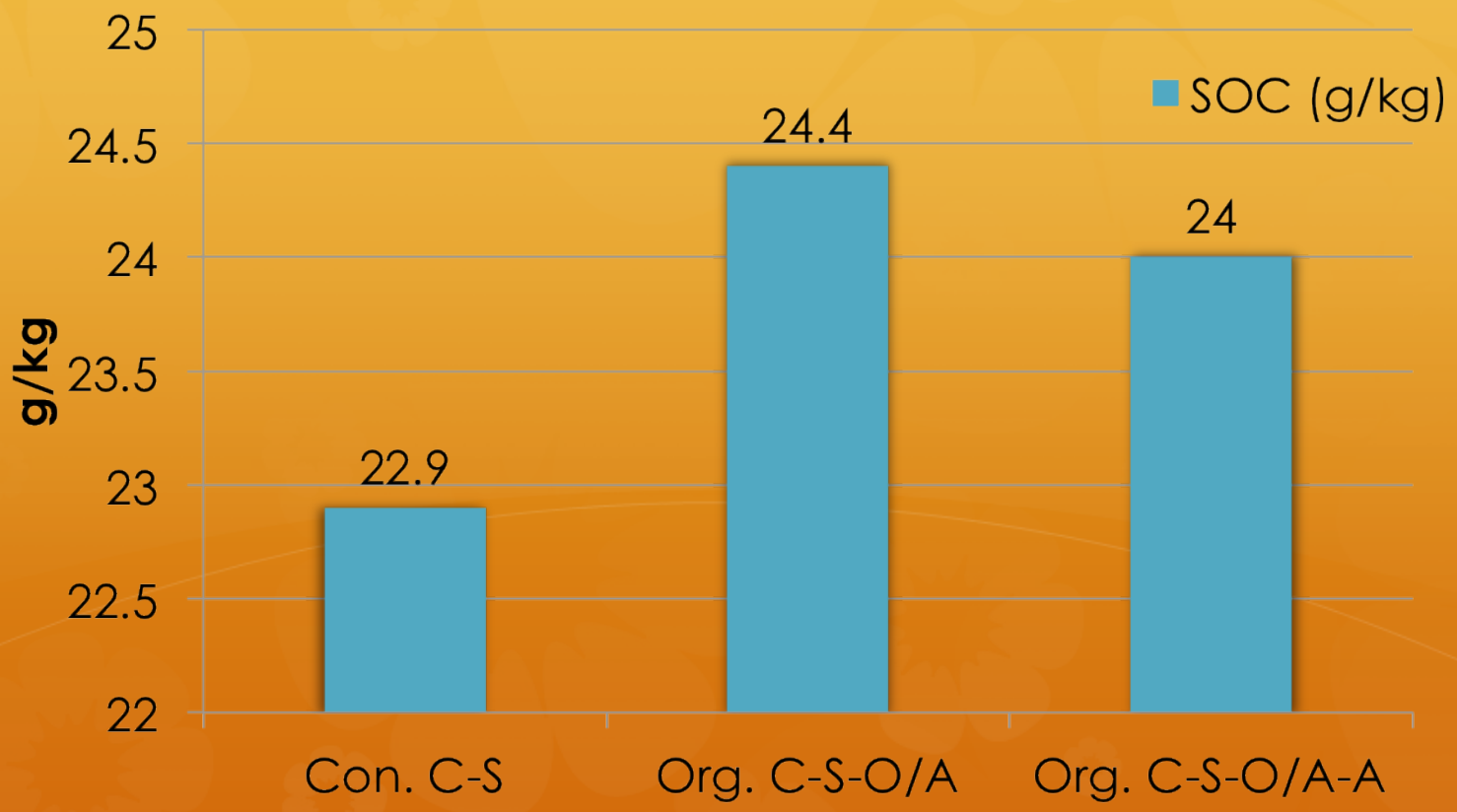


No difference between conventional and organic.

