Long-Term Organic Comparisons in the U.S.

Kathleen Delate, Professor
Organic Ag Program
Depts. of Horticulture and Agronomy, Iowa State University
Cynthia Cambardella, USDA-ARS, Ames, IA
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
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."
Prior to 1990, more than 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
<table>
<thead>
<tr>
<th>Name of Experiment</th>
<th>Date started</th>
<th>Comparison</th>
<th>Main crops</th>
<th>Lead entity Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farming Systems Trial</td>
<td>1981</td>
<td>Conv. C-S vs. Org. 3 and 4-yr rotations</td>
<td>Corn, soybean, wheat</td>
<td>Rodale Institute Pennsylvania</td>
</tr>
<tr>
<td>Sustainable Ag Farming Systems (SAFS)</td>
<td>1988</td>
<td>Conv. C, W &amp; T vs. Org. C, W, T</td>
<td>Corn, tomato, wheat</td>
<td>University of California-Davis</td>
</tr>
<tr>
<td>Variable Input Crop Management Systems (VICMS)</td>
<td>1989</td>
<td>Conv. C-S vs. Org. 3 (dropped Org 2) and 4-yr rotations</td>
<td>Corn, soybean, oat, alfalfa</td>
<td>University of Minnesota (Lamberton, MN)</td>
</tr>
<tr>
<td>Wisconsin Integrated Cropping Systems Trials (WICST)</td>
<td>1989</td>
<td>Conv. C-S vs. Org 3 and 4-yr rotation</td>
<td>Corn, soybean, wheat, oats, alfalfa</td>
<td>University of Wisconsin-Madison (Arlington, WI)</td>
</tr>
<tr>
<td>Beltsville Farming Systems Project (FSP)</td>
<td>1996</td>
<td>Conv. C-S vs. Org 2, 3 and 6-yr rotation</td>
<td>Corn, soybean, wheat</td>
<td>USDA-ARS Beltsville, MD</td>
</tr>
<tr>
<td>Long-Term Agroecological Research (LTAR)</td>
<td>1998</td>
<td>Conv. C-S vs. Org. 3 and 4-yr rotations</td>
<td>Corn, soybean, oat, alfalfa</td>
<td>Iowa State University, (Greenfield, IA)</td>
</tr>
</tbody>
</table>
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

- Yields
- Plant Tissue Nutrients
- Pest Insects
- Beneficial Insects
- Plant Pathogens
- Grain Quality
- Soil Quality: Chemical, Biological, Physical
- Economics
- Weeds
- Soybean Cyst Nematodes
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

<table>
<thead>
<tr>
<th>Nitrogen source</th>
<th>Composted manure</th>
<th>Legume cover crops</th>
<th>Ammonium nitrate and Urea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weed control</td>
<td>Cultivation</td>
<td>Cultivation</td>
<td>Herbicides</td>
</tr>
<tr>
<td>Primary tillage</td>
<td>Moldboard plow</td>
<td>Moldboard plow</td>
<td>Chisel plow</td>
</tr>
<tr>
<td>Planting date</td>
<td>Late</td>
<td>Late</td>
<td>Early</td>
</tr>
<tr>
<td>Cover crops</td>
<td>Rye</td>
<td>Rye, Hairy vetch</td>
<td>None</td>
</tr>
<tr>
<td>Cash crops that function as cover crops</td>
<td>Winter wheat, red clover/alfalfa hay</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Manure (MNR)
- Composted manure
- Moldboard plow
- Late
- Rye
- Winter wheat, red clover/alfalfa hay

### Legume (LEG)
- Legume cover crops
- Moldboard plow
- Late
- Rye, Hairy vetch

### Conventional (CNV)
- Ammonium nitrate and Urea
- Herbicides
- Chisel plow
- Early
- None
-4-yr transition: org = conv
-20-yr+: org (composted manure) > conv
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

Wheat-no fertilizer

Conv Org

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?

