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
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

- **cash-grain** (1990)
  - Corn
  - Soybean

- **dairy-forage** (1990)
  - Corn
  - Alfalfa
  - Alfalfa
  - Rotational grazing

- **native** (1998)
  - Switchgrass
  - CRP 6 spp.
  - Prairie 25 spp.

- **perenniality**

- **diversity**

4 reps each phase every year
Core data sets

Management
• agronomic calendars
• field notes/observation
• weather

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

Profitability
• input prices
• elevator prices
• hay auction prices

Environment
• spring & fall nitrates
• fall soil fertility
• soil organic carbon (SOC)
• soil archive
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   a. Soil loss (Hedtcke, unpublished)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: Intensify, 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)

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

## Corn yields (1990-2002)

<table>
<thead>
<tr>
<th>Cropping system</th>
<th>Normal spring (May + June ~9” ppt)</th>
<th>ARL</th>
<th>LAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS2: Conventional corn-soybean</td>
<td></td>
<td>173</td>
<td>132</td>
</tr>
<tr>
<td>CS3: Organic corn-soybean-wheat</td>
<td></td>
<td>167</td>
<td>124</td>
</tr>
<tr>
<td>Organic : conventional</td>
<td></td>
<td>96%</td>
<td>94%</td>
</tr>
</tbody>
</table>

Source: Posner et al. 2008
<table>
<thead>
<tr>
<th>Cropping system</th>
<th>ARL</th>
<th>LAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS2: Conventional corn-soybean</td>
<td>57</td>
<td>53</td>
</tr>
<tr>
<td>CS3: Organic corn-soybean-wheat</td>
<td>54</td>
<td>49</td>
</tr>
<tr>
<td>Organic : conventional</td>
<td>95%</td>
<td>92%</td>
</tr>
</tbody>
</table>

Normal spring (May + June ~9” ppt)

Posner et al. 2008
Grazed heifers performed as well as confined animals

Pastured (n=54) vs. Confined (n=61)

Average daily gain (lb d⁻¹)

Bars = 90% confidence limits

Hedtcke 2012
Grazed heifers performed as well as confined animals

Pastured (n=37) vs. Confined (n=48)

Milk (gal cow\(^{-1}\) day\(^{-1}\))

- Pastured: 9.7 gal
- Confined: 8.9 gal

\(P=0.09\)

Hedtcke 2012
Grazing most profitable WICST system

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

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

† 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

- CC: p < 0.0001
- CS: p < 0.0001
- CSW: p = 0.0122
- CAAA: p < 0.0001
- CoAA: p = 0.1199
- PAST: p = 0.2660
Yield resistance (observed/predicted)

### -2sd palmer Z index (drought)
- **Year:** 2012

<table>
<thead>
<tr>
<th>System</th>
<th>CoAA</th>
<th>CSW</th>
<th>PAST</th>
<th>CS</th>
<th>CAAA</th>
<th>CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimate</td>
<td>1.0231</td>
<td>1.0127</td>
<td>0.9946</td>
<td>0.9787</td>
<td>0.9376</td>
<td>0.7905</td>
</tr>
<tr>
<td>Group</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>AB</td>
<td>B</td>
<td>C</td>
</tr>
</tbody>
</table>

### +2sd palmer Z index (excess)
- **Year:** 2018

<table>
<thead>
<tr>
<th>System</th>
<th>CS</th>
<th>CSW</th>
<th>CC</th>
<th>CAAA</th>
<th>PAST</th>
<th>CoAA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimate</td>
<td>1.0395</td>
<td>1.0057</td>
<td>0.9621</td>
<td>0.9551</td>
<td>0.9282</td>
<td>0.7756</td>
</tr>
<tr>
<td>Group</td>
<td>A</td>
<td>AB</td>
<td>BC*</td>
<td>C*</td>
<td>C*</td>
<td>D*</td>
</tr>
</tbody>
</table>


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

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

Jokela et al. 2011

<table>
<thead>
<tr>
<th>Cropping system</th>
<th>0-5 cm</th>
<th>5-20 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasture</td>
<td>96</td>
<td>84</td>
</tr>
<tr>
<td>All others</td>
<td>87</td>
<td>78</td>
</tr>
<tr>
<td>P-value</td>
<td>0.01</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>
Most systems losing soil organic carbon

Sanford et al. 2012
C accumulating in surface POM...
...and microbial biomass...whose composition differs by cropping system

