A Presentation of the 2011 IA-MN-SD Drainage Research Forum

November 22, 2011
Okoboji, Iowa

IOWA STATE UNIVERSITY
University Extension

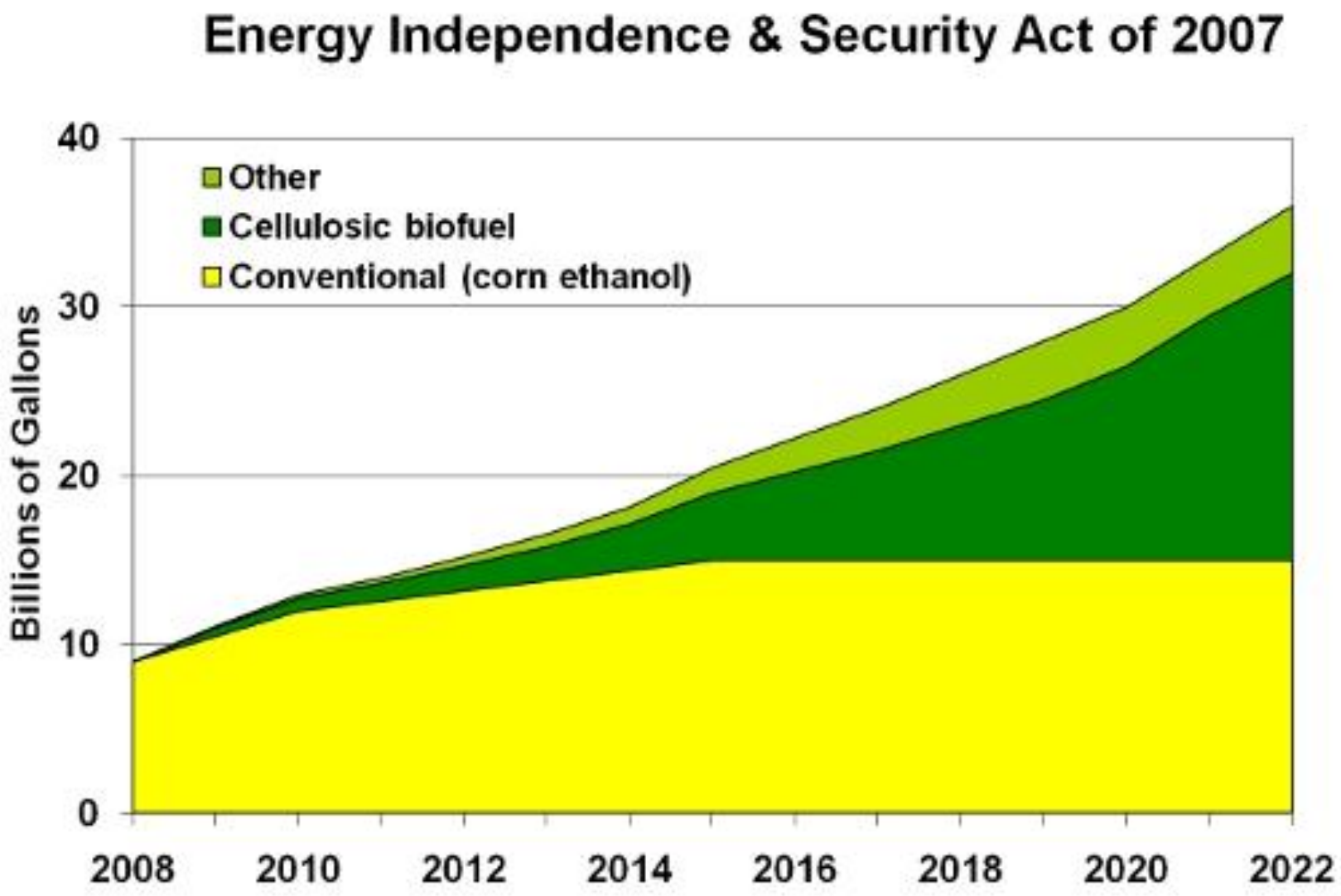
SDSU Extension

Biomass production strategies and potential environmental impacts in drained lands