Variable Input Crop Management Systems

- Inputs lower in organic rotation
- Even without price premiums, organic returns not lower than conventional
- Variability of net returns similar in conventional & organic

-Mahoney, Olson, & Porter
<table>
<thead>
<tr>
<th>Author</th>
<th>State</th>
<th>Weed control</th>
<th>Com Yield (% of CV)</th>
<th>Soybean Yield (% of CV)</th>
<th>Sm. Grain Yield (% of CV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liebhardt PA</td>
<td>poor</td>
<td>84</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>good</td>
<td>112</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>unrated</td>
<td>---</td>
<td>103</td>
<td>90 w</td>
<td></td>
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<tr>
<td>Porter MN</td>
<td>poor</td>
<td>---</td>
<td>64</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>good</td>
<td>---</td>
<td>98</td>
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<tr>
<td></td>
<td>unrated</td>
<td>92</td>
<td>---</td>
<td>100 o</td>
<td></td>
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<tr>
<td>Delate and Cambardella IA</td>
<td>good</td>
<td>114</td>
<td>111</td>
<td>---</td>
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<tr>
<td>Smith and Gross MI</td>
<td>poor</td>
<td>72</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>WIC ST WI</td>
<td>poor</td>
<td>75</td>
<td>79</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>poor</td>
<td>98</td>
<td>94</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Posner et al., 2008</td>
<td>unrated</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>93 w</td>
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</table>
### UW: Effect of weed pressure on corn yield

<table>
<thead>
<tr>
<th>Rotation</th>
<th>Wet springs (May + June &gt;10” rain)</th>
<th>Normal springs</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>ARS</td>
<td>LAC</td>
</tr>
<tr>
<td>Conventional (corn-soybean)</td>
<td>160</td>
<td>137</td>
</tr>
<tr>
<td>Organic (3-yr grain)</td>
<td>115</td>
<td>103</td>
</tr>
<tr>
<td>Org: conv</td>
<td>72%</td>
<td>76%</td>
</tr>
</tbody>
</table>

Feb 22, 2013 Janet Hedtcke
UW-Madison, Agronomy Dept
# UW: Effect of weed pressure on soybean yield

Rotation | Wet springs (May + June > 10” rain) | Normal springs
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ARS</td>
<td>LAC</td>
</tr>
<tr>
<td>Conventional (corn-soybean)</td>
<td>48</td>
<td>57</td>
</tr>
<tr>
<td>Organic (3-yr grain)</td>
<td>38</td>
<td>44</td>
</tr>
<tr>
<td>Org:conv</td>
<td>79%</td>
<td>76%</td>
</tr>
</tbody>
</table>

Feb 22, 2013
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

Forty-four plots—four rotations—five crops

2014: 17–year comparison of conventional & organic crops

Supported by the Leopold Center for Sustainable Ag
Farmers decide treatments and provide input on results

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

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

-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 cover crops
Average Com Yields
LTAR–2002-2010

- Corn yields at 15.5% moisture
- No difference between organic and conventional yields
Yields the same despite lower N at late spring testing in organic, due to slow-release manure-based fertilizers used.
Soybean at 13% moisture

No difference between organic and conventional yields

- Soybean Yield (bu/acre)
  - Con. C-S: 48.9 bu/acre
  - Org. C-S-O/A: 51.5 bu/acre
  - Org. C-S-O/A-A: 50.8 bu/acre

Average Soybean Yields
LTAR-2002-2010
Average Organic Oat Yields
LTAR–2002-2010

Only numerical difference in yield increase with extra year of alfalfa
Yields averaging 4 tons/acre until drought in 2012.
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

No difference between conventional and organic.
Low damage overall due to CB-tolerant varieties used.
Average Soybean Cyst Nematodes
LTAR – 2002-2010

