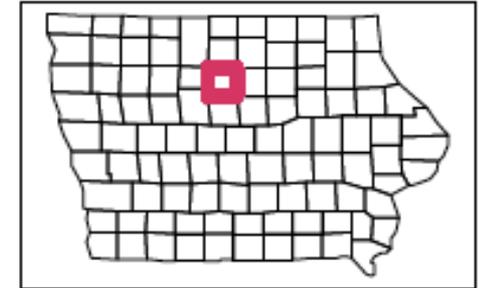
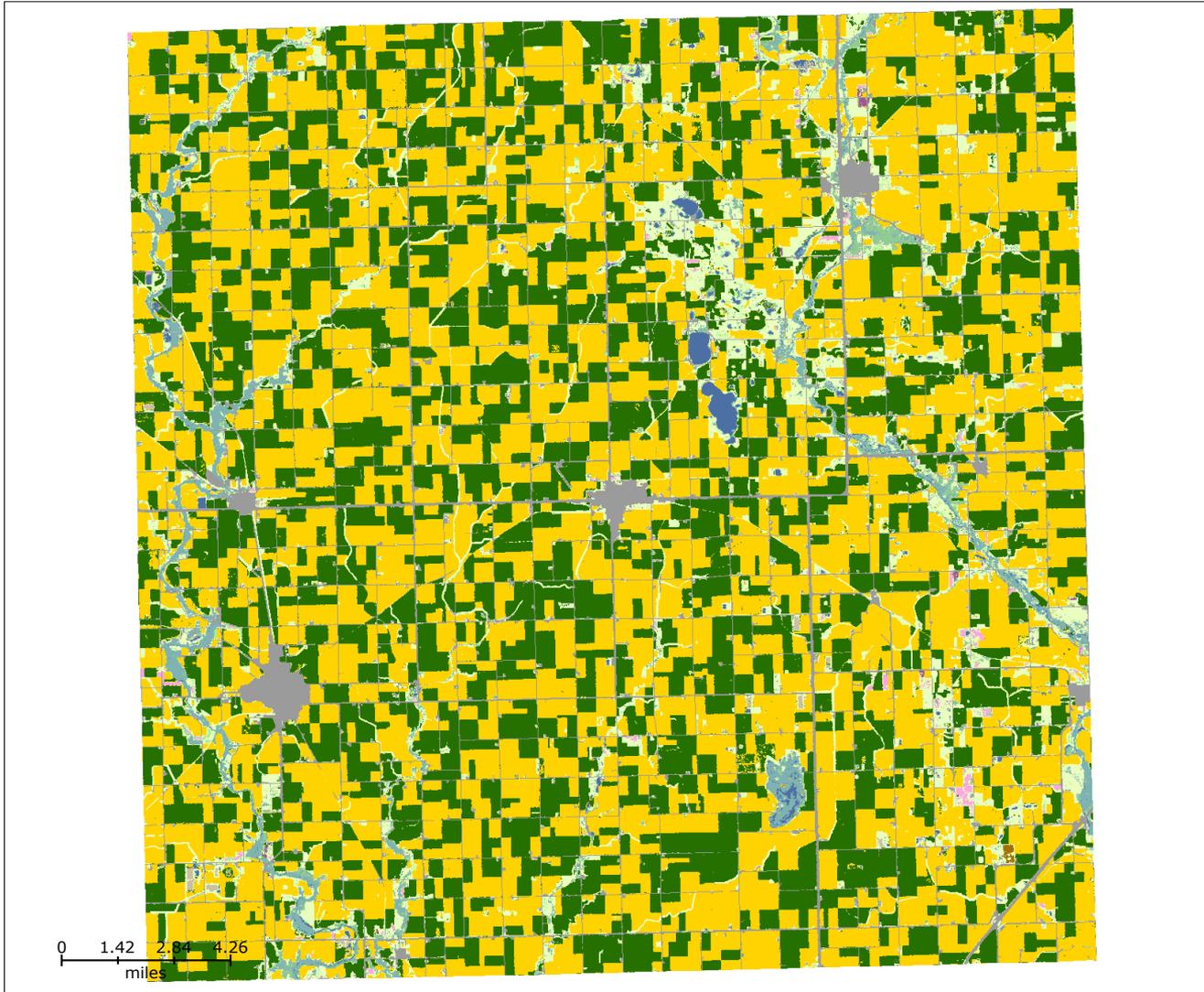