Matt Liebman

Iowa State University

The Push for Biofuels



King Corn and the Ethanol Boom

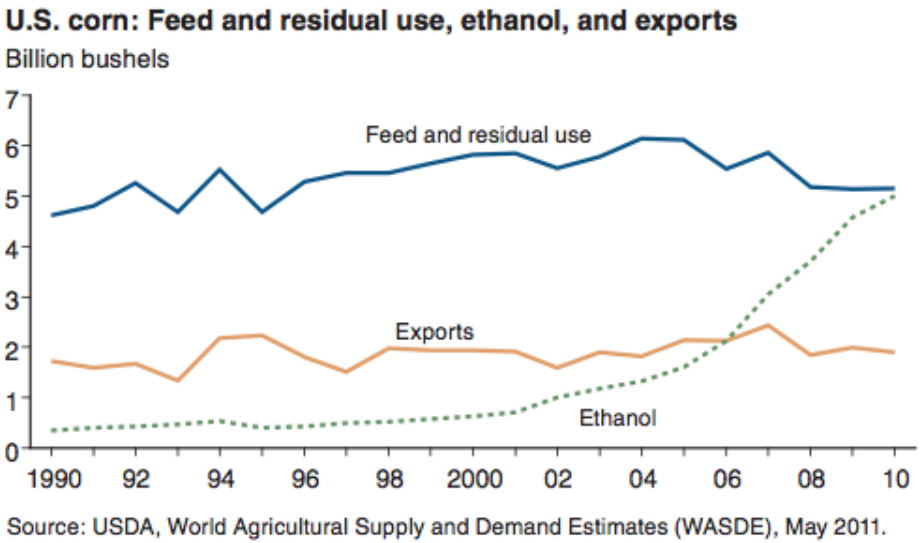
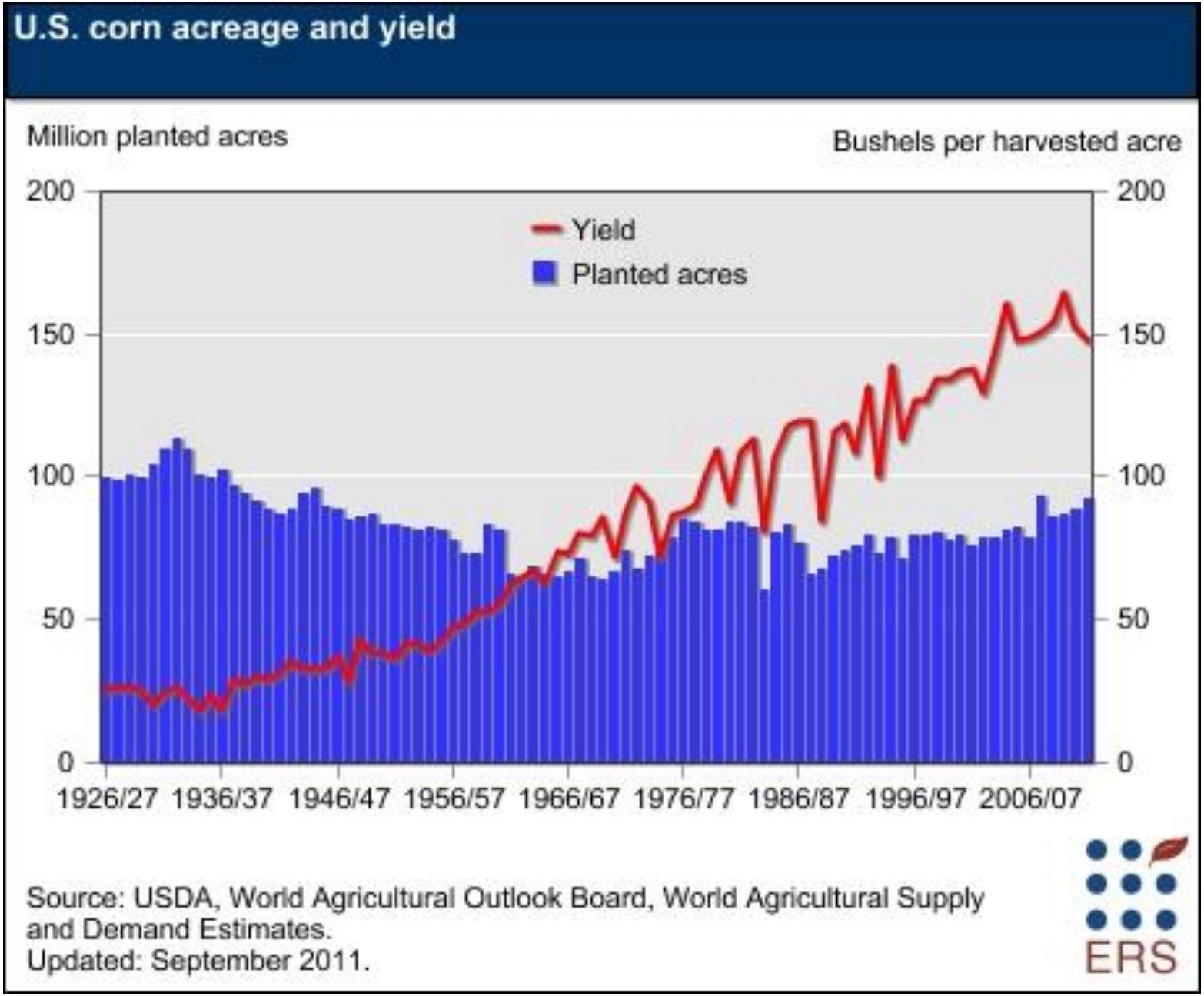
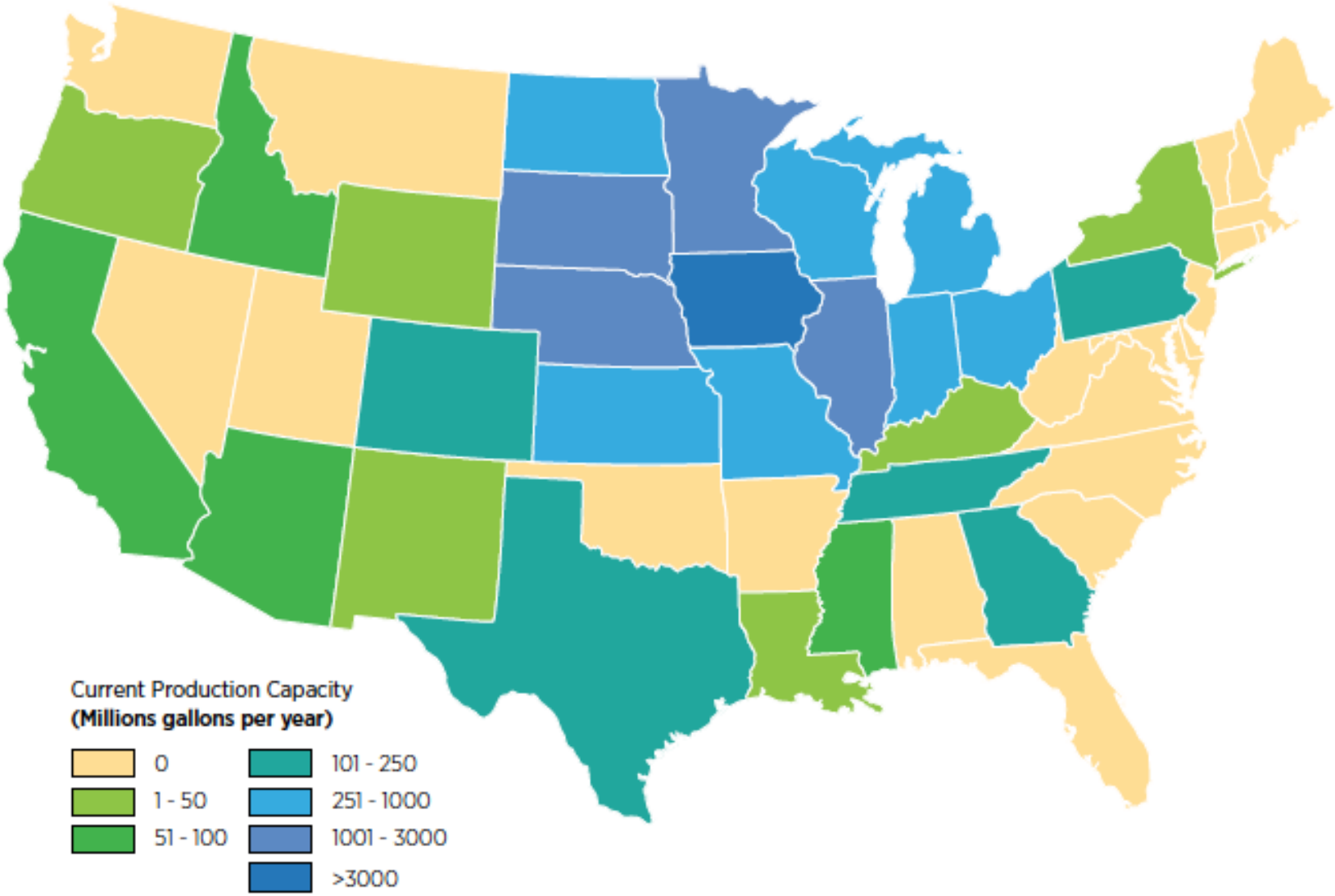


Photo credits: US DOE-NREL

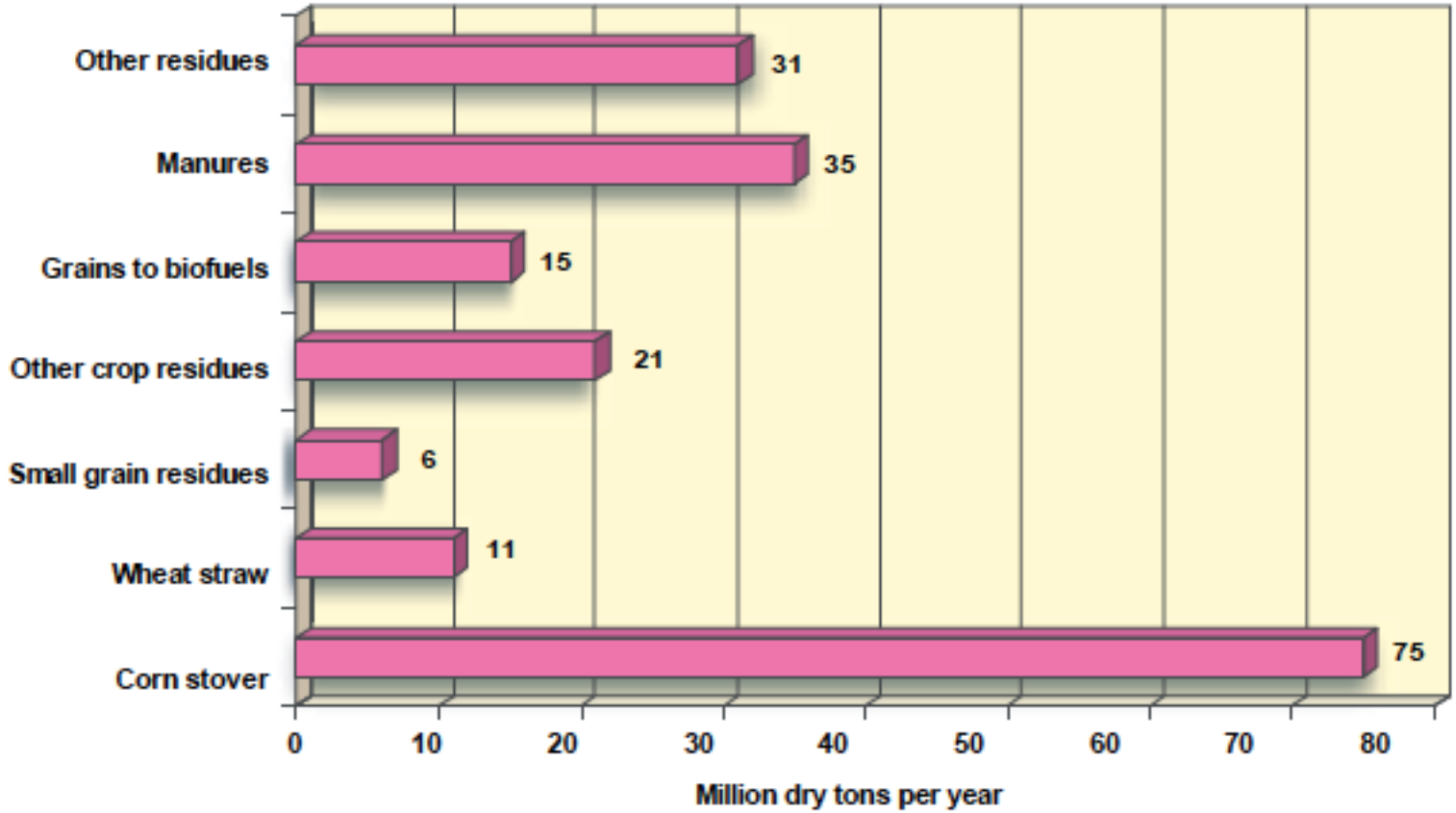


http://www.ers.usda.gov/Briefing/Corn/background.htm

Figure 2.5 Ethanol operating capacity by state



Source: RFA (2010a)



- The total current availability of biomass from cropland is approximately 194 million dry tons/year.
- Slightly more than one-fifth of this biomass is currently used.
- Corn stover is a major untapped source of agriculture-derived biomass.
- Small grain residues include sorghum, barley, oats, and rice. Other crop residues include cotton, other oil seeds (e.g., sunflower, peanuts, canola), tobacco, sugar crops, potatoes, beans, miscellaneous root crops, and double crops. Other residues include secondary agricultural processing residues, MSW, and fats and greases.

