Sustainable agriculture is the production of food, fiber, and fuel using farming techniques that protect the environment, public health, human communities, and animal welfare. This form of agriculture enables us to produce a sufficient amount of healthful food now without compromising the ability of future generations to do the same.

On-Farm Diversification to Protect Iowa’s Soil, Water, and Wildlife

Matt Liebman
Iowa State University
A SIMPLIFIED, HOMOGENEOUS LANDSCAPE
Corn and soybean in Iowa: 63% of total land area, 82% of cropland

Yellow = corn
Green = soybean

Wright County, 2011
583 sq. miles
(1,509 sq. km.)

USDA–NASS Cropland Data Layer
Iowa, 2013: A remarkable record of production

- 2.2 billion bushels of corn harvested
- 411 million bushels of soybean harvested
- 2.3 million cattle, 42.5 million hogs & pigs, 14.8 billion eggs marketed
- 3.7 billion gallons of ethanol produced
- $29.7 billion of farm income from crops and livestock

Emerging and continuing challenges related to low diversity

- Soil erosion
- Water quality degradation via nutrient and pesticide emissions
- Herbicide resistant weeds
- New crop diseases
- Volatility in farm economies
- Reductions of wildlife populations (e.g. monarchs)
Investigations of the effects of diversification at three scales:

• Plot and field: Marsden Farm cropping systems study, Boone, IA
• Small watershed: STRIPS project, Neal Smith NWR, Prairie City, IA
• Landscape: modeling analyses, western IA
Can **diversifying** corn and soybean systems with small grain and forage crops:
- reduce requirements for agrichemical inputs?
- maintain or improve productivity and profitability?
- improve environmental performance characteristics?
Marsden Farm Cropping Systems Experiment, Boone Co., IA
2001–present, 36 plots, 60’ x 275’ each
2–year rotation: corn–soybean (cash grain)
3–year rotation: corn–soybean–oat/red clover (green manure)
Diversification includes the integration of crop and livestock systems:
Composted cattle manure is applied to red clover and alfalfa, before corn, in the 3-year and 4-year rotations.

N added by clover and alfalfa through biological nitrogen fixation, N, P, K, and other nutrients recycled through manure application.
Managing weeds in longer rotations with diverse tactics

Banded herbicides

Cultivation

Asynchronous harvests

Stubble clipping & hay removal
## Mean annual mineral N fertilizer and herbicide use, 2006–2014

<table>
<thead>
<tr>
<th>Rotation</th>
<th>N fertilizer</th>
<th>Herbicides</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2-year</td>
<td>3-year</td>
</tr>
<tr>
<td></td>
<td>lb N/acre</td>
<td>lb a.i./acre</td>
</tr>
<tr>
<td>Corn</td>
<td>147</td>
<td>23</td>
</tr>
<tr>
<td>Soybean</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Oat</td>
<td>--</td>
<td>2</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Rotation av.</td>
<td>74</td>
<td>9</td>
</tr>
<tr>
<td>Reduction</td>
<td>-88%</td>
<td>-92%</td>
</tr>
</tbody>
</table>

Davis et al. (2012) and unpublished data
Mean Yields, 2006–2014

<table>
<thead>
<tr>
<th>Crop</th>
<th>2 year rotation</th>
<th>3 year rotation</th>
<th>4 year rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn (bu/acre)</td>
<td>188 b</td>
<td>194 ab</td>
<td>197 a</td>
</tr>
<tr>
<td>Soybean (bu/acre)</td>
<td>47 c</td>
<td>52 b</td>
<td>55 a</td>
</tr>
<tr>
<td>Oat (bu/acre)</td>
<td>---</td>
<td>93 b</td>
<td>97 a</td>
</tr>
<tr>
<td>Alfalfa, 2nd year (tons/acre)</td>
<td>---</td>
<td>---</td>
<td>4.1</td>
</tr>
</tbody>
</table>

Sources: Liebman et al., 2008; Gómez et al., 2012; Davis et al., 2012; unpublished data.
<table>
<thead>
<tr>
<th></th>
<th>Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2-year</td>
</tr>
<tr>
<td>Labor inputs (hr/acre)</td>
<td>0.7 c</td>
</tr>
<tr>
<td>Gross returns ($/acre)</td>
<td>745 a</td>
</tr>
<tr>
<td>Costs of production, including labor ($/acre)</td>
<td>341 a</td>
</tr>
<tr>
<td>Diversity greater labor requirements, lower gross returns, lower costs, similar profits management ($/acre)</td>
<td></td>
</tr>
</tbody>
</table>
## Environmental performance indicators