**Adding Oats to a
Corn-Soybean Cropping System**

**Matt Liebman
Iowa State University**

Iowa agriculture lacks diversity

Corn and soybean: 63% of total Iowa land area, 82% of cropland

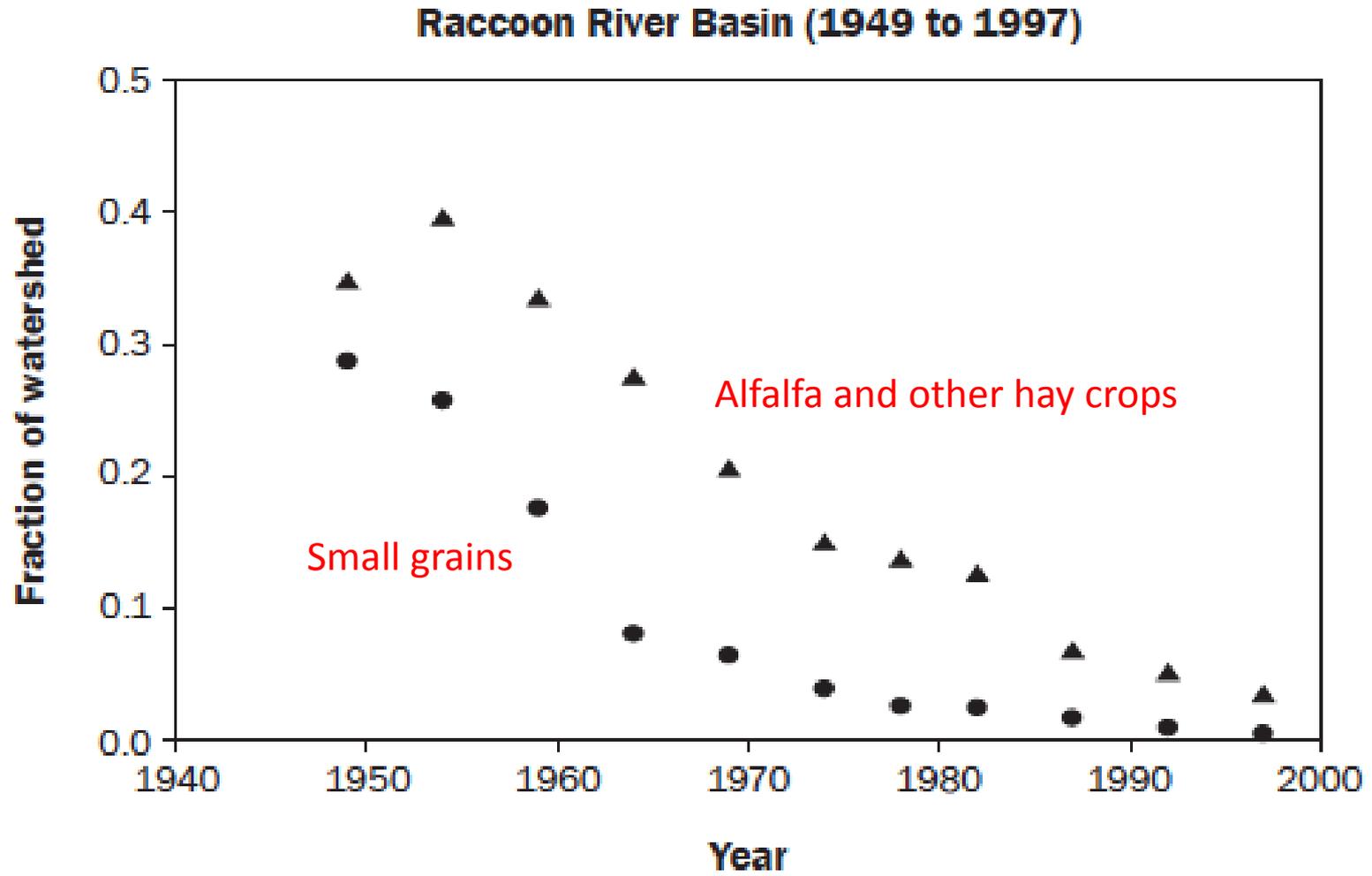


Wright County, 2011
583 sq. miles
(1,509 sq. km.)

Yellow = corn
Green = soybean

Figure 2

Change in area planted to small grains and alfalfa and hay crops (ha) within the Raccoon River Basin from 1949 through 1997.



Yield reduction for major crops grown in shortened rotations or monoculture

| Crop | Yield decline |
|---|---------------|
| Barley (<i>Hordeum vulgare</i>) | 11-19% |
| Corn (<i>Zea mays</i>) | 7-36% |
| Oilseed rape (<i>Brassica napus</i>) | 3-25% |
| Potato (<i>Solanum tuberosum</i>) | 10-30% |
| Rice (aerobic) (<i>Oryza sativa</i>) | 19-54% |
| Soybean (<i>Glycine max</i>) | 8-20% |
| Sugarcane (<i>Saccharum</i> spp.) | 3-50% |
| Sweet potato (<i>Ipomoea batatas</i>) | 21-57% |
| Wheat (<i>Triticum aestivum</i>) | 9-20% |

Challenges related to low cropping system diversity

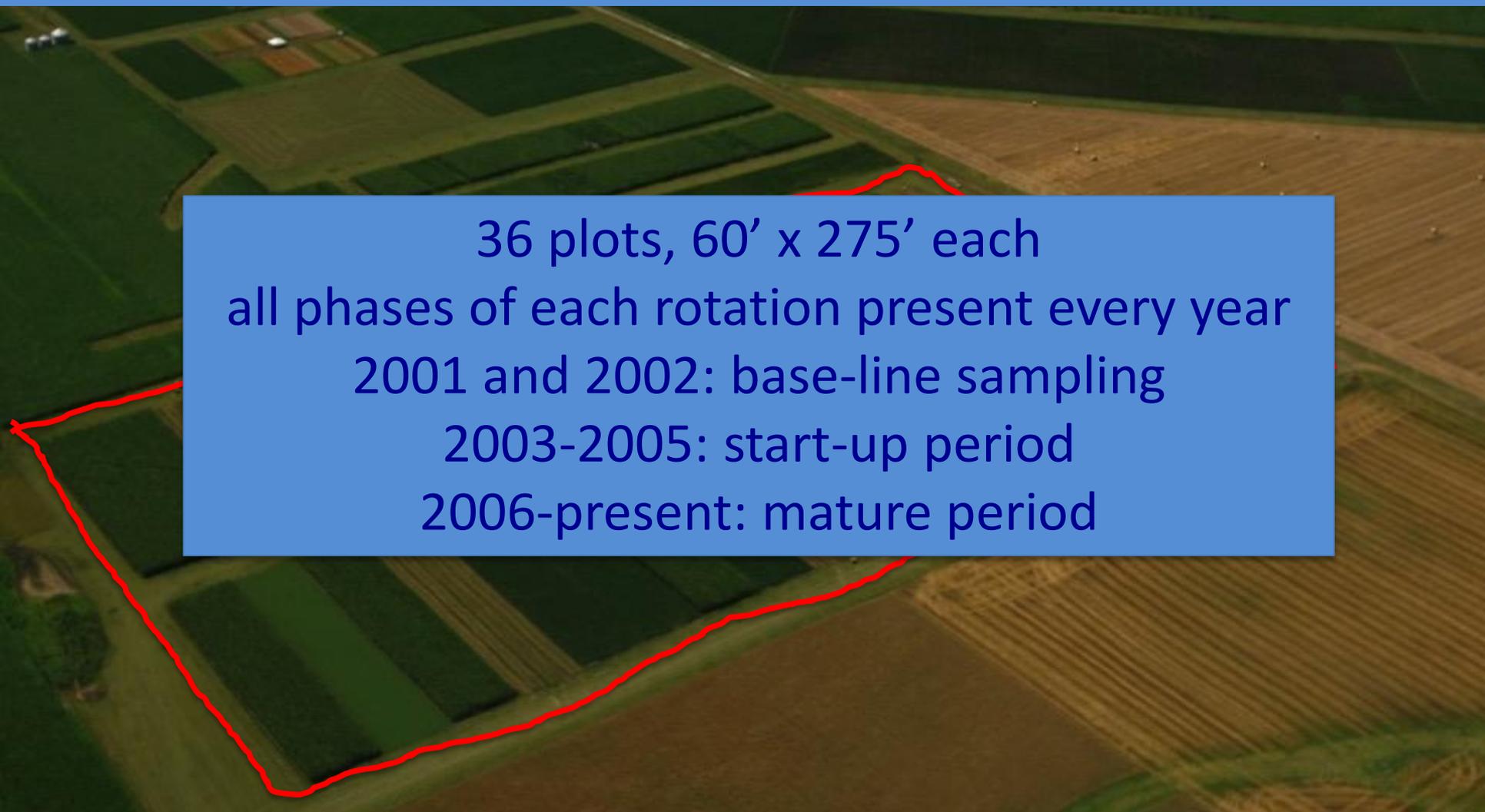
- Soil erosion
- Water quality degradation via nutrient and pesticide emissions
- Herbicide resistant weeds
- New crop diseases
- Economic volatility
- Reductions of wildlife populations, including monarch butterflies, bees and other pollinators



Can **diversifying** corn and soybean systems

- reduce requirements for purchased inputs?
- maintain or improve productivity and profitability?
- reduce susceptibility to diseases?
- improve environmental performance characteristics?