Figure 17: Current availability of biomass from agricultural lands

Source: USDOE & USDA 2005

Corn grain and biomass conversion scenario

Photo credit: US DOE-NREL

170 bushels/acre @ 2.84 gal/bushel

= 483 gal ethanol/acre

2 dry tons/acre of stover (50% of total stover) @ 79 gal/ton =158 gal ethanol/acre

Total: 641 gal /acre

Some concerns about heavy reliance on corn, especially with residue removal

Photo credits: US DOE-NREL

Water moving through subsurface drains carries nitrogen

Photo courtesy of A.H. Heggenstaller

Nitrate-nitrogen loss to tile drains

(Randall et al., 1997)

Cropping system	NO_3-N loss (lb acre^{-1} yr^{-1})
Continuous corn	49
Corn-soybean rotation	46
Alfalfa	2
CRP (perennial grasses and alfalfa)	1

Intensity of Tile Drainage

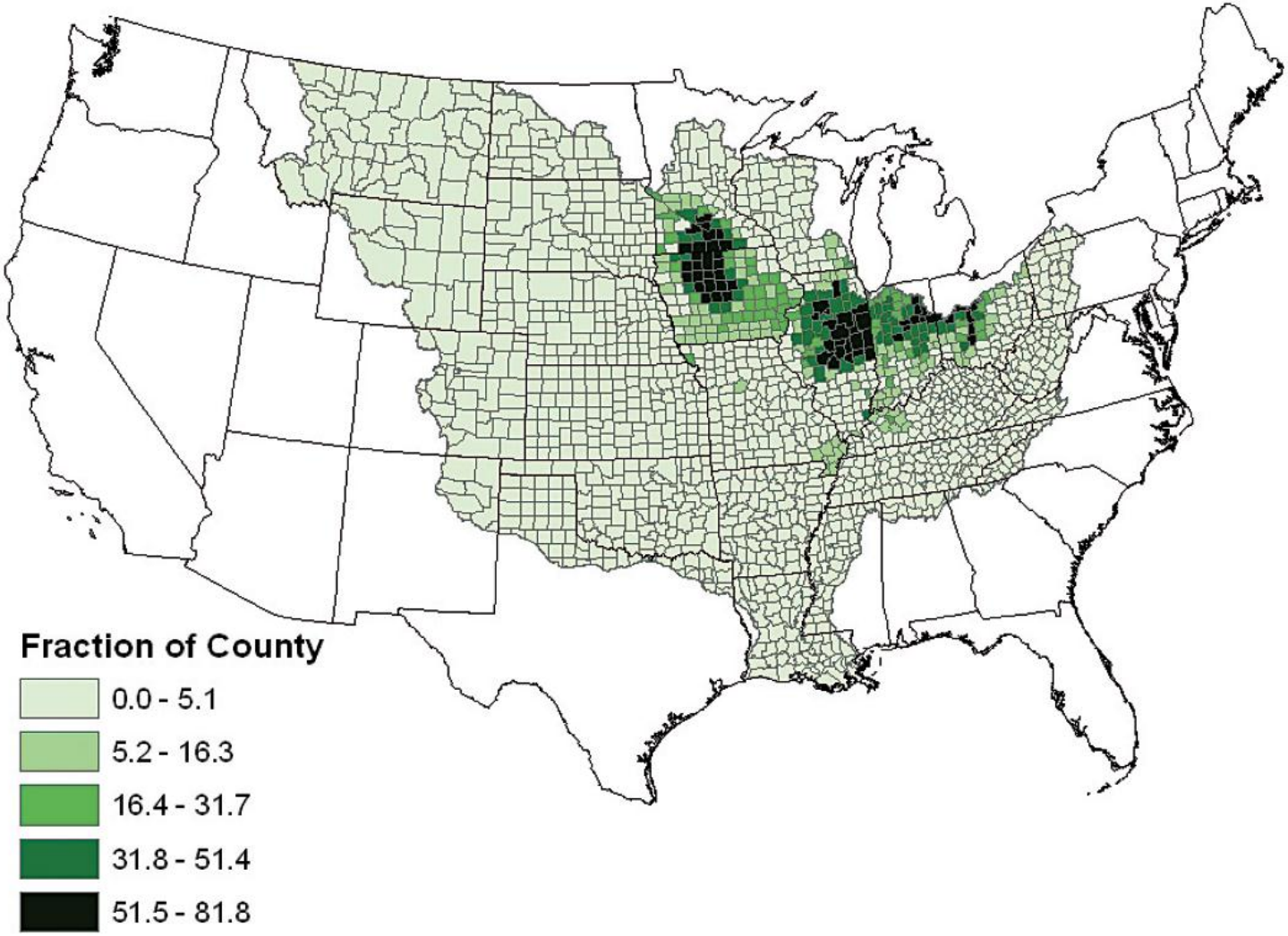
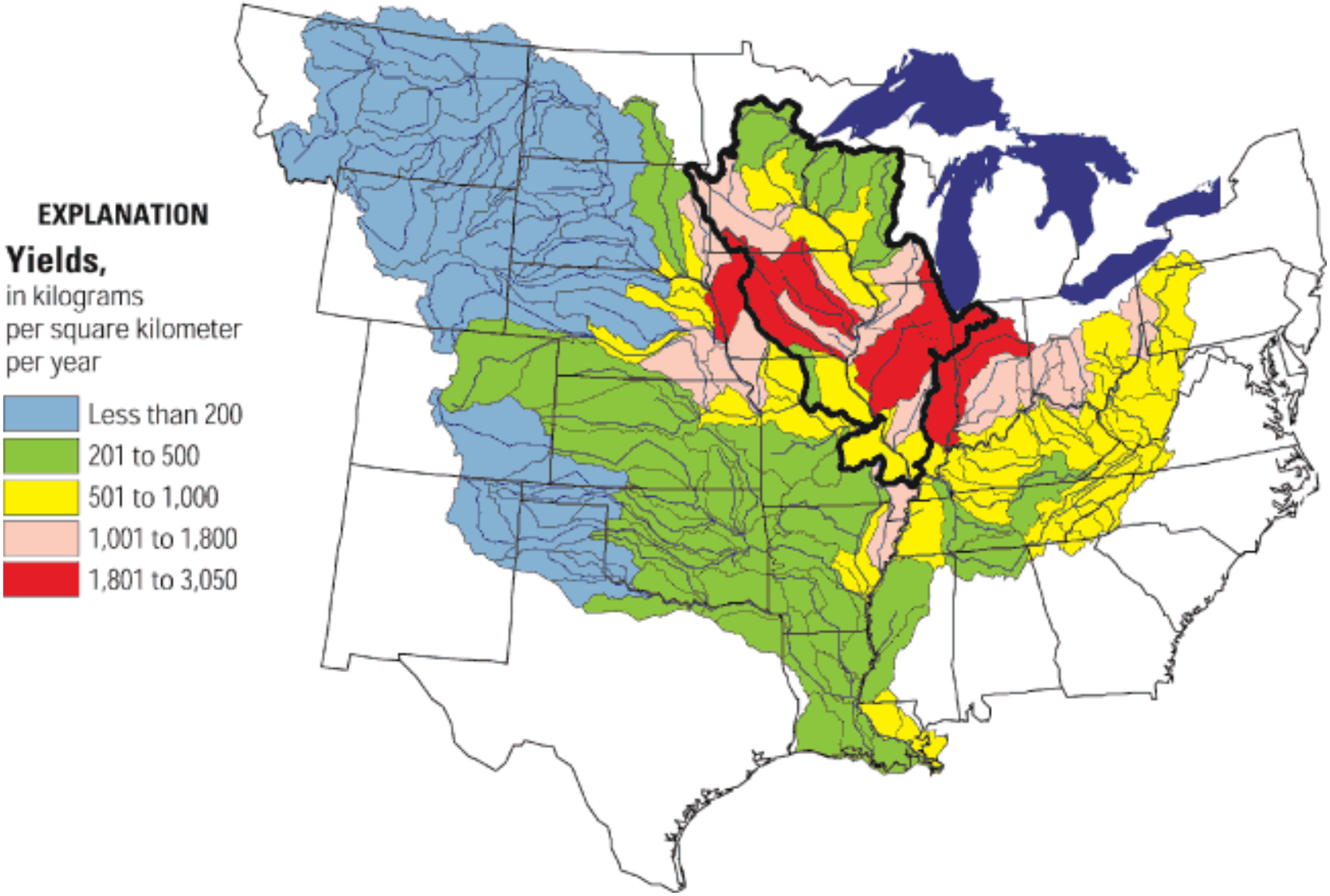


Fig. 5. Fraction of county area that is tile drained in the Mississippi River basin.