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Eggs/100 cc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Con. C-S</td>
<td>23.6</td>
</tr>
<tr>
<td>Org. C-S-O/A</td>
<td>23.6</td>
</tr>
<tr>
<td>Org. C-S-O/A-A</td>
<td>38.9</td>
</tr>
</tbody>
</table>

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

- Con. C-S: 24.2%
- Org. C-S-O/A: 23.3%
- Org. C-S-O/A-A: 27.8%
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.
<table>
<thead>
<tr>
<th>Tmnt</th>
<th>P mgkg(^{-1})</th>
<th>K mgkg(^{-1})</th>
<th>Mg mgkg(^{-1})</th>
<th>Ca mgkg(^{-1})</th>
<th>ph</th>
<th>Aggs %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conv C-S</td>
<td>35.0</td>
<td>240</td>
<td>371</td>
<td>3455</td>
<td>6.32</td>
<td>22.9</td>
</tr>
<tr>
<td>Organic C-S-O/A</td>
<td>84.6</td>
<td>290</td>
<td>439</td>
<td>4026</td>
<td>6.81</td>
<td>24.3</td>
</tr>
<tr>
<td>Organic C-S-O/A-A</td>
<td>57.2</td>
<td>247</td>
<td>430</td>
<td>3899</td>
<td>6.69</td>
<td>28.9</td>
</tr>
<tr>
<td>LSD(_{0.05})</td>
<td>11.9</td>
<td>40</td>
<td>54</td>
<td>240</td>
<td>0.28</td>
<td>4.7</td>
</tr>
</tbody>
</table>

Higher P, K, Mg and Ca concentrations, and lower soil acidity in organic rotations.
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.
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).
Increasing diversity/lengthening rotations improves agronomic, economic and environmental performance.

- 6-yr rotation (C-S-W-A-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 critical 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

U.S. Drought Monitor

July 24, 2012
Valid 7 a.m. EDT

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://droughtmonitor.unl.edu/

Released Thursday, July 26, 2012
Author: Richard Heim, NOAA/NESDIS/NCDC
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

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>2 year: Tomato/fallow/corn/fallow&lt;br&gt;Conventional</td>
<td>4500</td>
<td>3.5</td>
<td>30,642</td>
</tr>
<tr>
<td>2 year: Tomato/WLCC/corn/WLCC&lt;br&gt;Organic</td>
<td>7350</td>
<td>4.5</td>
<td>16,526</td>
</tr>
<tr>
<td>2 year: Tomato/WLCC/corn/WLCC&lt;br&gt;Integrated nutrient management (with micro-plots)&lt;br&gt;Mixed</td>
<td>• 6300&lt;br&gt;• 6000</td>
<td>• 4.3&lt;br&gt;• 4.3</td>
<td>• 35,849&lt;br&gt;• 33,356</td>
</tr>
<tr>
<td>4 year (super-bio): Tomato/wheat/beans/WLCC/corn/WLCC/sunflower/WLCC</td>
<td>3810</td>
<td>2.3</td>
<td>18,400</td>
</tr>
<tr>
<td>6 year: Alfalfa-tomato-corn</td>
<td>3133</td>
<td>3.8</td>
<td>13,371</td>
</tr>
<tr>
<td>1 year: Reduced tillage corn-wheat</td>
<td>5000</td>
<td>2.3</td>
<td>20,091</td>
</tr>
<tr>
<td>2 year, Conv. Tomato/wheat</td>
<td>1500</td>
<td>1.8</td>
<td>26,467</td>
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<tr>
<td>2 year, Fertilized wheat/fallow</td>
<td>1000</td>
<td>0</td>
<td>15,570</td>
</tr>
<tr>
<td>2 year, Unfertilized wheat/fallow</td>
<td>750</td>
<td>0</td>
<td>9,031</td>
</tr>
<tr>
<td>Native grass pasture</td>
<td>400</td>
<td>0</td>
<td>2,636</td>
</tr>
</tbody>
</table>

Proposed by K. Scow, UC-Davis