Marsden Farm Cropping Systems Experiment, Boone Co., IA
2-year rotation: corn-soybean (cash grain)
3-year rotation: corn-soybean-oat/red clover (green manure)
4-year rotation: corn-soybean-oat/alfalfa-alfalfa (hay)



36 plots, 60' x 275' each
all phases of each rotation present every year
2001 and 2002: base-line sampling
2003-2005: start-up period
2006-present: mature period

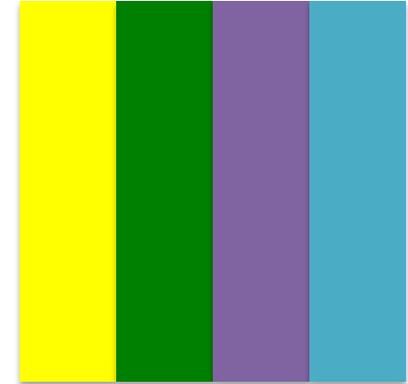
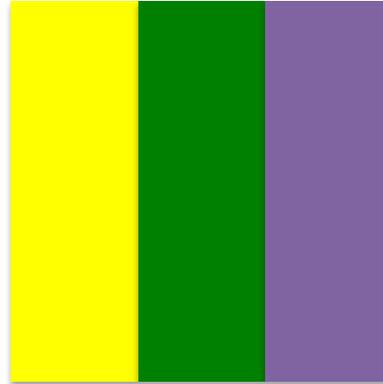
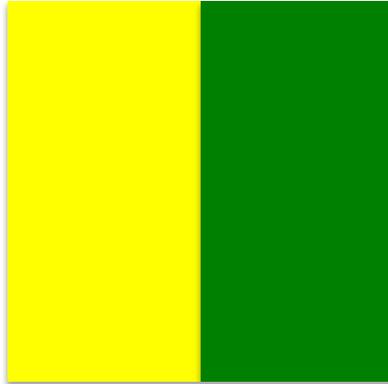
Changes in crop location in different rotation systems over time

2-year rotation

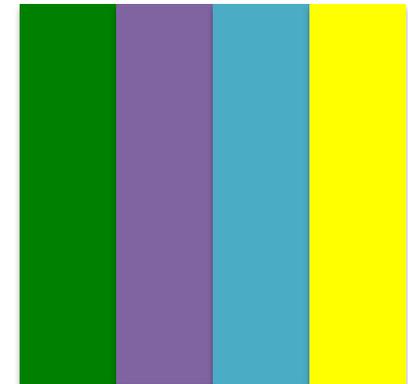
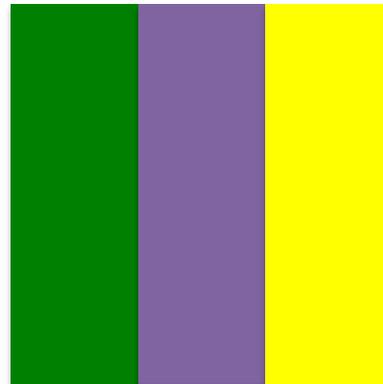
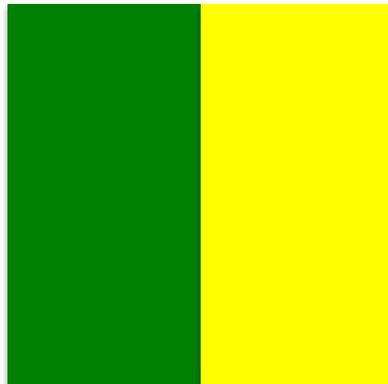
3-year rotation

4-year rotation

Year 1



Year 2



Diversification includes the integration of crops and livestock:
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

Nitrogen Fertility Management in Contrasting Rotation Systems

| Rotation | Corn |
|-------------------|---|
| 2-year | 100 lb N/acre applied at planting with additional N side-dressed according to soil test results |
| 3-year and 4-year | (Legume residues + manure) No fertilizer N applied at planting N side-dressed according to test results |

Tillage:

In the 3-year and 4-year rotations, red clover and alfalfa are incorporated with a moldboard plow in the fall preceding corn production. Moldboard plowing is not used in the 2-year rotation.



Management practices for oat

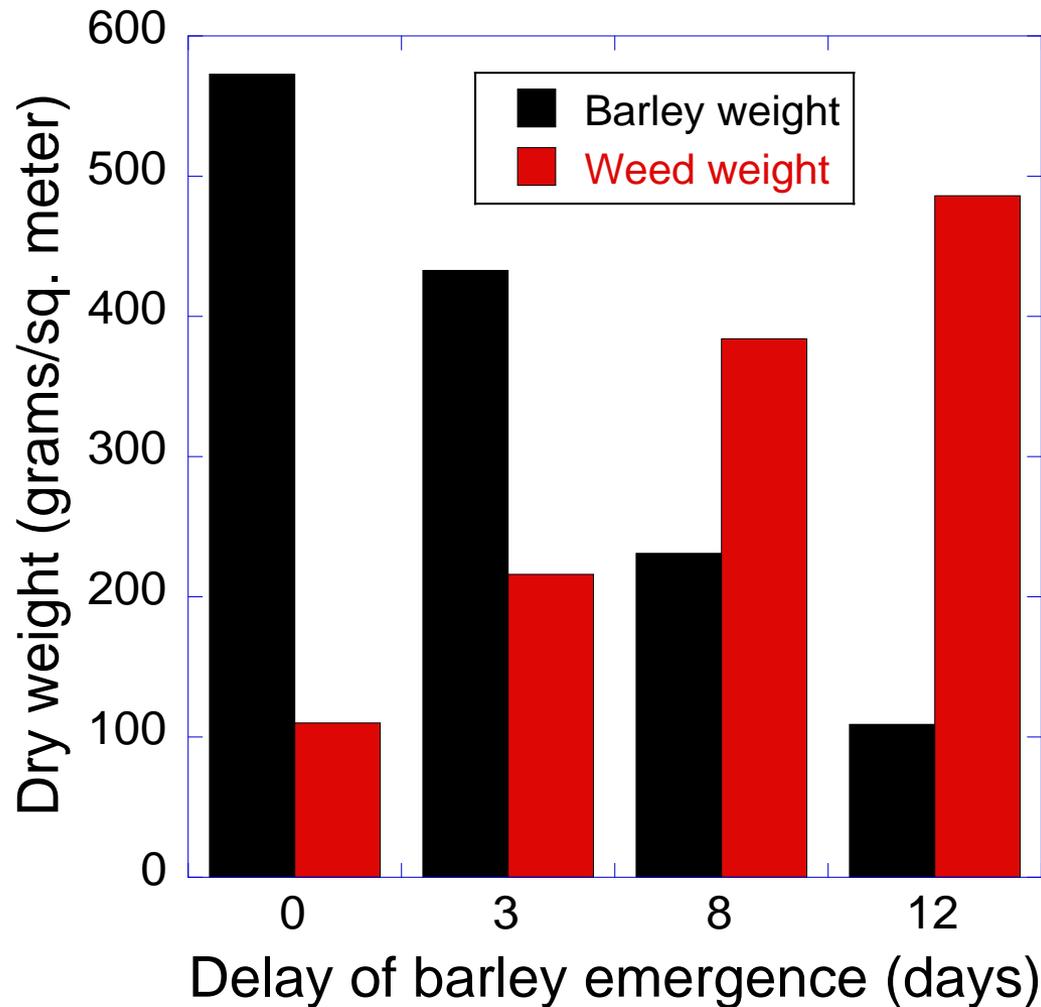
- Soybean residue disked or field cultivated.
- Ground is then cultipacked.
- Oat (IN09201) sown with JD 1520 drill @ 80 lbs/acre with red clover @ 12 lbs/acre or alfalfa @ 15 lbs/acre.
- Row spacing: 7.5”.
- Average oat density: 22 plants per square foot.
- Direct harvest of grain with a JD 9450 combine.
- Straw raked, baled, and removed.
- Grain stubble mowed 5 to 6 weeks later for weed control.
- September alfalfa hay harvest possible when moisture is sufficient.