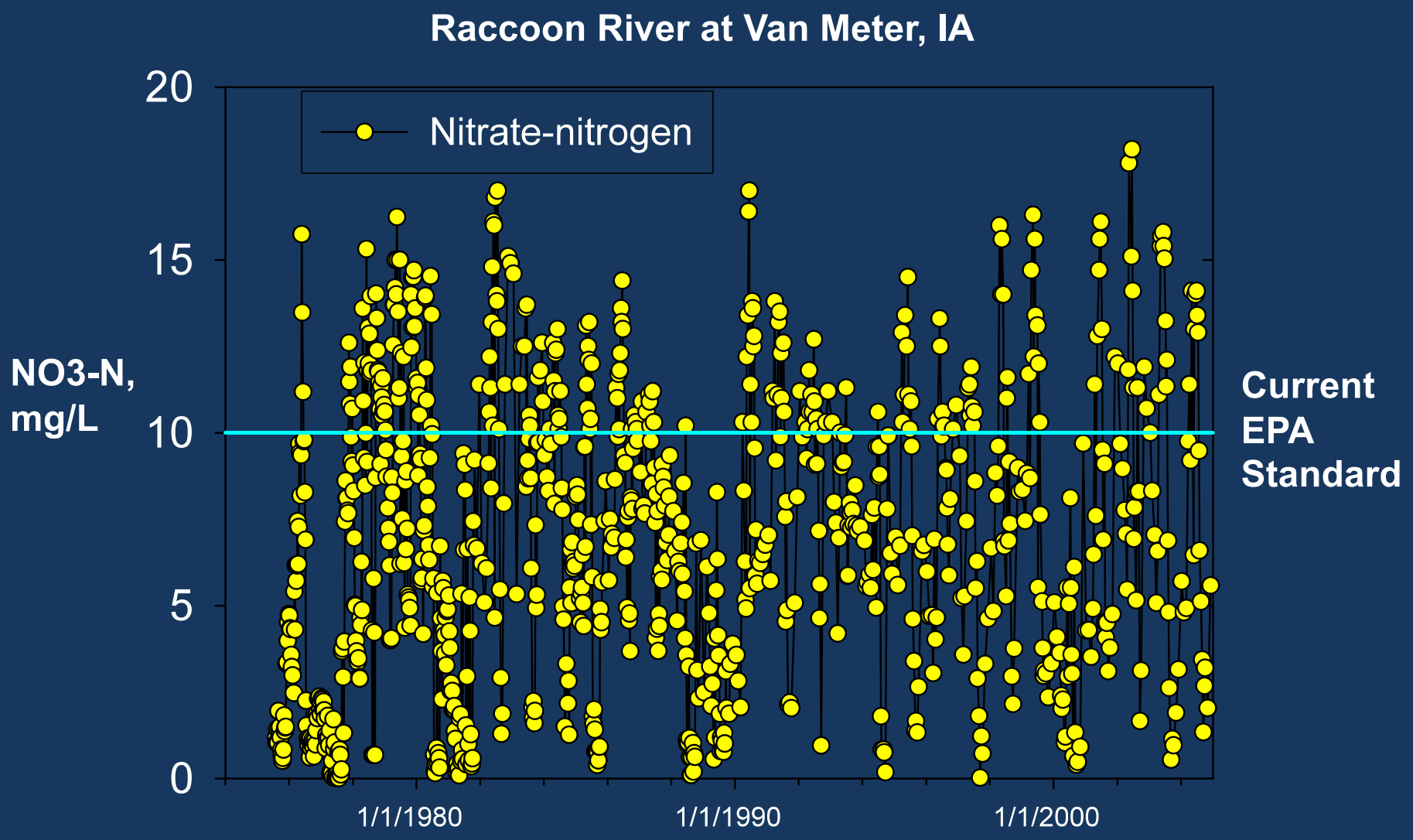
Source: David et al., JEQ, 2010

Nitrogen lost from land to streams



(Goolsby et al.,1999)

"Unfortunately, the Raccoon River has the highest average nitrate concentration of any of the 42 largest tributaries in the Mississippi River Basin." – Des Moines Water Works, 2007

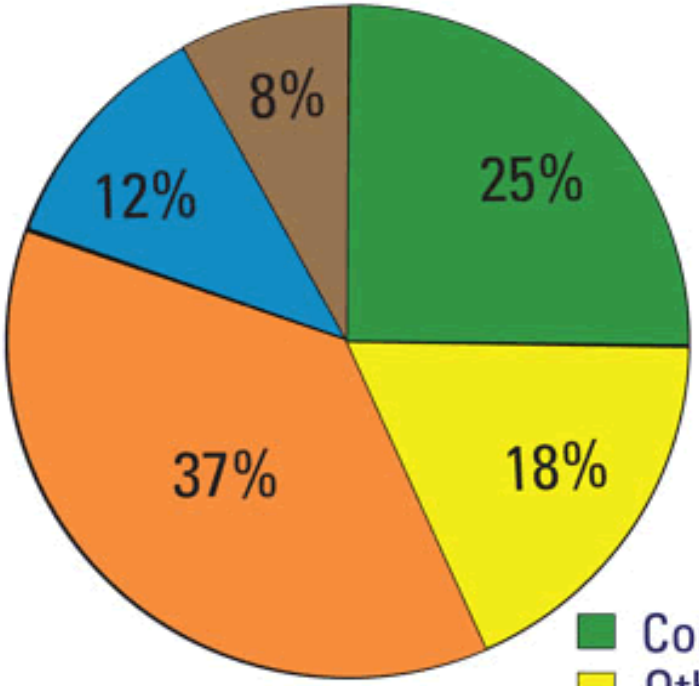


Des Moines River Water Quality Network Database

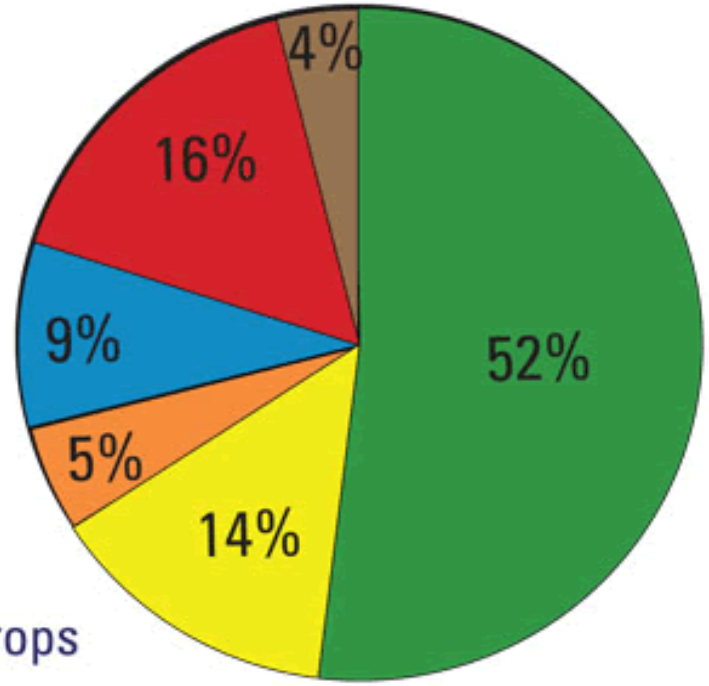
USGS
science for a changing world

Sources of nutrients delivered to the Gulf of Mexico

PHOSPHORUS



NITROGEN



Sources

- Corn and soybean crops
- Other crops
- Pasture and range
- Urban and population-related sources
- Atmospheric deposition
- Natural land

U.S. Department of the Interior
U.S. Geological Survey

Crop residue is a primary soil conservation and protection tool.