Soils Data

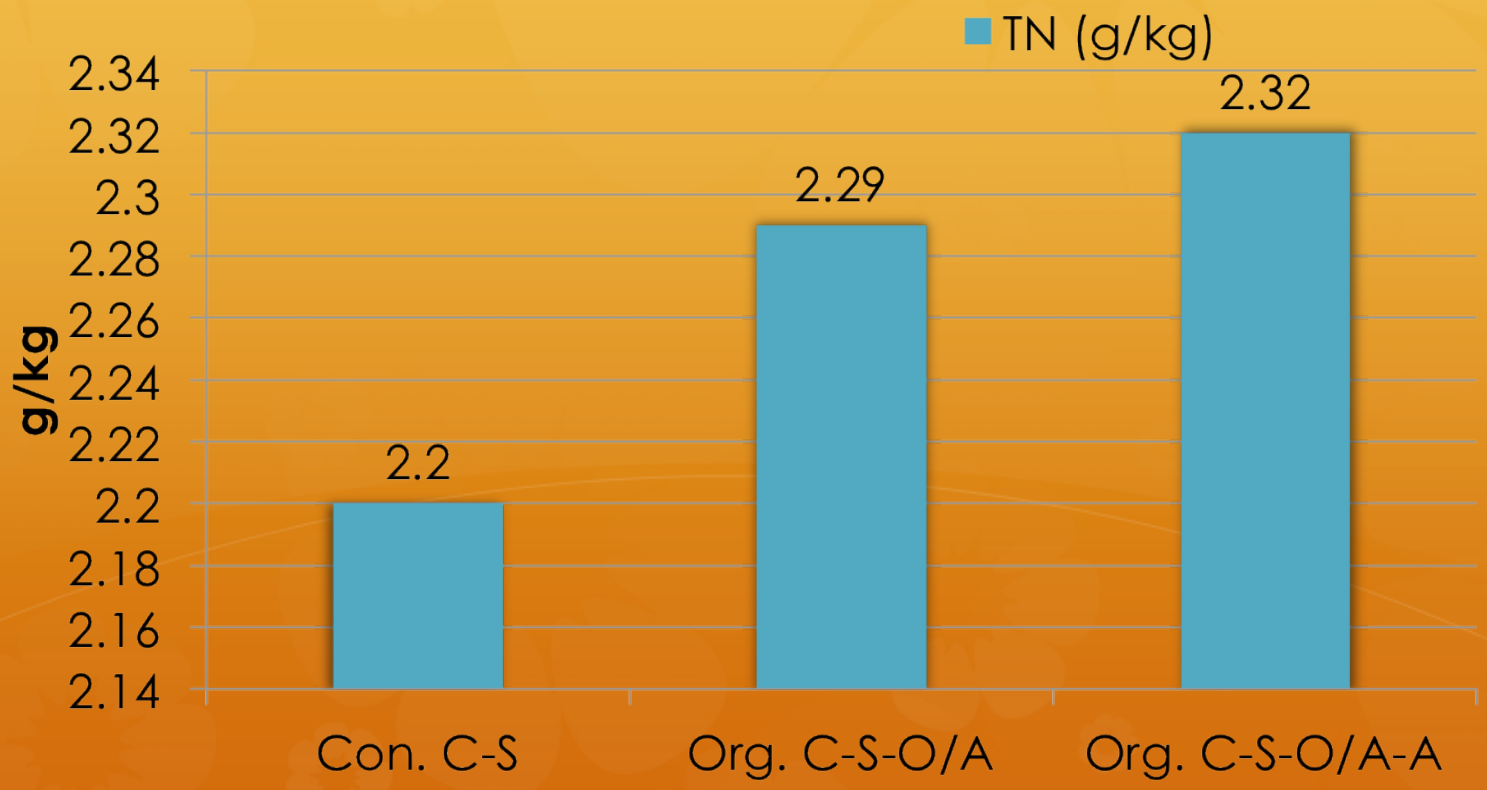
- **Dr. Cynthia Cambardella. USDA-ARS, National Lab for Ag. and the Environment,Ames, IA**
- **Soil sampling each fall in each plot**
- Five randomly-located soil cores (0-15 cm) from each plot every fall after harvest but before tillage for cover crops

Soil SOC (g/kg) at LTAR, Fall 2009 (depth: 0-6 in)



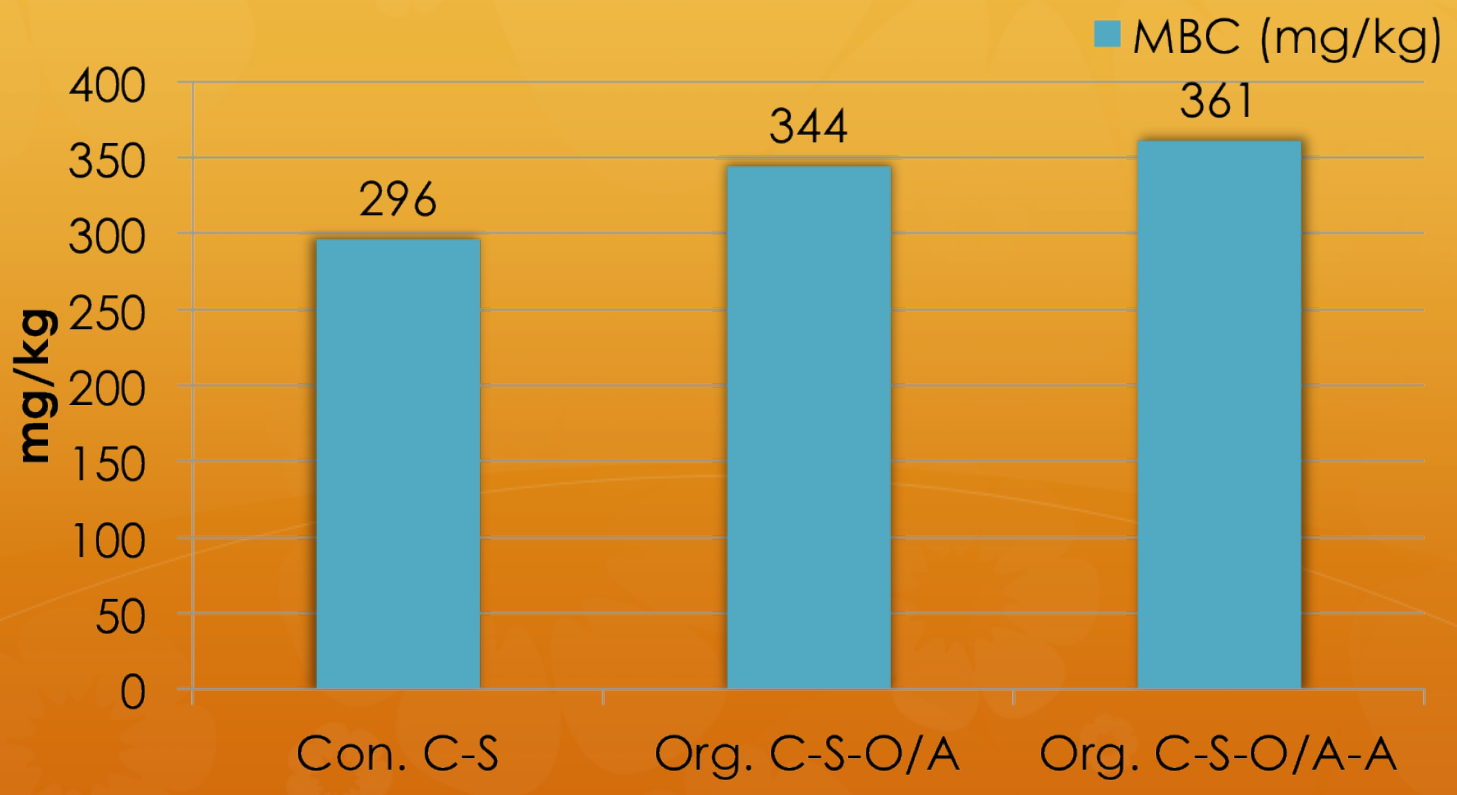
Carbon sequestration greater in organic plots.