Restrictions on Crop Rotation for Various Herbicides

| Herbicide: active ingredient and product | Months Before Planting | | |
|--|------------------------|---------|--------|
| | Oat | Alfalfa | Clover |
| atrazine (many products) | 21 | 21 | 21 |
| acetochlor (Harness/Surpass/Breakfree) | 18 | 9 | 9 |
| chloransulam-methyl (FirstRate) | 30 | 9 | 30 |
| flumioxazin (Valor) | 12 | 12 | 12 |
| isoxaflutole (Balance Flex) | 18 | 10 | 18 |
| pyroxasulfone (Zidua) | 18 | 10 | 18 |
| sulfentrazone (Spartan/Authority) | 30 | 12 | 18 |

Source: Weed Control Guide for Ohio, Indiana and Illinois

Effects of the timing of barley emergence relative to weed emergence (80–90% common lambsquarters). The results indicate the need to start with a 'clean' seedbed.



31 March 2015



16 April 2015



23 April 2012



14 May 2012



11 June 2012



9 July 2012



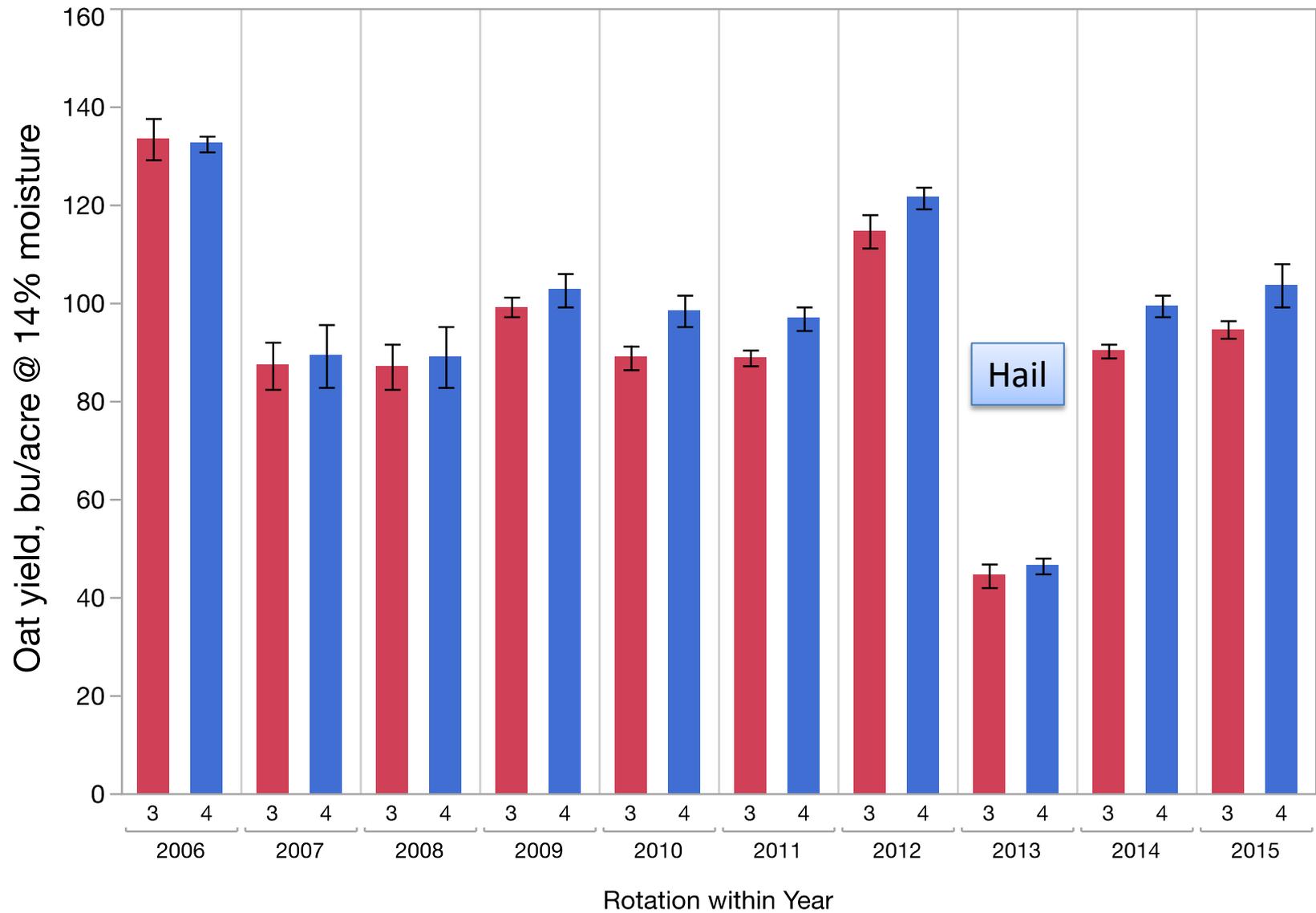
Mean oat yield, 2006-2015

| Rotation system | Yield, bu/acre @ 14% moisture |
|-----------------------------|----------------------------------|
| 3-year, oat with red clover | 93 ± 3.5 |
| 4-year, oat with alfalfa | 98 ± 3.6 |
| | p = 0.002 |