Photo source: USDA-NRCS

Residue affects soil sediment and nutrient loss in runoff

	Residue mass (lb acre^{-1})		
	750	1500	3000
Water runoff, inches yr^{-1}	5.3	3.7	3.3
Soil erosion, tons acre^{-1} yr^{-1}	19.1	4.6	2.4
N loss, lb acre^{-1} yr^{-1}	124	37	21
P loss, lb acre^{-1} yr^{-1}	59	14	9
K loss, lb acre^{-1} yr^{-1}	46	20	20

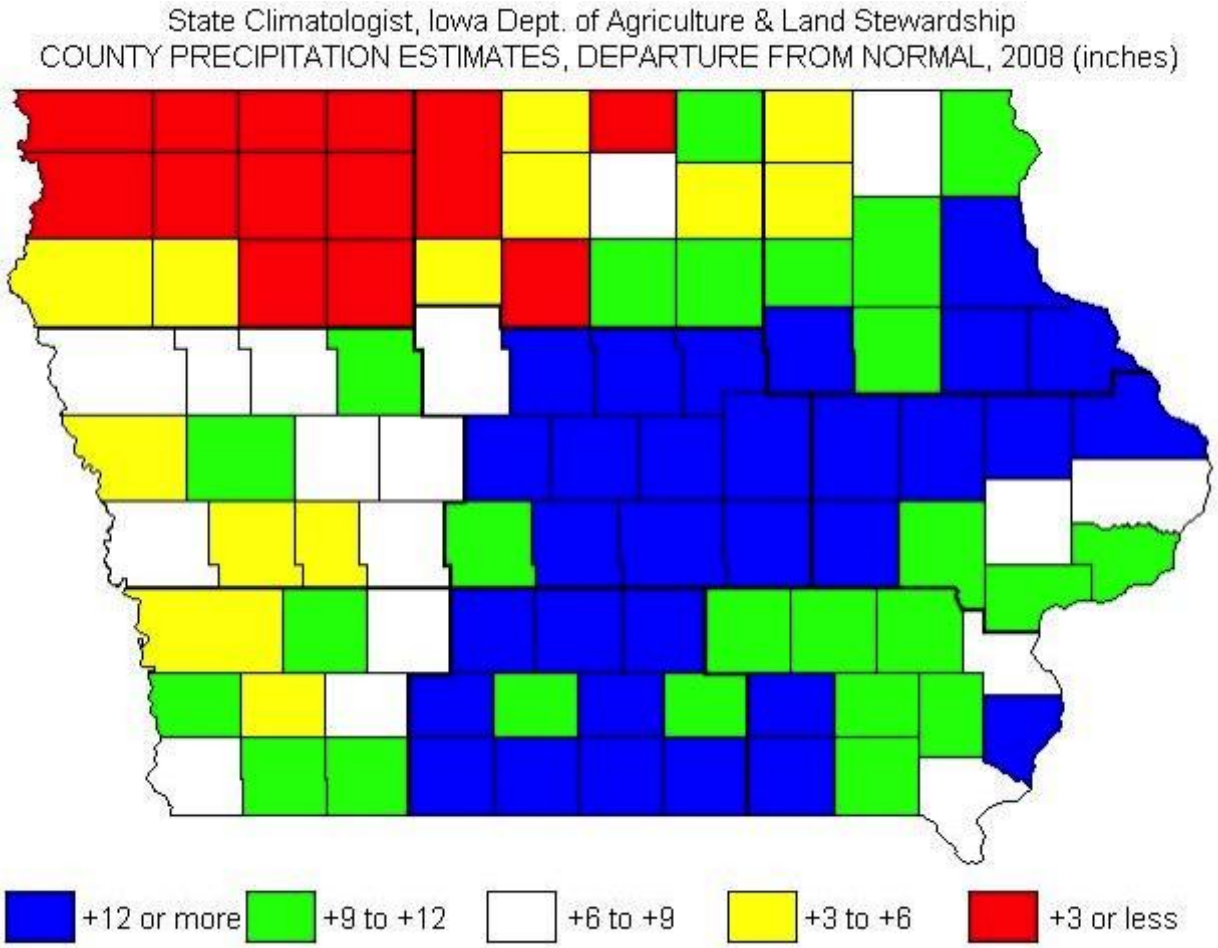
Corn in no-tillage plots, 5.8% slope,
Egan-Wentworth silty clay loam, Madison, SD.
Source: Lindstrom (1986)

New Challenges and Uncertainties for Conservation in the Midwestern U.S.

"During the 21st century, precipitation is likely to continue its upward trend, at a slightly accelerated rate; 10 to 30% increases are projected across much of the region….In addition, increases in the proportion of precipitation coming from heavy and extreme precipitation are very likely."

Climate Change Impacts on the United States
The Potential Consequences of Climate Variability and Change
Overview: Midwest
National Assessment Synthesis Team, US Global Change Research Program (2000)
http://www.usgcrp.gov/usgcrp/Library/nationalassessment/overviewmidwest.htm

County Precipitation Estimates, Departure from Normal (inches), Iowa, 2008



Farm fields near Ames, IA, 12 June 2008.
Source: Ames Tribune, 13 June 2008.

“The survey by the Iowa Department of Agriculture and Land Stewardship shows that an estimated 2.3 million acres — about 10 percent of Iowa’s cropland — has suffered severe erosion damage, which is defined as the loss of 20 tons or more of soil per acre.”
-- Associated Press, 30 July 2008

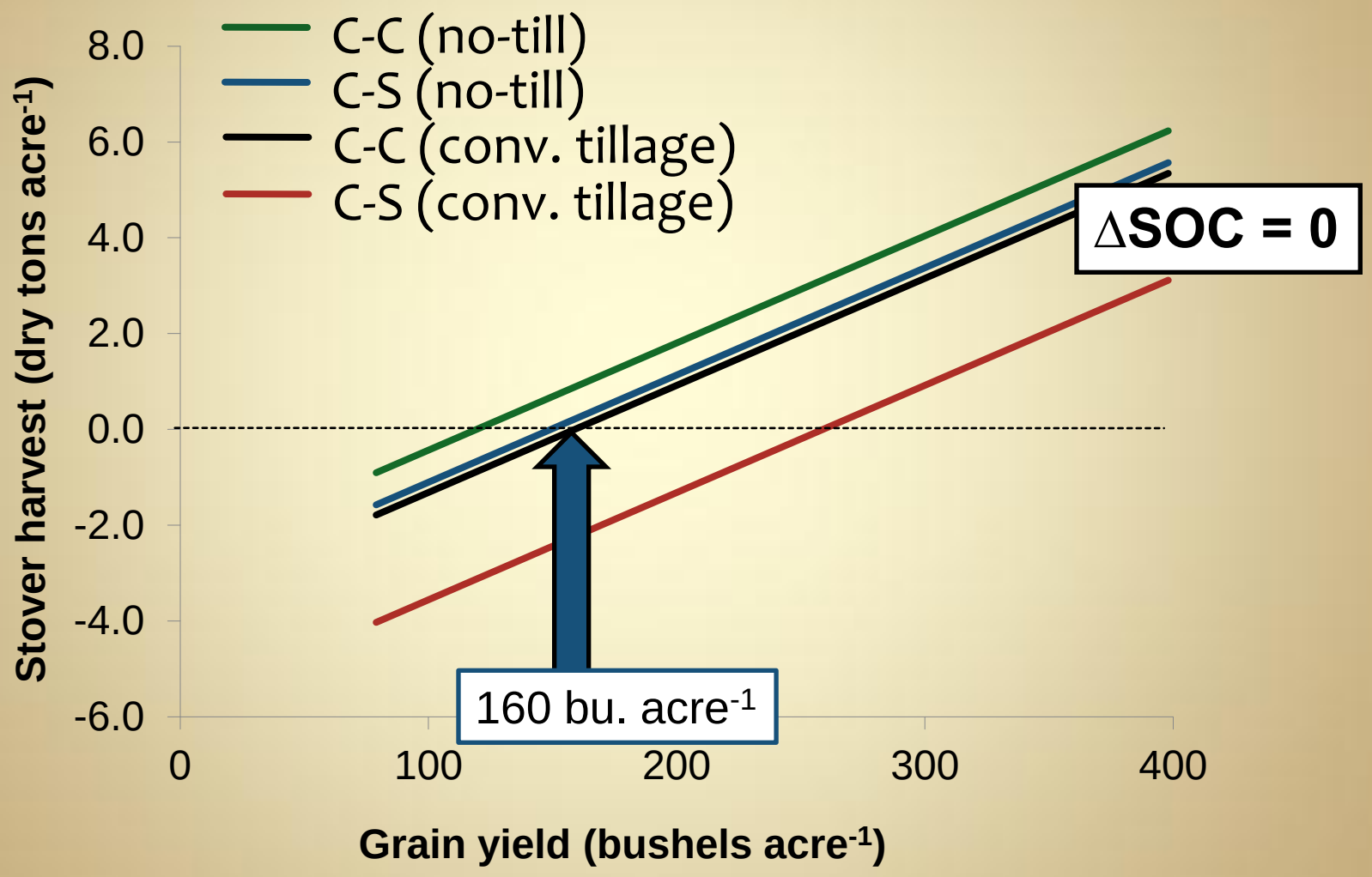
[image: http://talk.newagtalk.com/forums/get-attachment.asp?action=view&attachmentid=27418]