Soil TN (g/kg) at LTAR, Fall 2009 (depth: 0-6 in)



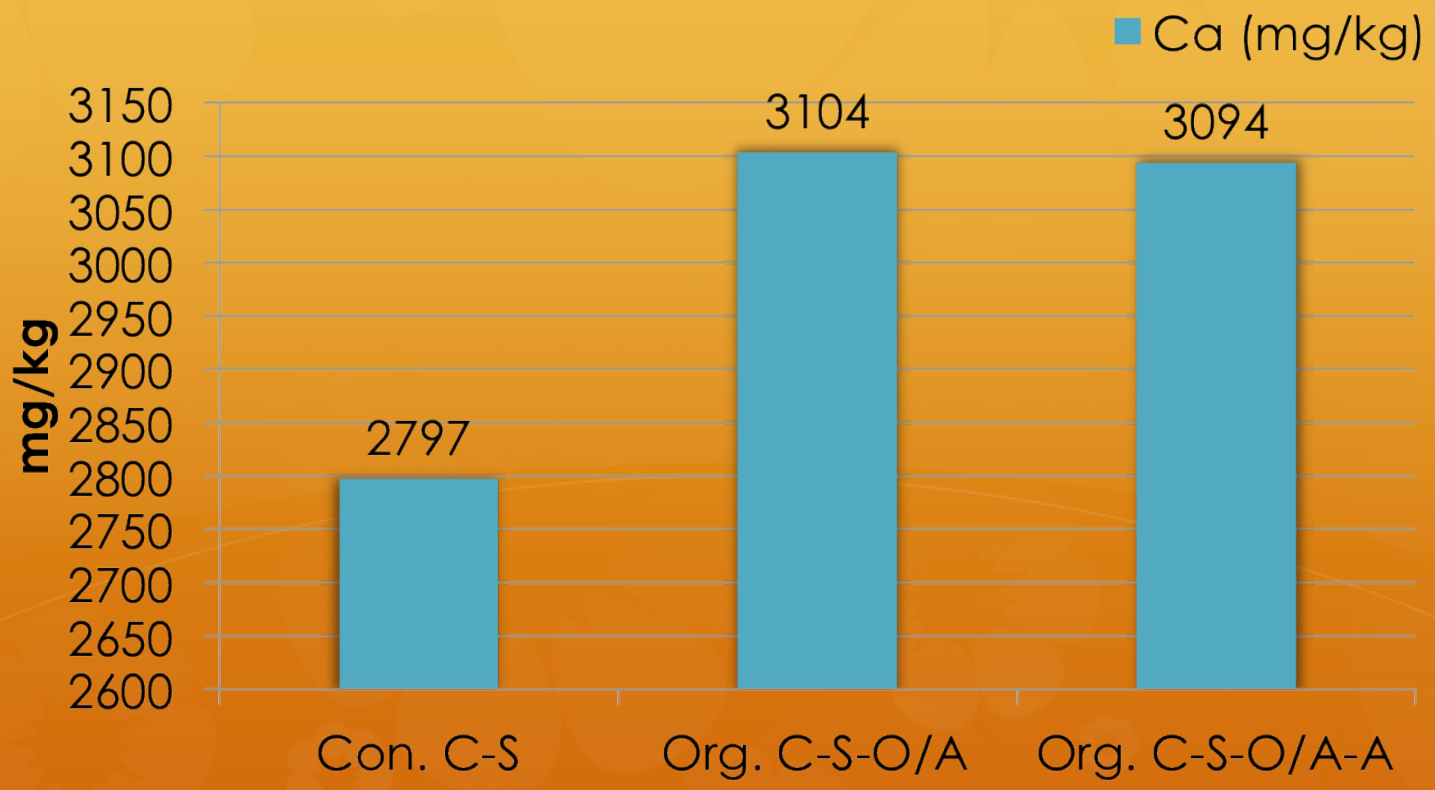
Nitrogen storage in the soil for the next crop greater in organic plots.