Average test weight: 35 lb/bu

Range: 33 to 38 lb/bu

Oat yields, 2006-2015



Rotation 3 4





Clipping stubble for weed suppression, mid-August



Average Nitrogen Content of Legumes in October, 2006-2013

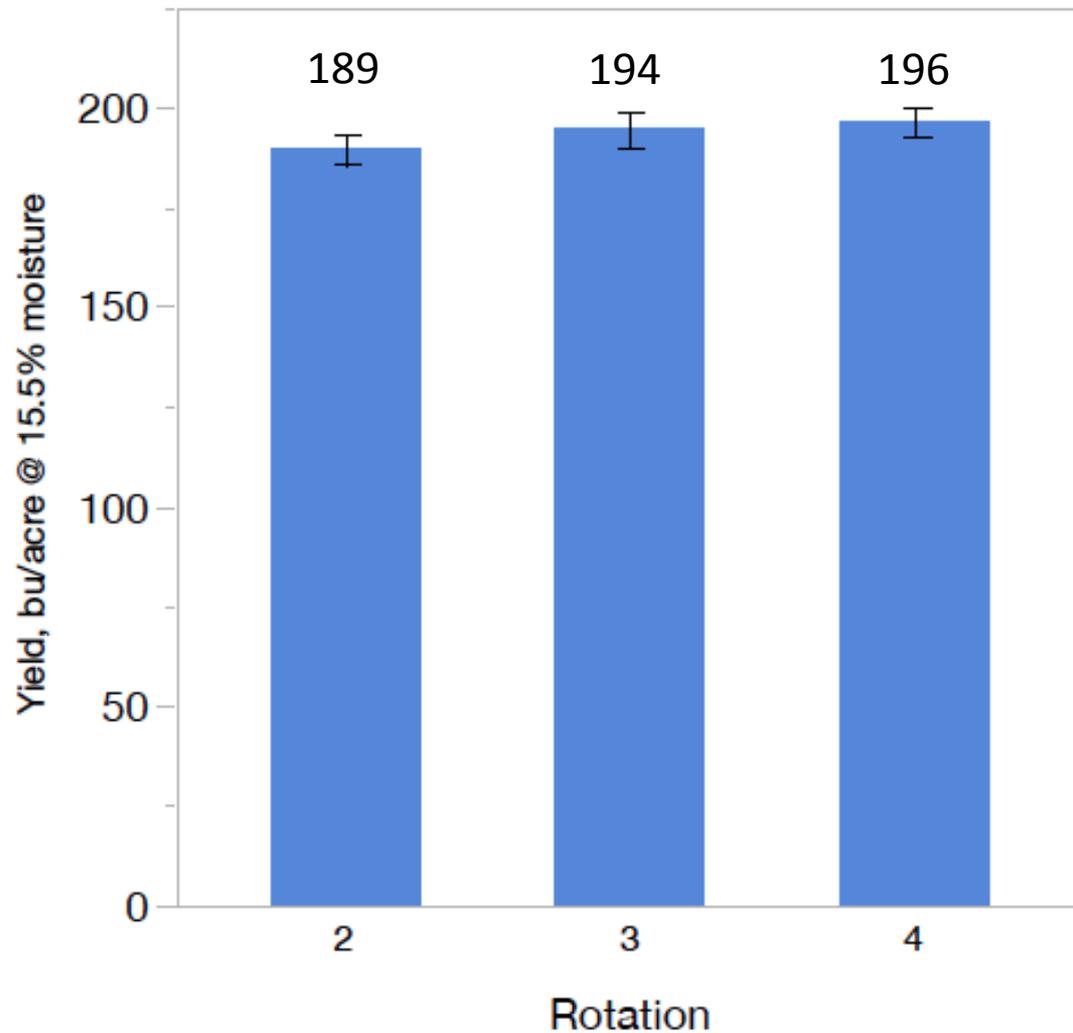
| | Shoots | Roots (to 12") | Total |
|-----------------------------------|--------|----------------|-------|
| | | lb N/acre | |
| Red clover (1 st year) | 112 | 43 | 155 |
| Alfalfa (2 nd year) | 47 | 74 | 121 |

Average N content of composted manure
applied at 7 tons/acre: 101 lbs N/acre

Mean annual mineral N fertilizer use, 2006-2015

| Rotation | 2-year | 3-year | 4-year |
|------------------|-----------|--------|--------|
| | lb N/acre | | |
| Corn | 148 | 23 | 21 |
| Soybean | 2 | 2 | 2 |
| Oat | -- | 2 | 2 |
| Alfalfa | -- | -- | 2 |
| Rotation average | 75 | 9 | 6 |
| Reduction | | -88% | -92% |

Corn yields, 2008-2015



2-yr vs. 3-yr and 4-yr: $p=0.02$

3-yr vs. 4-yr: $p=0.50$

Can adding oat and forage legumes to corn- and soybean-based cropping systems reduce problems with plant diseases?

Sudden Death Syndrome

- Caused by a soilborne fungus - *Fusarium virguliforme*
- Root infection causes root rot and poor root vigor
- Leaf symptoms caused by fungal toxins moved from roots to leaves
- Disease favored by cool, wet weather
- Yield losses can be severe



Rotation effects on soybean in 2010 during SDS epidemic: Longer rotations were healthier