Residue removal can deplete soil organic carbon

	Change in SOC after 13 years, 0-12 inch depth	
Treatment	tons acre^{-1}	as % of original
Stover harvested	-6.2	-13.6%
Stover returned	+3.2	+7.1%

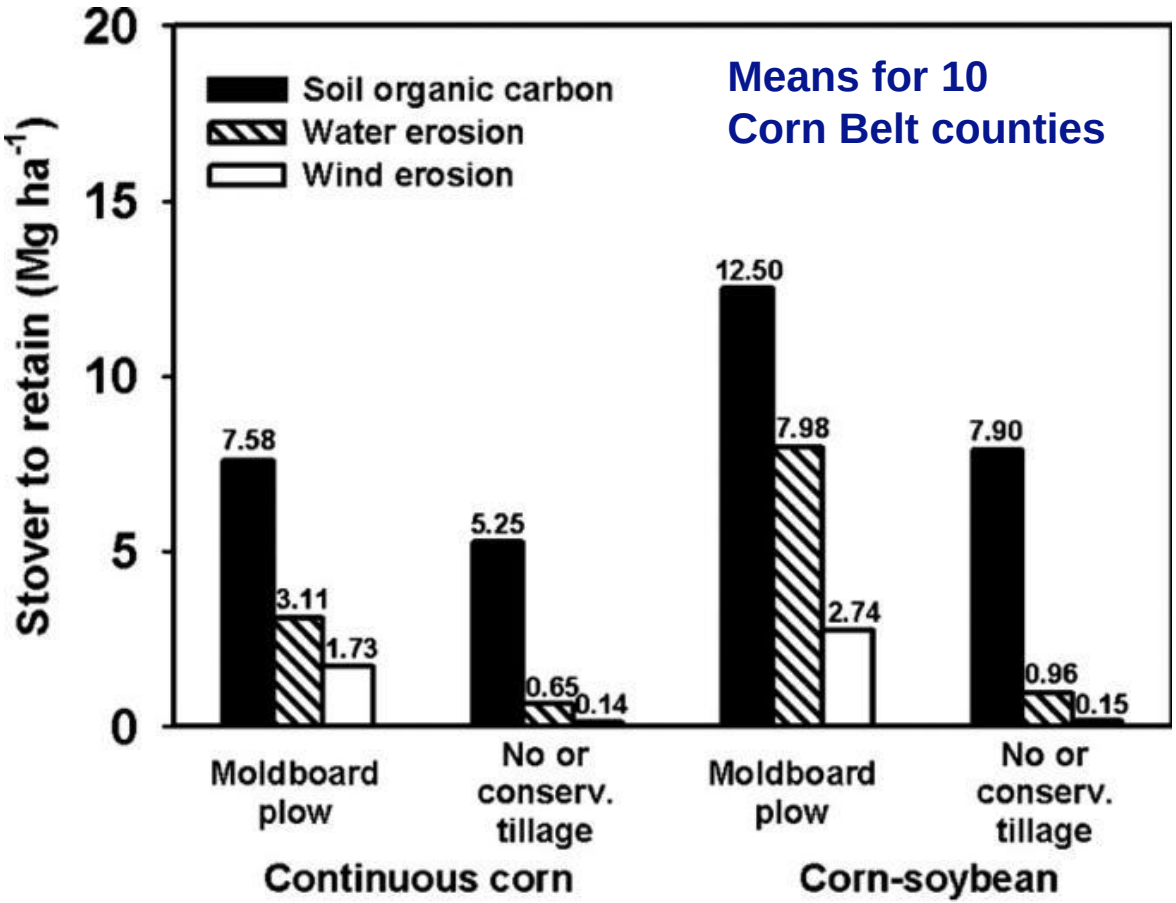
No-till, continuous corn fertilized with 180 lb N acre^{-1} yr^{-1}, Waukegan silt loam, Rosemount, MN. Source: Clapp et al. (2000)

Sustainable stover harvest



Source: Wilhelm et al. (2007)

The amount of residue necessary to maintain soil carbon is considerably greater than the amount needed to prevent erosion.



Wilhelm et al. 2007. Corn stover to sustain soil organic carbon further constrains biomass supply. Agron. J. 99: 1665-1667.

Table 6.3 Estimate of U.S. Cellulosic Biomass by 2020 (NAS, 2009)

Feedstock	Millions of dry tons
Corn stover	112
Wheat and grass straw	18
Hay	18
Dedicated energy crops	164
Woody	124
Animal manure	12
MSW	100
Total	**548**

What benefits might perennial species offer?

- Build and conserve soil
- Capture and store carbon
- Hold and recycle nutrients
- Retain and filter water
- Provide wildlife habitat
- Assist in regulating certain pests