Soil MBC (mg/kg) at LTAR, Fall 2009 (depth: 0-6 in)



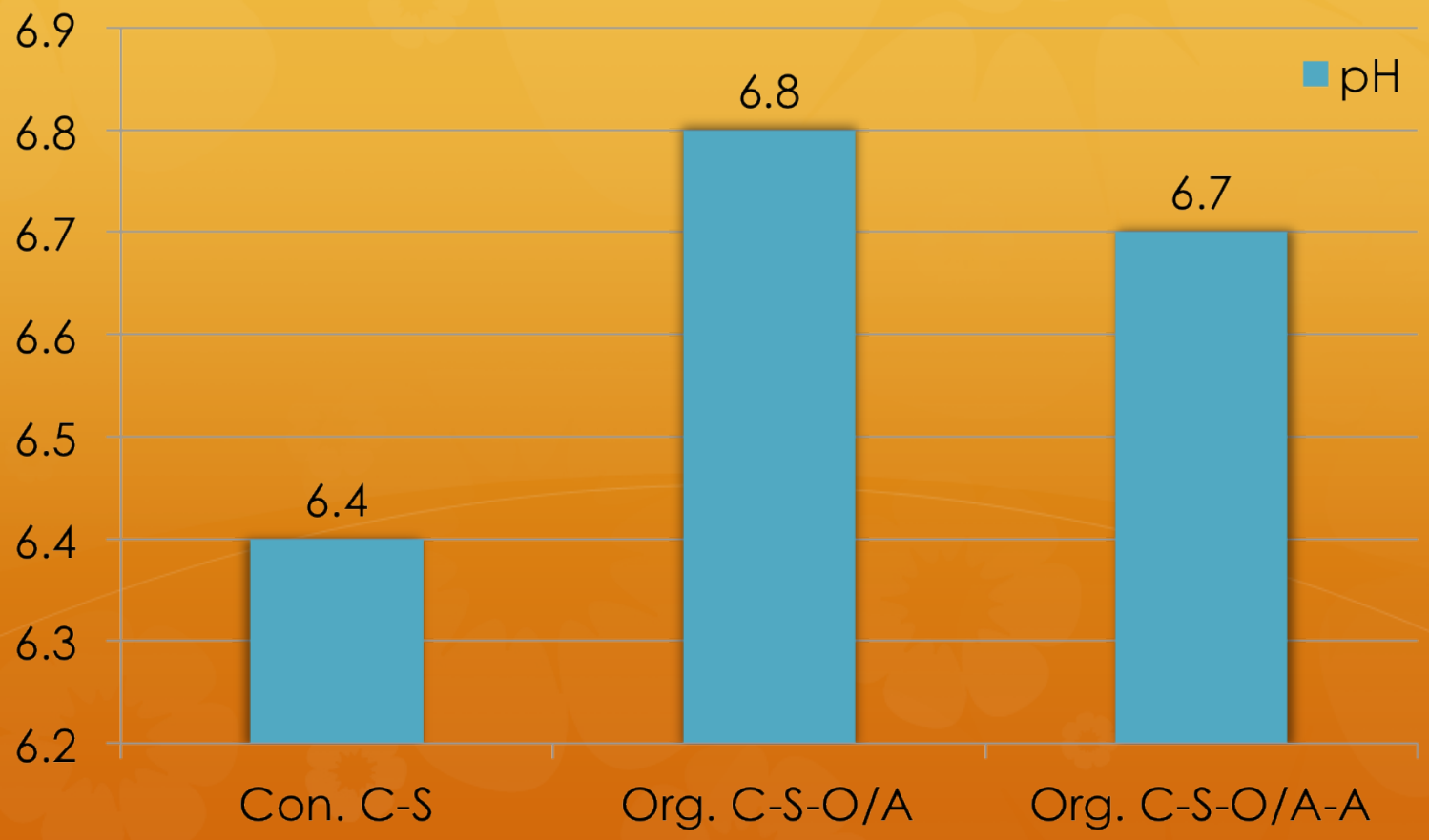
Beneficial soil microbial populations greater in organic plots

Soil Ca (mg/kg) at LTAR, Fall 2009 (depth: 0-6 in)