Measurements by L. Leandro, ISU Plant Pathology & Microbiology

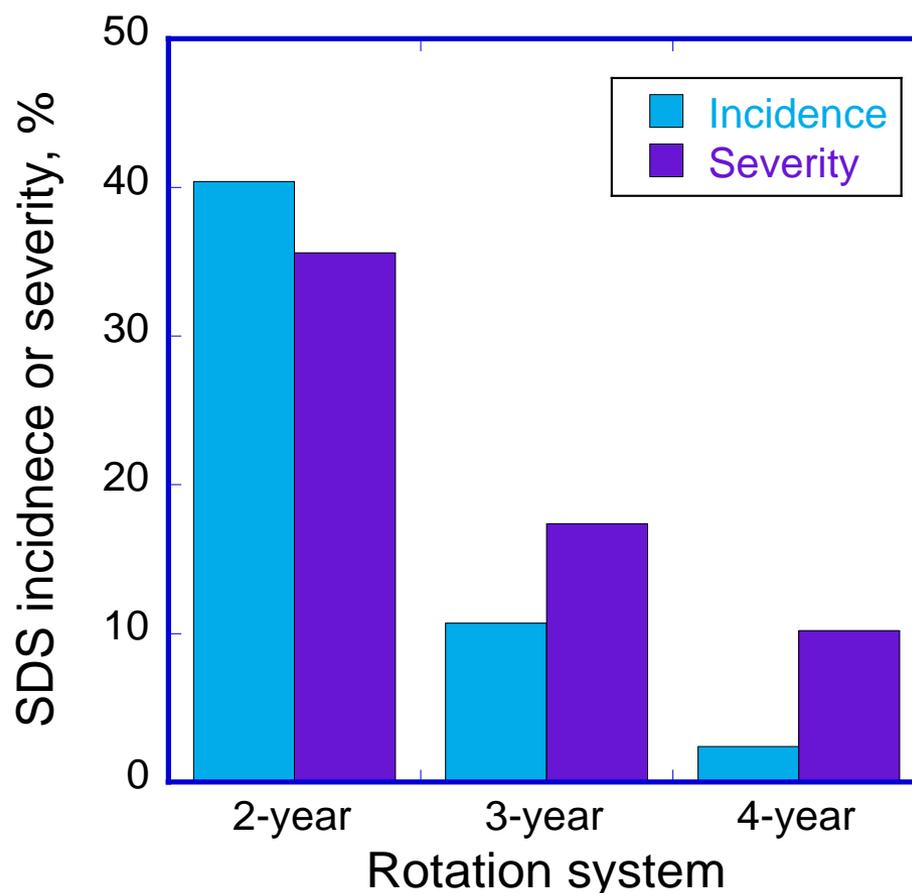
3-year rotation

2-year rotation

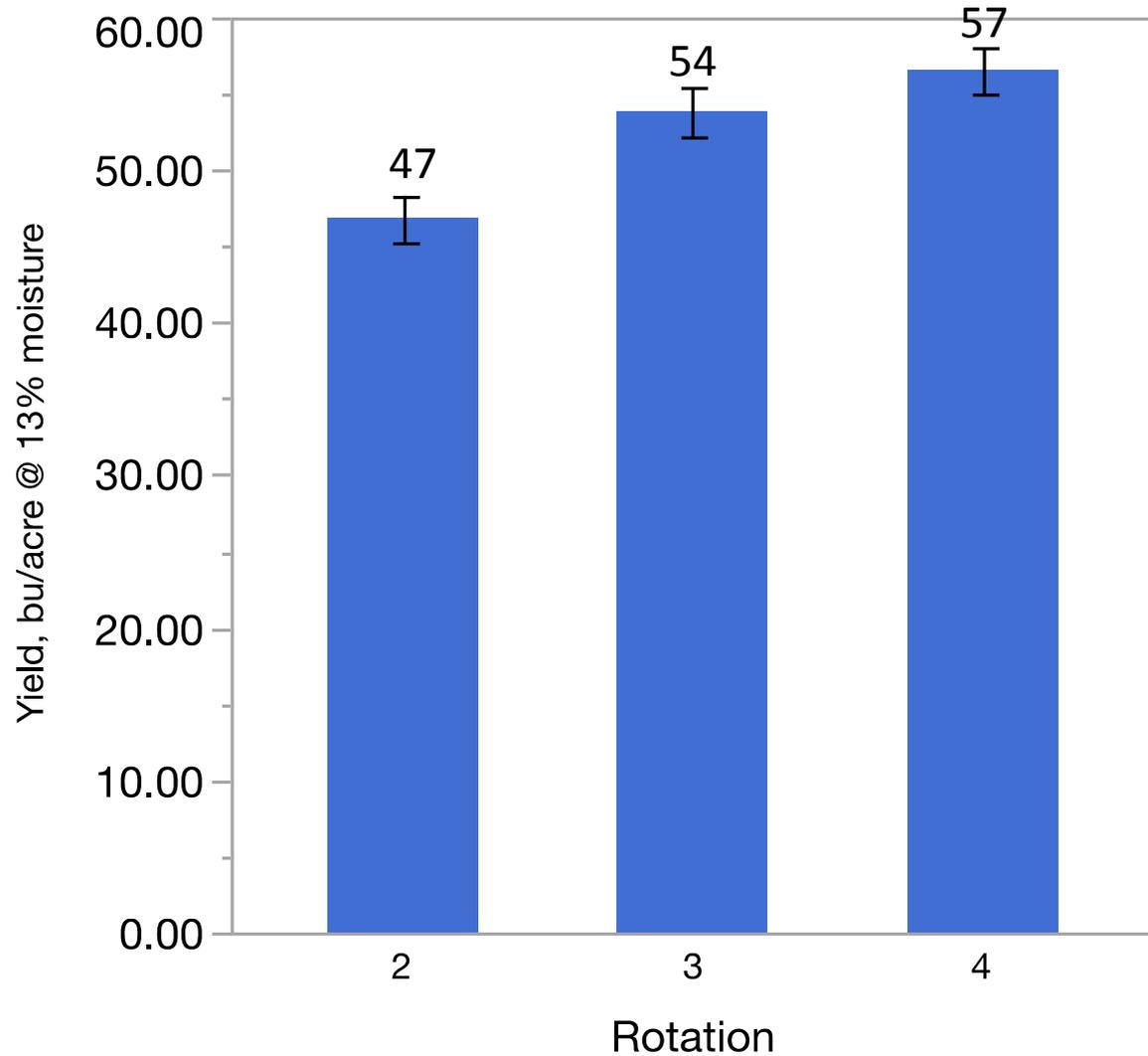
Photo courtesy of L. Miller

Mean SDS incidence and severity, 2010-2014, as affected by rotation system

Rotation effects were highly significant ($p < 0.001$)



Soybean yields, 2008-2015



2-yr vs. 3-yr and 4-yr: $p < 0.0001$

3-yr vs. 4-yr: $p = 0.13$

Cost and Price Assumptions

Input costs were taken from ISU Extension's annual report "Costs of Crop Production in Iowa," and from local businesses.

Machinery operation costs and labor were based on field notes and ISU's "Estimating field capacity of farm machines."

Grain and hay prices were taken from marketing year average crop prices from the Iowa office of the USDA National Agricultural Statistics Services. Subsidy payments were not included.

We assumed manure was generated by on-farm or near-by livestock and without cost for the material, but with labor and machinery costs for spreading.

Oat budgets, \$/acre

| | Oat + red clover | Oat + alfalfa |
|--|------------------|---------------|
| Revenue (grain, straw, alfalfa) | 389 | 487 |
| | | |
| Machinery | 16 | 18 |
| Seed | 49 | 92 |
| Fertilizer | 28 | 50 |
| Pesticides | 0 | 0 |
| Insurance, Misc. | 13 | 15 |
| Harvest | 53 | 80 |
| Labor | 9 | 15 |
| Land | 256 | 256 |
| Total Costs | 423 | 525 |
| | | |
| Returns to Management | -34 | -27 |

Corn budgets, \$/acre

| | After soy (2-yr) | After oat/clover (3-yr) | After alfalfa (4-yr) |
|------------------------|---------------------|----------------------------|-------------------------|
| Revenue | 911 | 940 | 944 |
| | | | |
| Machinery | 27 | 45 | 46 |
| Seed | 96 | 96 | 96 |
| Fertilizer | 136 | 36 | 56 |
| Pesticides | 42 | 42 | 42 |
| Insurance, Misc. | 44 | 40 | 41 |
| Harvest | 90 | 90 | 90 |
| Labor | 8 | 16 | 16 |
| Land | 256 | 256 | 256 |
| Total Costs | 697 | 620 | 642 |
| | | | |
| Returns to Mgt. | 214 | 320 | 302 |

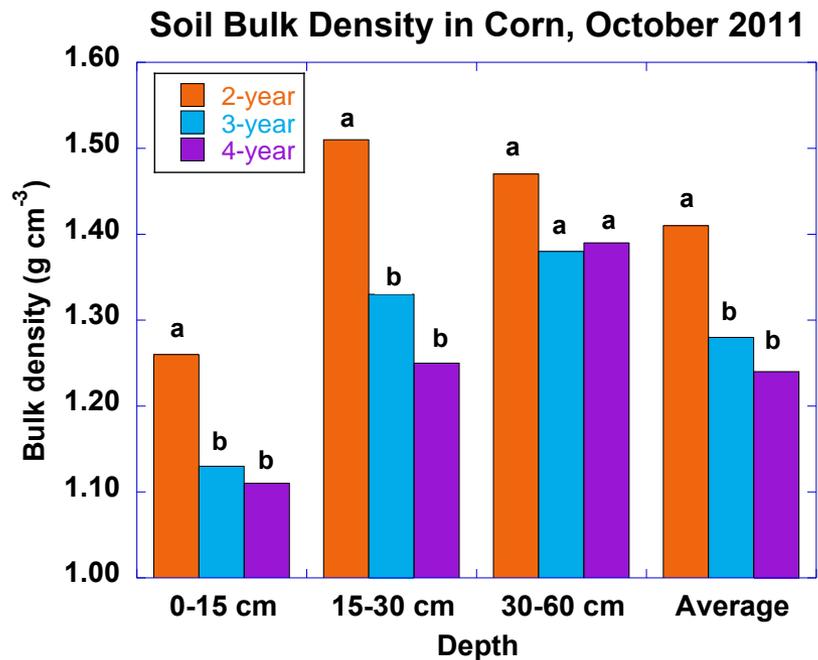
Whole rotation budgets, \$/acre

| | C-S (2-yr) | C-S-O/cl (3-yr) | C-S-O/alf-A (4-yr) |
|------------------------------|---------------|--------------------|-----------------------|
| Revenue | 725 | 645 | 680 |
| | | | |
| Production costs | 333 | 236 | 260 |
| Labor | 8 | 11 | 15 |
| Land | 256 | 256 | 256 |
| Total Costs | 597 | 503 | 531 |
| | | | |
| Returns to Management | 128 | 142 | 149 |