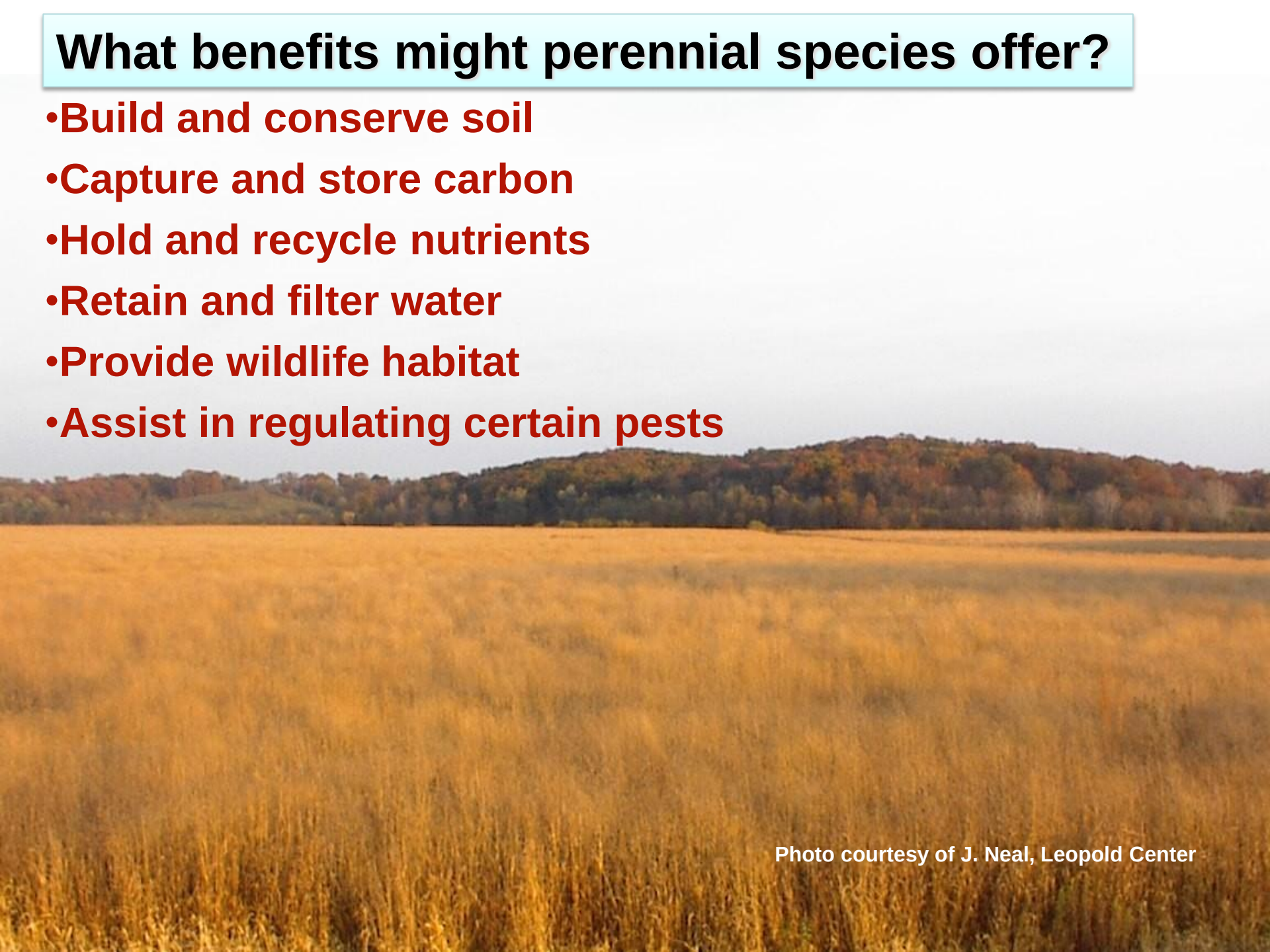
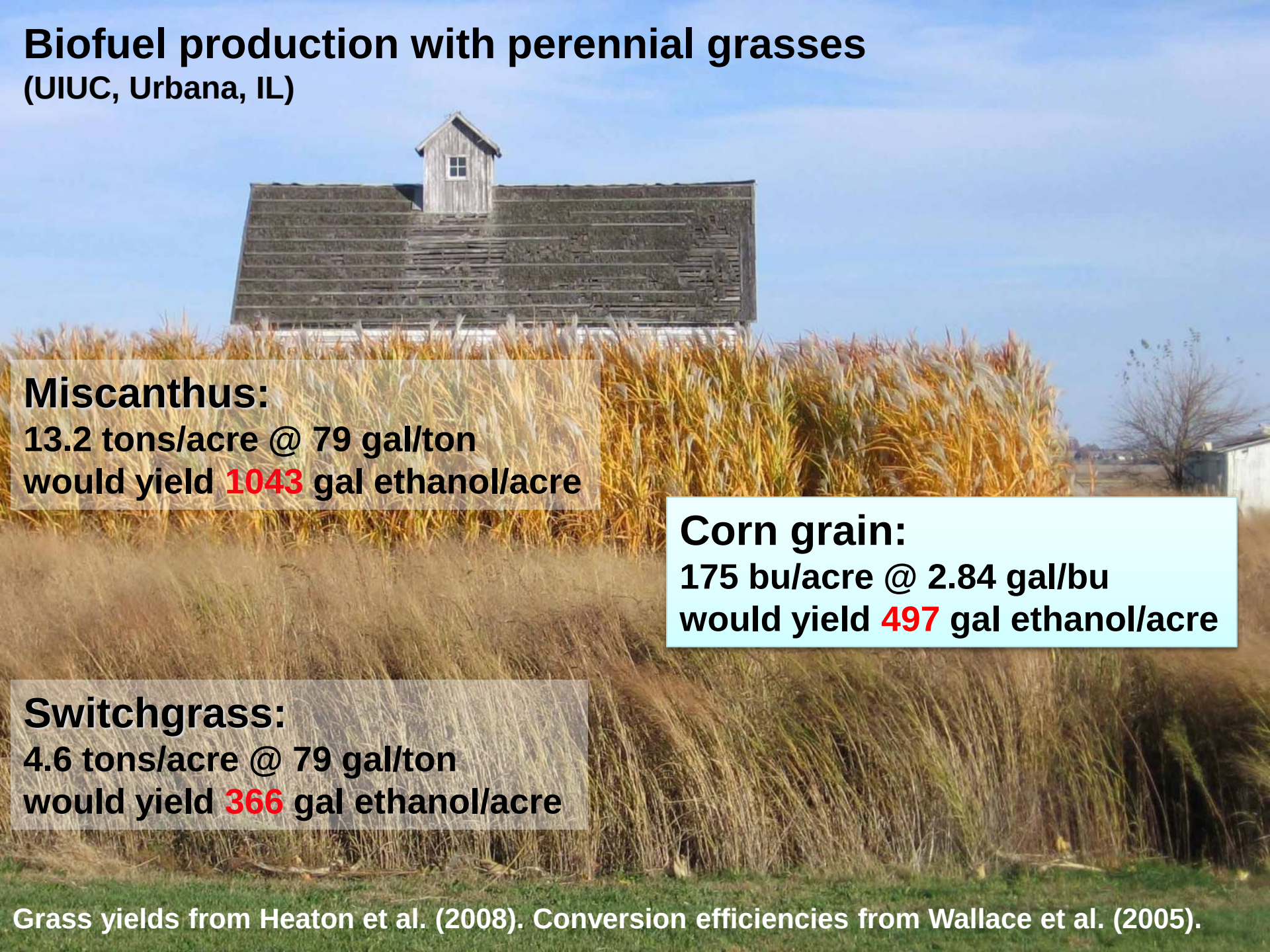


Photo courtesy of J. Neal, Leopold Center

Biofuel production with perennial grasses
(UIUC, Urbana, IL)



Miscanthus:
13.2 tons/acre @ 79 gal/ton
would yield 1043 gal ethanol/acre

Corn grain:
175 bu/acre @ 2.84 gal/bu
would yield 497 gal ethanol/acre

Switchgrass:
4.6 tons/acre @ 79 gal/ton
would yield 366 gal ethanol/acre

Grass yields from Heaton et al. (2008). Conversion efficiencies from Wallace et al. (2005).

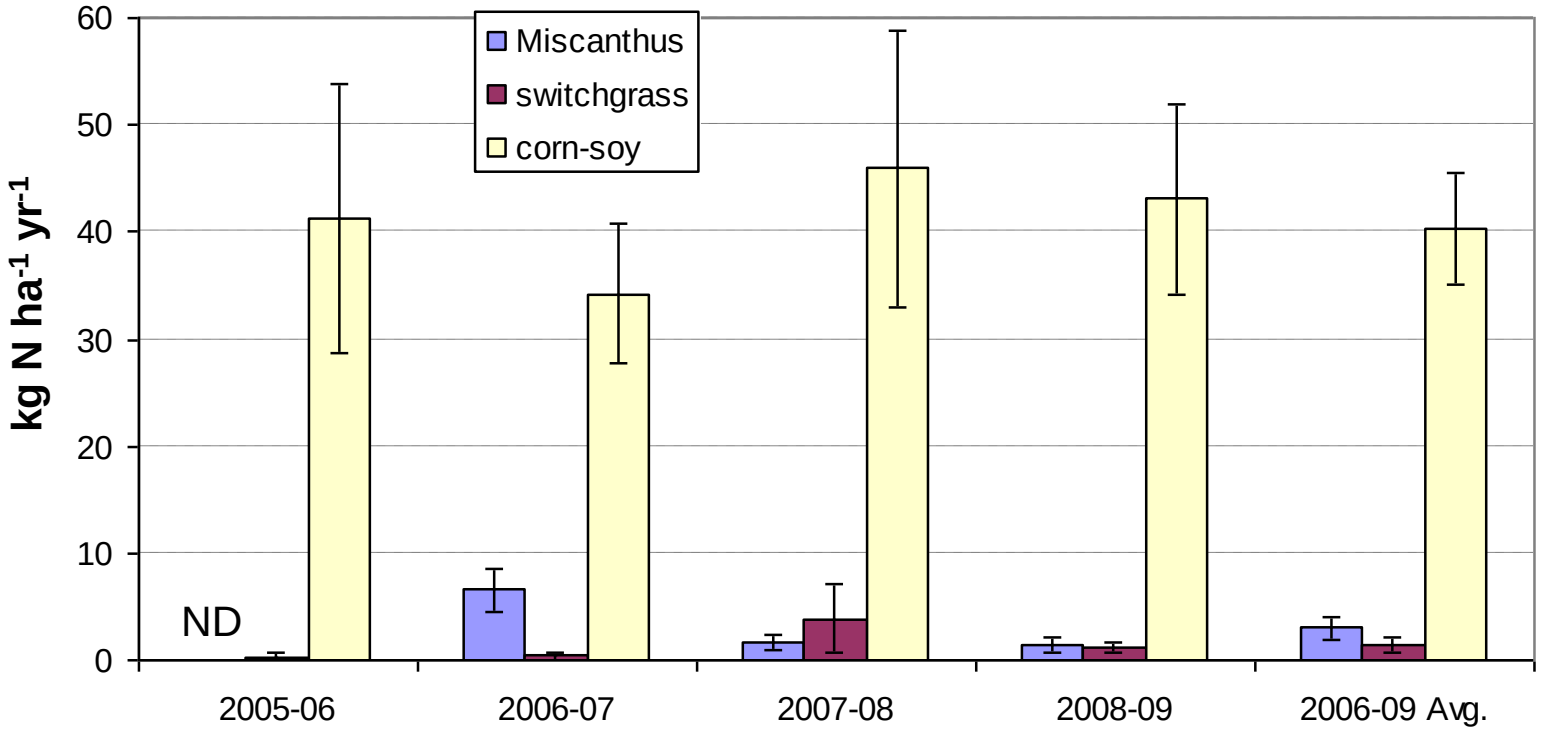
Root growth of perennial species can greatly exceed that of corn and soybean