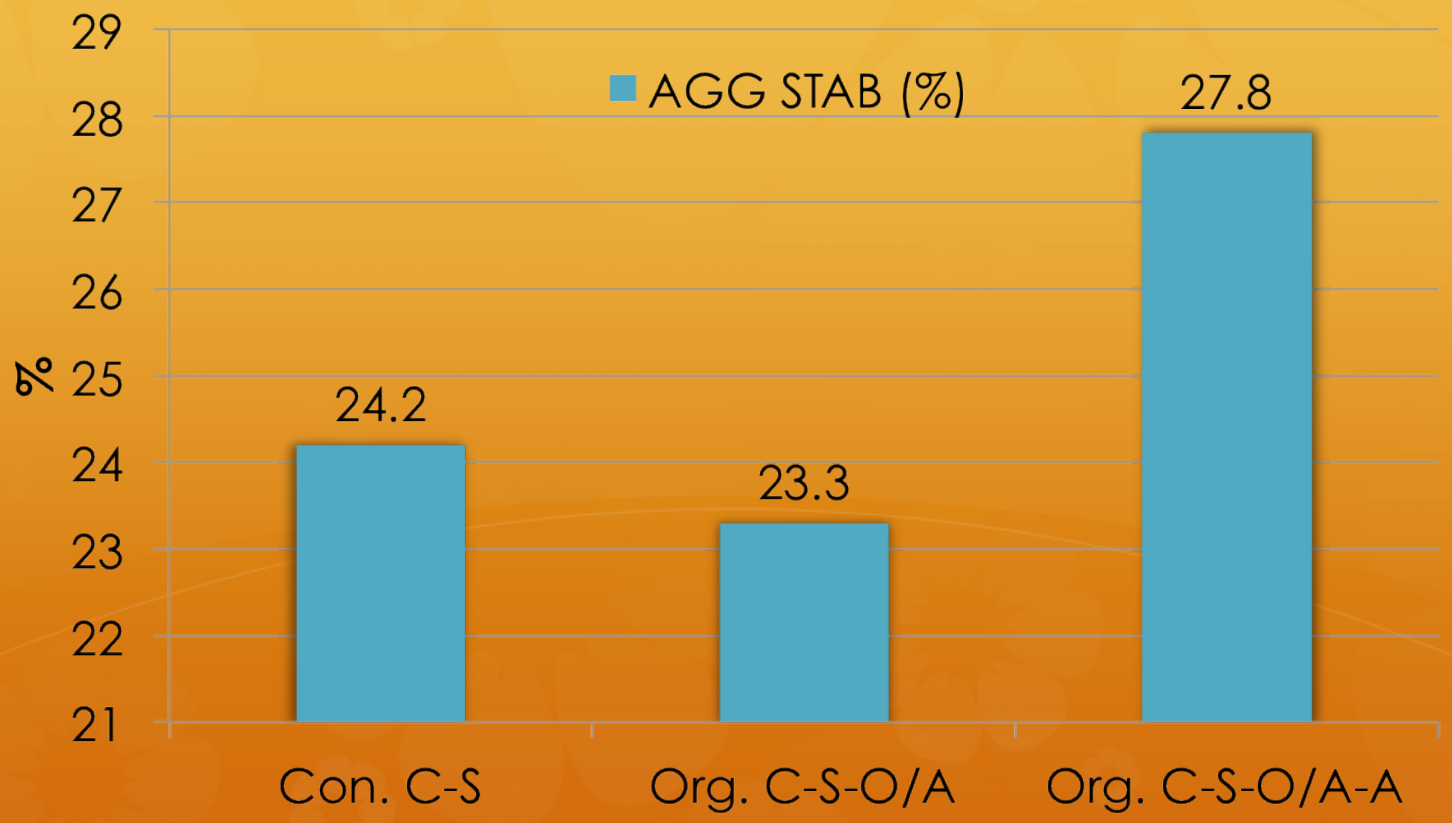


Soils becoming less acidic in organic fields

Soil pH at LTAR, Fall 2009 (depth: 0-6 in)



Soil AGG STAB (%) at LTAR, Fall 2009 (depth: 0-6 in)



Soil quality: LTAR 2013

Tmnt	SOC gkg^{-1}	TN gkg^{-1}	POM-C gkg^{-1}	POM-N gkg^{-1}	MBC $mgkg^{-1}$	PMINN $mgkg^{-1}$	NO3-N $mgkg^{-1}$	NH4-N $mgkg^{-1}$
Conv C-S	23.7	2.3	2.7	0.16	299	33.1	25.02	0.37
Organic C-S-O/A	24.5	2.4	2.7	0.20	308	40.9	9.18	0.60
Organic C-S-O/A-A	24.4	2.4	3.1	0.26	351	43.0	10.99	1.70
LSD $_{0.05}$	1.2	2.3	ns	0.09	45	5.1	8.45	ns

The 4-yr organic rotation had higher microbial biomass C and more stable macroaggregates than the 3-yr organic rotation in fall 2013, suggesting the extra year of alfalfa increased the resilience of the 4-yr organic rotation to extreme drought encountered in 2013