Fossil Energy Inputs [GJ ha⁻¹ yr⁻¹], 2008-2014

| | 2-Year Rotation | 3-Year Rotation | 4-Year Rotation |
|---------------------------|--------------------|--------------------|--------------------|
| Fuel for Operations | 2.6 | 2.0 | 1.8 |
| Fertilizer | 5.5 | 0.9 | 0.9 |
| Herbicide | 0.4 | 0.3 | 0.2 |
| Seed Production | 0.3 | 0.3 | 0.3 |
| Grain Drying | 1.5 | 1.0 | 0.8 |
| Total Energy Costs | 10.3 | 4.5 | 3.9 |

Cropping System Effects on Soil Physical Properties



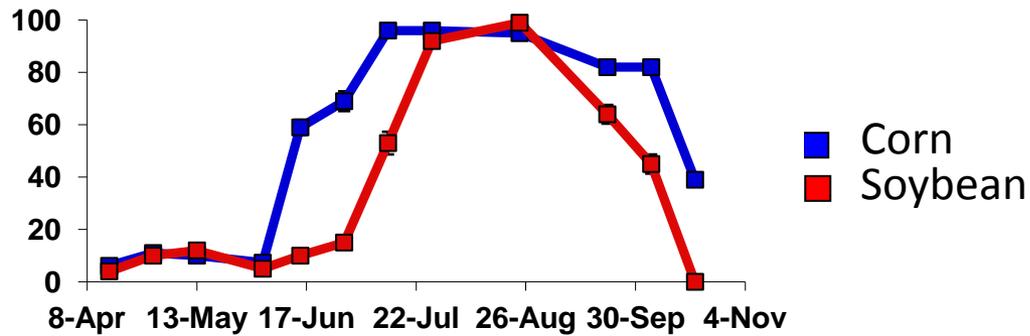
Soil Quality Indicators in Corn (0-20 cm)

| Rotation | Particulate organic matter carbon | Microbial biomass carbon | Potentially mineralizable nitrogen |
|----------|-----------------------------------|---------------------------|------------------------------------|
| | mg POM-C cm ⁻³ soil | μg C g ⁻¹ soil | mg PMN cm ⁻³ soil |
| 2-year | 1.86 b | 312.6 c | 30.8 b |
| 3-year | 2.44 a | 388.7 b | 42.1 a |
| 4-year | 2.38 a | 472.2 a | 38.3 a |

Soil managed with longer rotations has more POM-C, microbial biomass, and PMN.

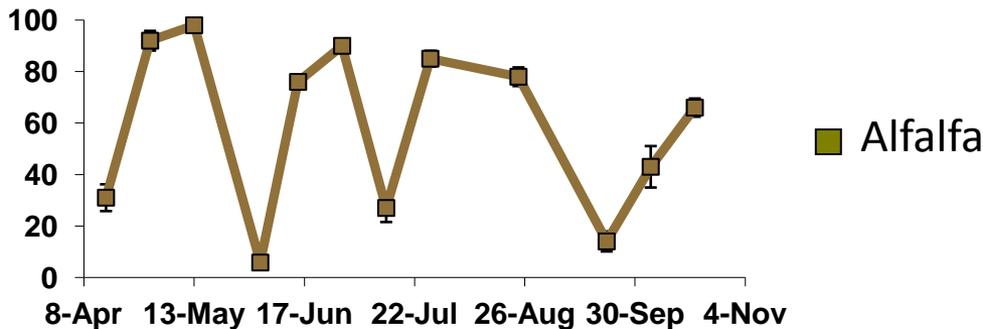
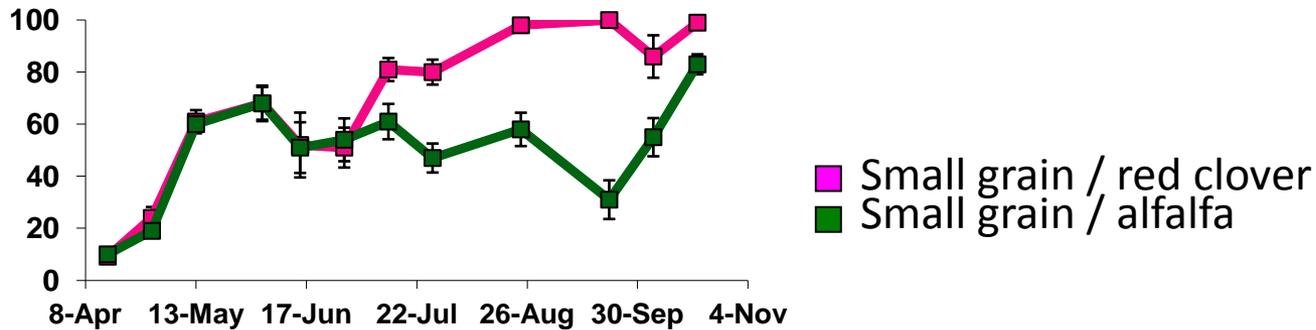
Sources: Lazicki et al., in review; King 2014.

Light Interception in Different Crops

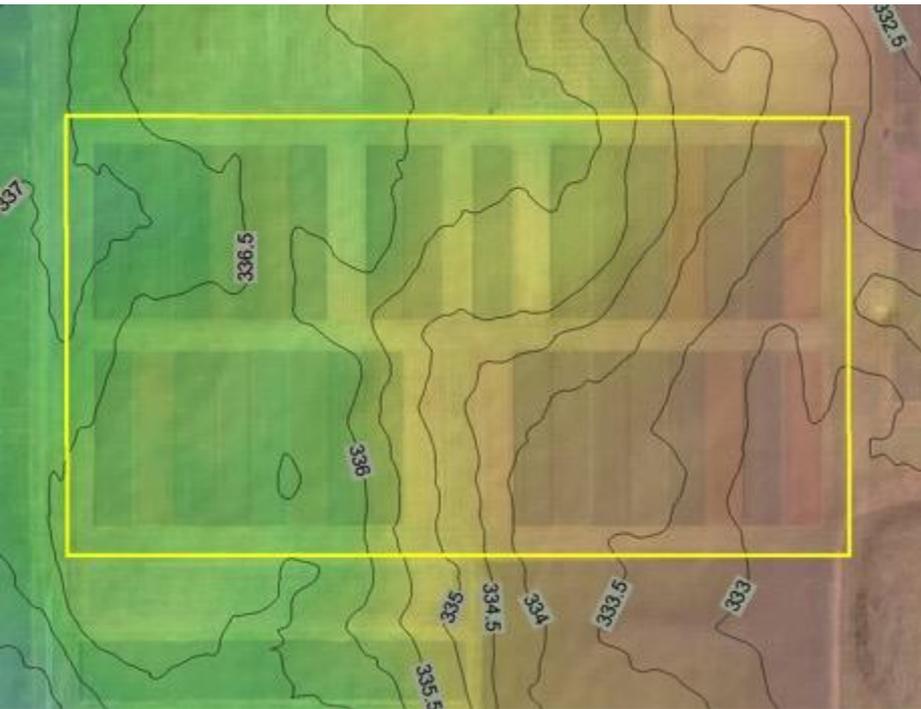


Diverse crops have complementary patterns of canopy development → more living cover