Cluster analysis of PLFA absolute abundance

Vereecke, in prep
SOC mechanisms

Plant biomass

- Climate
- Texture
- Mineralogy
- Disturbance
- Inputs

Microbial necromass

- Plant C:N
- Microbial C:N

MAOM-C

- POM-C
- POM C:N
- Microbial necromass
- F:B necromass

Rui, in prep

SOC mechanisms

- Plant biomass
- POM
- Microbial necromass
- MAOM

Climate

Texture

Mineralogy

Disturbance

Inputs

Rui, in prep
Higher oxidative enzyme activity in COA
CC
Continuous Corn

COA
Organic Forage

Pasture

CUE

CO₂ loss

F:B Ratio

Microbial necromass production

Oxidation of MAOM
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 improvement

Profitability
1. Organic > Conventional w/ premiums
2. Managed grazing most profitable

Environment
1. Weed management in organic systems resulting in higher soil losses
2. Annual systems losing soil C, perennials holding on
3. Exploring microbial mechanisms for SOC accrual
US Dairy Forage Research Center

Future

Extensify
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)
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

Year

Problems

Consolidation

Credit: Mark Hoffman
Problems
Abandonment
Corn profitability in Northern Crescent
(USDA ERS data)
Problems

Efficiency → Imbalance → Distribution
Problems

Distribution

Photo credit: National Weather Service.
Problems

Eutrophication

Photo: Katie Rice

Photo: Emily Stanley
Problems

Eutrophication
Problems

Drainage

http://cbbel-in.com

Photo: Gary Sands
Problems Flooding

NEW AT 6:00
RESIDENTS BRACE FOR FLOODS
FORT ATKINSON
Problems

Flooding

Photo: University of Wisconsin-Madison
Yahara River watershed
Corn & soybean cover

<table>
<thead>
<tr>
<th>Cover</th>
<th>Acres</th>
<th>Percent of area</th>
<th>P Loading (lbs/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>1,464,328</td>
<td>23.5</td>
<td>1,160,062</td>
</tr>
<tr>
<td>Soybean</td>
<td>455,204</td>
<td>7.3</td>
<td>188,518</td>
</tr>
<tr>
<td>Total</td>
<td>1,919,532</td>
<td>30.8</td>
<td>1,348,580</td>
</tr>
</tbody>
</table>
Solutions

Corn & soybean cover 500 ft. from stream

<table>
<thead>
<tr>
<th>Cover</th>
<th>Acres</th>
<th>Percent of corn &amp; soybeans</th>
<th>P Loading (lbs/yr)</th>
<th>Percent of P loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>282,511</td>
<td>19</td>
<td>870,627</td>
<td>69%</td>
</tr>
<tr>
<td>Soybean</td>
<td>78,490</td>
<td>17</td>
<td>145,555</td>
<td>62%</td>
</tr>
<tr>
<td>Total</td>
<td>361,000</td>
<td>19</td>
<td>1,016,182</td>
<td>68%</td>
</tr>
</tbody>
</table>
Perennial grasslands should reduce P-loading

Corn & soybean cover 500 ft. from stream

<table>
<thead>
<tr>
<th>Cover</th>
<th>Acres</th>
<th>Percent of former corn &amp; soybean land</th>
<th>P Loading (lbs/yr)</th>
<th>Percent reduction across all current &amp; former corn &amp; soybean land</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn -&gt; Grass</td>
<td>282,511</td>
<td>19</td>
<td>9,440</td>
<td>68%</td>
</tr>
<tr>
<td>Soybean -&gt; Grass</td>
<td>78,490</td>
<td>17</td>
<td>2,270</td>
<td>61%</td>
</tr>
<tr>
<td>Corn+Soybean -&gt; Grass</td>
<td>361,000</td>
<td>19</td>
<td>11,710</td>
<td>67%</td>
</tr>
</tbody>
</table>
### Yahara River watershed

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

destabilizing climate change
polluting lakes & streams
reducing biodiversity

land cover

stabilizing climate
purifying water
mitigating floods
providing habitat
Solutions
Solutions

Current Ag System

Outcomes

Obesity & disease
Abandoned communities
Climate change &
eutrophication

Landscape

Confinement
livestock production

Socio-technical

Power
Input suppliers

Power
Processors & retailers

Institutions
Policy
Finance
Knowledge

Niche

Graziers
Grazing networks
Academics

Sustainable Ag System

Outcomes

Healthy people
Healthy communities
Healthy ecosystems

Landscape

Perennial grassland
agriculture

Socio-technical

Power
Farmers

Power
Consumers

Institutions
Policy
Finance
Knowledge

Niche

Society
Policymakers
Lenders
Decision support

Transformation

Catalyst
I. Stakeholder-driven landscape design

Educate & empower

II. Decision support tool (DST)

Use DST output to inform design

Identify relevant sustainability dimensions

III. Knowledge generation

Identify gaps

Validate models

Catalyst

Sustainability Process
Grassland 2.0!