Soil quality–2013

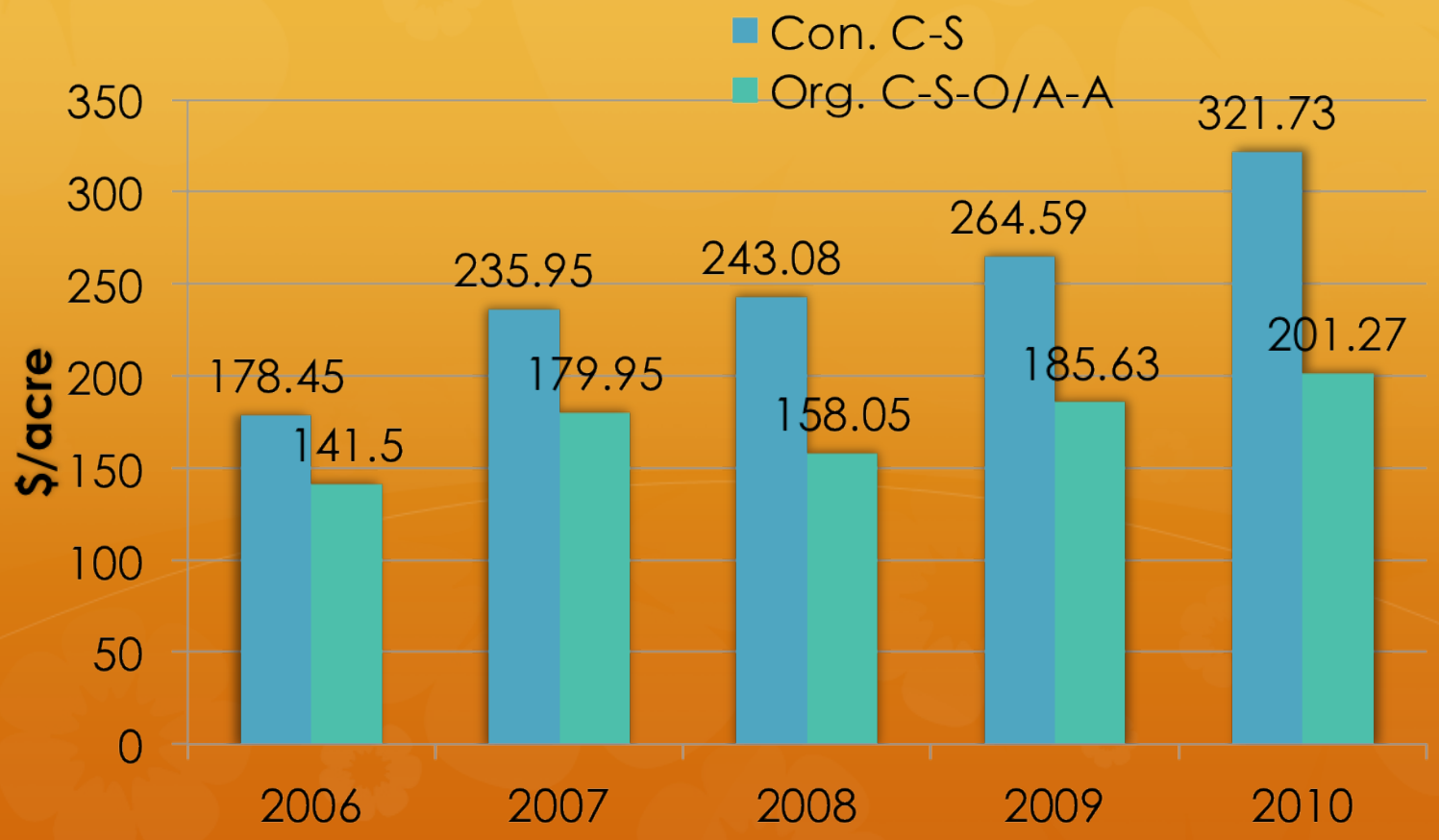
Tmnt	P $mgkg^{-1}$	K $mgkg^{-1}$	Mg $mgkg^{-1}$	Ca $mgkg^{-1}$	ph	Aggs %
Conv C-S	35.0	240	371	3455	6.32	22.9
Organic C-S-O/A	84.6	290	439	4026	6.81	24.3
Organic C-S-O/A-A	57.2	247	430	3899	6.69	28.9
$LSD_{0.05}$	11.9	40	54	240	0.28	4.7

Higher P, K, Mg and Ca concentrations, and lower soil acidity in organic rotations