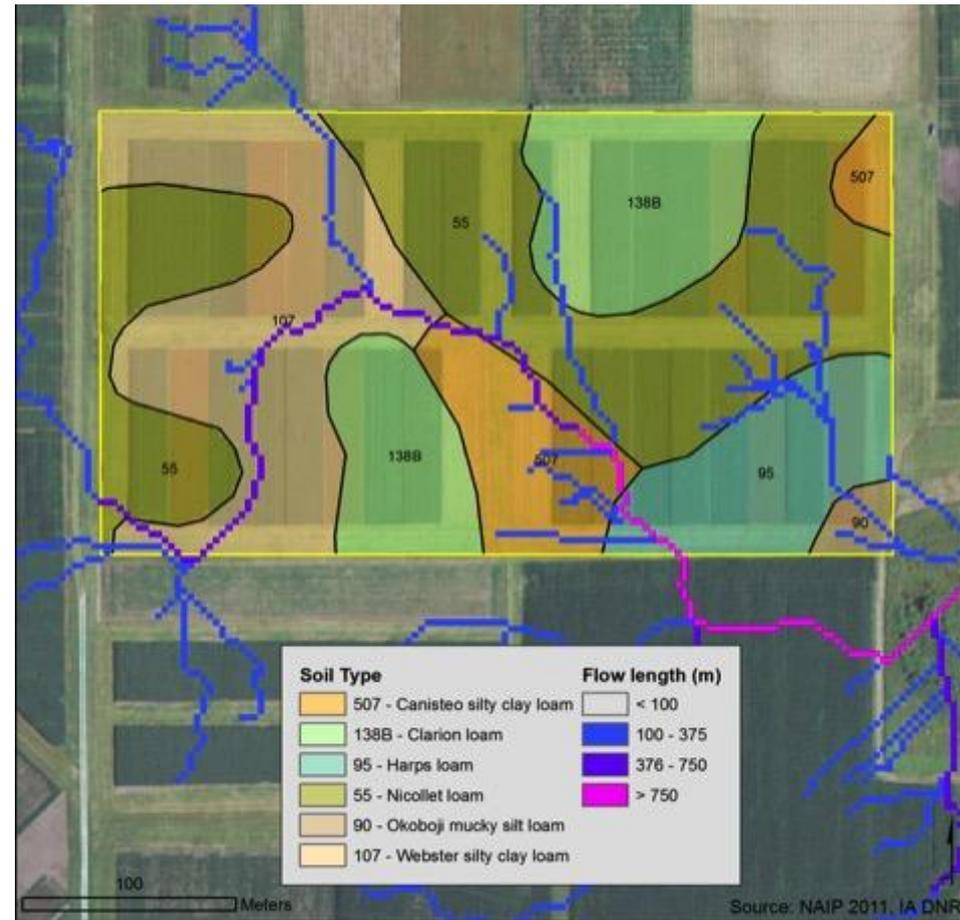
% canopy light interception



Site information used for soil erosion estimates



Elevation



Soil type and surface flow paths

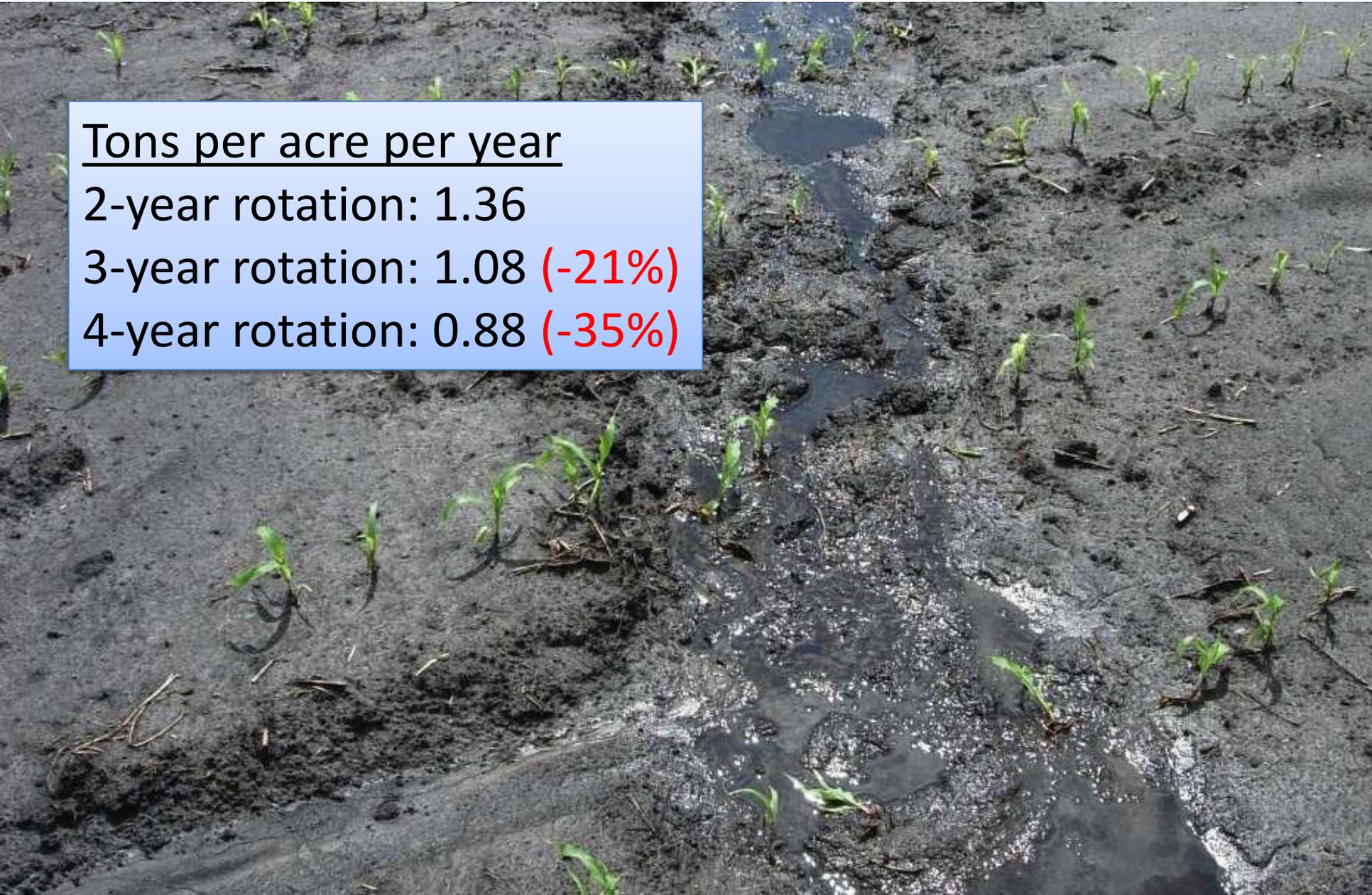
Estimated Sheet and Rill Erosion (RUSLE2)

Tons per acre per year

2-year rotation: 1.36

3-year rotation: 1.08 (-21%)

4-year rotation: 0.88 (-35%)



Nitrate Concentration of Soil Water, 2004-2011