<table>
<thead>
<tr>
<th></th>
<th>Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2-year</td>
</tr>
<tr>
<td>Estimated sheet and rill erosion (tons per acre per year)</td>
<td>1.36</td>
</tr>
<tr>
<td>Herbicide-related aquatic ecotoxicity (comparative toxic units per hectare per year)</td>
<td>10,974</td>
</tr>
<tr>
<td>Fossil energy use (barrels of oil equivalent per acre per year)</td>
<td>0.61</td>
</tr>
</tbody>
</table>
Increasing cropping system diversity can balance productivity, profitability, and environmental health

Can diversifying annual cropland by converting small areas to perennial prairie vegetation provide conservation benefits that are disproportionately greater than the land area converted?
Science-based Trials of Row-crops Integrate with Prairie Strips

prairiestrips.org
STRIPS, Phase 1
Neal Smith National Wildlife Refuge, Prairie City, IA
12 experimental watersheds, 1 to 8 acres each, 6 to 10% slope

Four treatments:
100% crop (no-till)
10% buffer, at foot slope
10% buffer, in contour strips
20% buffer, in contour strips
Experimental Watershed Treatments

12 watersheds:
Balanced Incomplete Block Design:
3 reps x 4 treatments x 3 blocks

0%
10%
10%
20%

= corn - soybean row crops, ZERO TILLAGE
= reconstructed prairie
33 native perennial species

A prairie buffer strip in corn, 2010. Stiff, upright stems don’t lay flat in pounding rain storms.
Surface Runoff Monitoring

H-flumes monitor movement of water, sediment, and nutrients
Sediment Loss in Runoff (2007–2012)

Helmers et al., 2012

>95% reduction in sediment export from watersheds with prairie filter strips

Cumulative sediment export (kg/ha⁻¹)

- 100% Row Crop
- 10% Perennial Cover at Toe Slope
- 10% Perennial Cover in Contour Strips
- 20% Perennial Cover in Contour Strips
Weaving prairie strips into cropland has reduced water runoff by 40%, total N losses in runoff by 84%, and total P losses in runoff by 90% compared with all-crop watersheds.

Birds, 2007–2012: Catchments with prairie strips had 2.6 times as many individuals and 2.3 times as many species as all-crop catchments.

A. MacDonald
No influence on per acre crop yield
No additional weed issues
STRIPs Phase II...  
...our first adopter
Grazing prairie conservation strips in southern Iowa, Pinhook Farm, fall 2013.
Mean harvested prairie biomass, 2010–2013, on the STRIPS plots was 3.1 tons dry matter/acre. Will feedstocks for cellulosic biofuels become a revenue source?
How do diversified crop/livestock systems affect soil erosion and leachable nitrogen at a landscape scale?

Shelby County, Iowa
Watersheds with headwaters in Crawford and Shelby Counties, IA

Burkart et al. (2005)
Two scenarios

• **Current conditions** for crops, non-agricultural vegetation, cattle, and hogs

• **Alternative conditions** comprising more land in oat, forages, riparian buffers and eco-reserves; decreased land in corn and soybean; **increased** cattle (1.5x) and hogs (8x); no synthetic N fertilizer
Existing and alternative land use patterns, western Iowa
Predicted soil erosion, via WEPP model, for current (A) and alternative (B) land uses in western Iowa

**A. Current Land Use**
- Soil Loss: 4.5 - 5.5
- 5.6 - 11.2
- 11.3 - 18.2
- 18.3 - 22.1

**B. Alternative Land Use**
- Soil Loss: 1.1 - 2.2
- 2.3 - 3.3
- 3.4 - 4.6
- 4.5 - 5.5
Predicted leachable soil nitrate–N concentrations for current and alternative land uses in western Iowa

**NO₃–N, kg/ha**

- Median: 32 kg NO₃–N/ha  
- Median: 10 kg NO₃–N/ha

**Current conditions**

Diversified and integrated crop–livestock systems
The outstanding scientific discovery of the 20th century is not television, or radio, but rather the complexity of the land organism. – Aldo Leopold

We need to focus on biology and ecology, not just technology.