Soils Summary

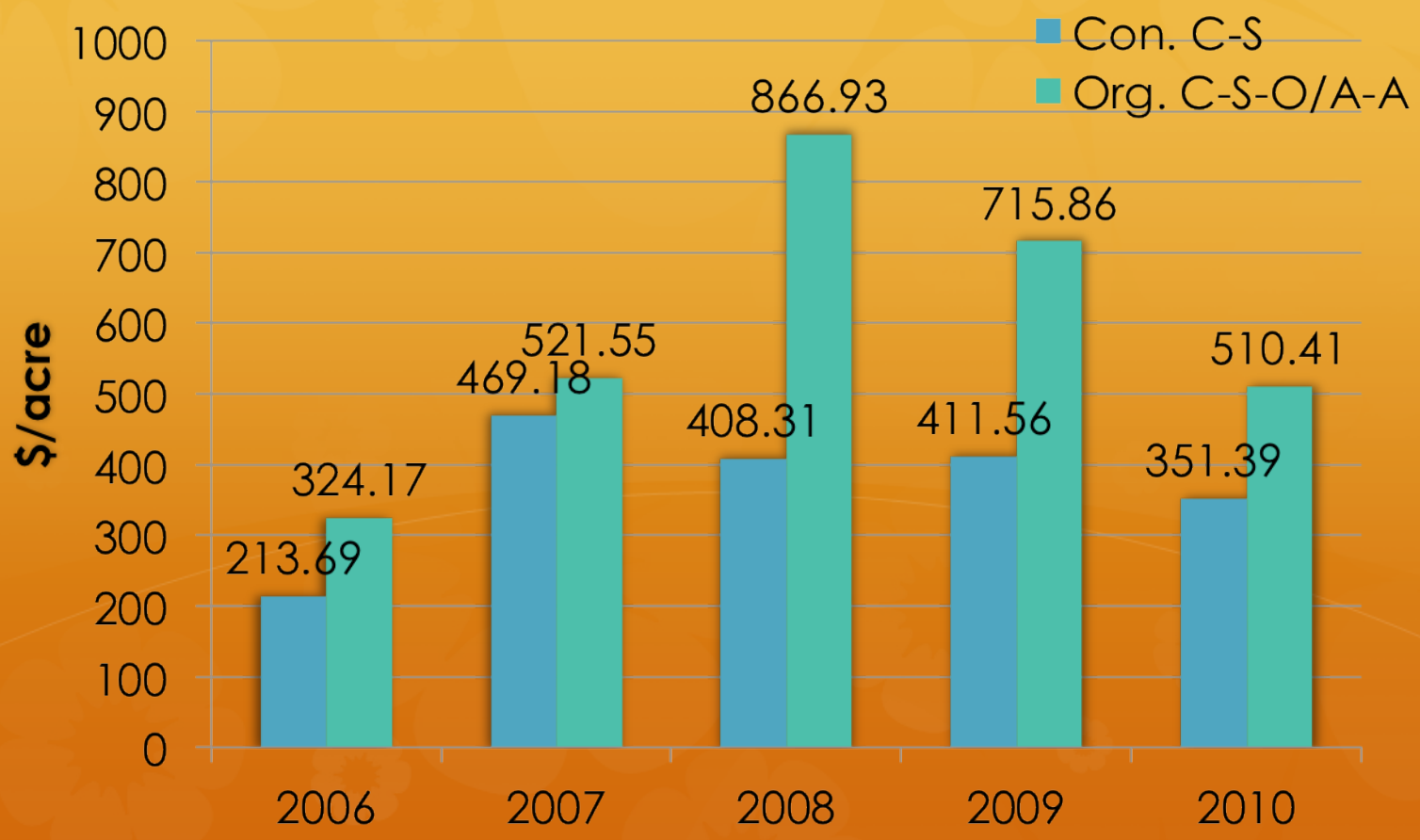
- Soil quality enhancement was particularly evident for labile soil C and N pools, which are critical for maintenance of N fertility in organic systems, and for basic cation concentrations, which control nutrient availability through the relationship with cation exchange capacity (CEC)
- Despite the serious drought in 2012 and 2013, organic management enhanced agroecosystem resilience and maintained a critical soil function, the capacity to supply nutrients to the crops

Costs of Rotational Average ($/acre) between Conventional and Organic Systems at LTAR, 2006-2010



Organic costs, on average, $100/acre less than conv

Returns to Land and Management ($/acre), Rotational Average, between Conventional and Organic Systems at LTAR, 2006-2010 .



Organic returns, on average, 1.5 – 2 x greater

Economic returns greater for organic crops

- Economic returns to land and management were $510/acre in the organic C-S-O/A-A rotation compared to $351/acre in the C-S rotation.
- Even during transition, returns are not significantly lower due to lower costs of production (no pesticides, fertilizers).

USDA-ARS FSP

- Increasing diversity/lengthening rotations improves agronomic, economic and environmental performance
- 6-yr rotation (C-S-W-A-A-A) yields greater than 3-yr rotation and 2-yr C-S
- Weed pressure decreased with longer rotations
- Risk decreases as rotation length increases

Increased crop diversity benefits nutrient management

- N mineralization potential, POMN and SOC of all organic systems were greater than the conv NT
- N mineralization potential of the organic system was, on average, 34% greater than NT after 14 years
- N availability increased with longer rotation
- SOC greater in 6-yr organic than conv. NT at all depths except 0 to 2 inches
- Greater C associated with greater soil organic N
- 6-year rotation used less poultry litter

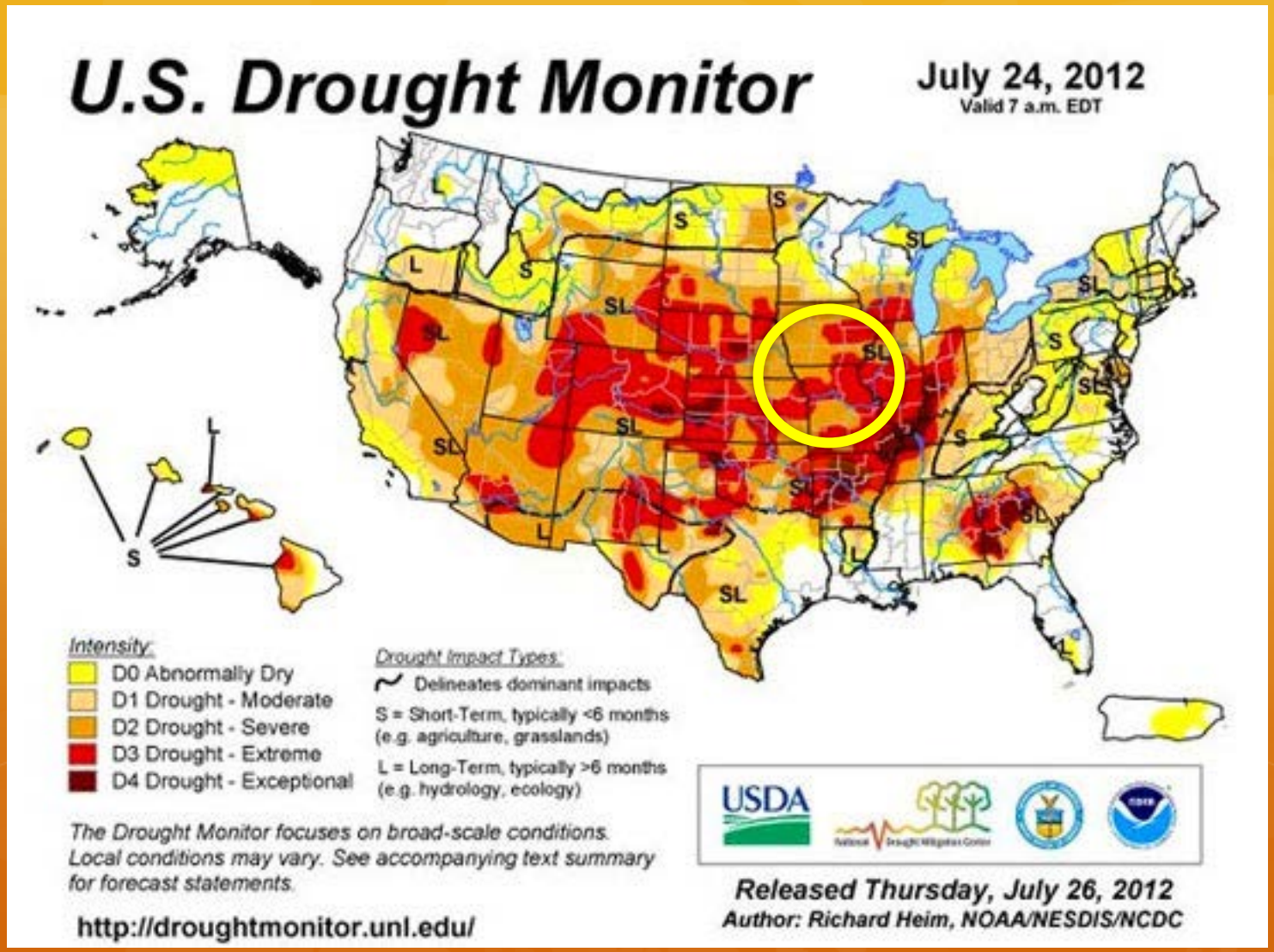
Conclusions

- Support for LT 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
- Diversity = stability: longer rotations with perennials provide greater yield stability

- Fine-tuning nutrient & water mng't

Cathy Greene of USDA-ERS visits LTAR

The Drought of 2012



2012: Yields down 20 – 90% in Iowa

Not just drought but high heat too

4th hottest and 5th driest summer among 140 years of records

Next Frontier: WATER

Proposal: Systems	Soil Carbon (kg/ha/crop)	Water (acre-feet/crop)	Energy (MJ/acre/crop)
2 year: Tomato/fallow/corn/fallow Conventional	4500	3.5	30,642
2 year: Tomato/WLCC/corn/WLCC Organic	7350	4.5	16,526
2 year: Tomato/WLCC/corn/ WLCC Integrated nutrient management (with micro-plots) Mixed	• 6300 • 6000	• 4.3 • 4.3	• 35,849 • 33,356
4 year (super-bio): Tomato/wheat/beans/WLCC/corn/WLCC/sunflower/WLCC	3810	2.3	18,400
6 year: Alfalfa-tomato-corn	3133	3.8	13,371
1 year: Reduced tillage corn-wheat	5000	2.3	20,091
2 year, Conv. Tomato/wheat	1500	1.8	26,467
2 year, Fertilized wheat/fallow	1000	0	15,570
2 year, Unfertilized wheat/fallow	750	0	9,031
Native grass pasture	400	0	2,636

Proposed

K. Scow, UC-Davis