Source: Tufekcioglu et al. (2003); data from Story Co., IA

Crop	Root biomass Mg/ha to 125 cm depth
Corn	3.4
Soybean	2.4
Switchgrass	16.8

Nitrate-N Leaching Below 50 cm

(Source: McIsaac et al. 2010)

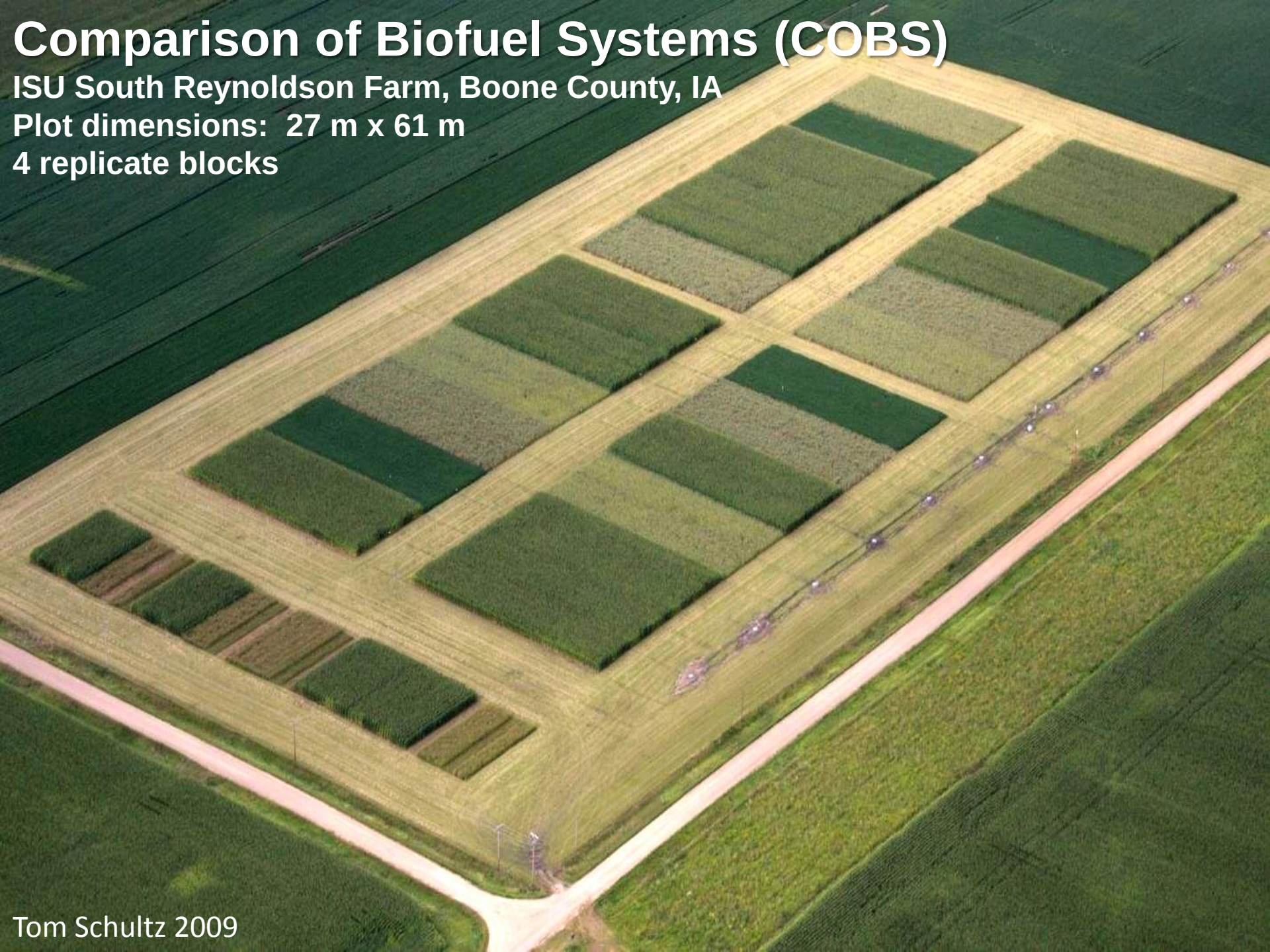


ND = no data for Miscanthus in 2005

Biofuel production with perennial crops can involve trade-offs, and requires us to consider multiple performance indicators.

Comparison of Biofuel Systems (COBS)

ISU South Reynoldson Farm, Boone County, IA
Plot dimensions: 27 m x 61 m
4 replicate blocks



Tom Schultz 2009

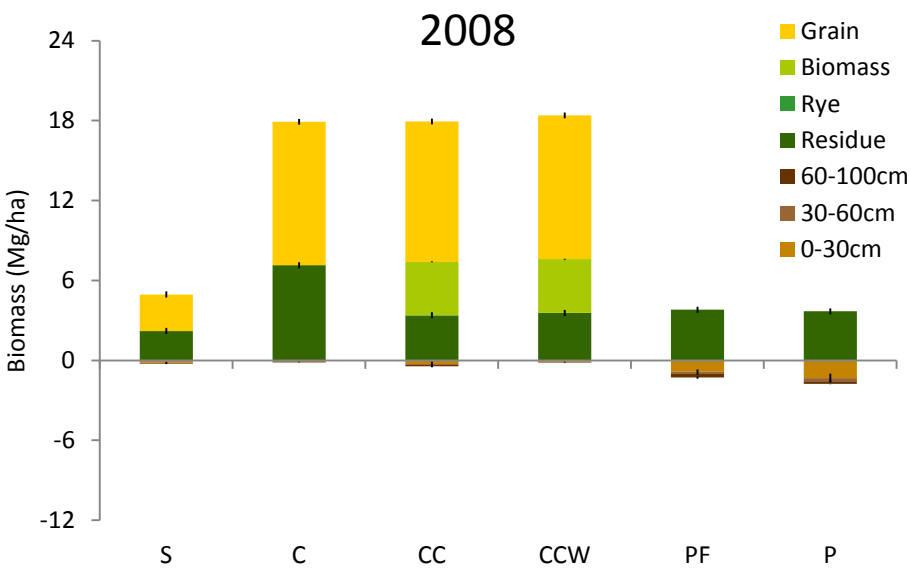
Five cropping systems (no tillage):

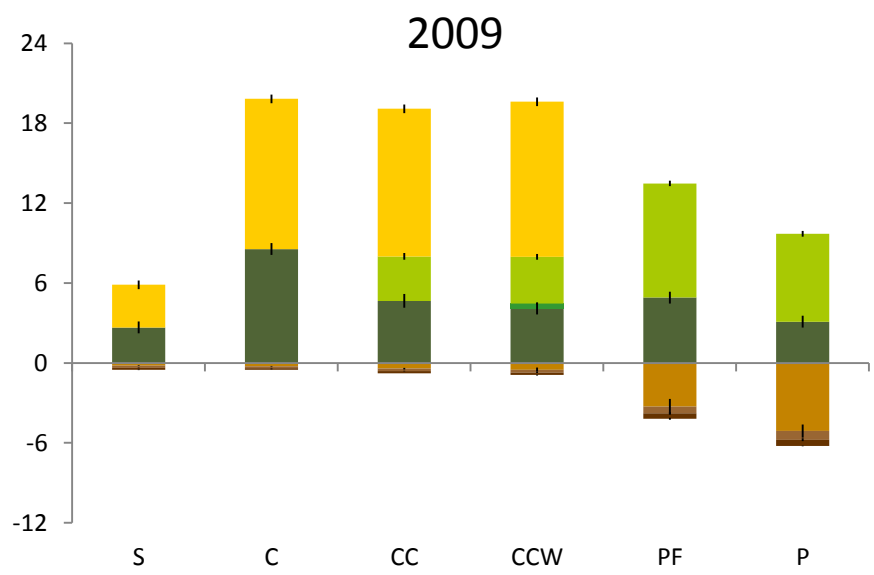
- Corn-soybean rotation (grain harvested)
- Continuous corn (grain + stover harvested)
- Continuous corn + rye cover crop (grain + stover harvested)
- Multi-species reconstructed prairie
- Nitrogen fertilized multi-species reconstructed prairie

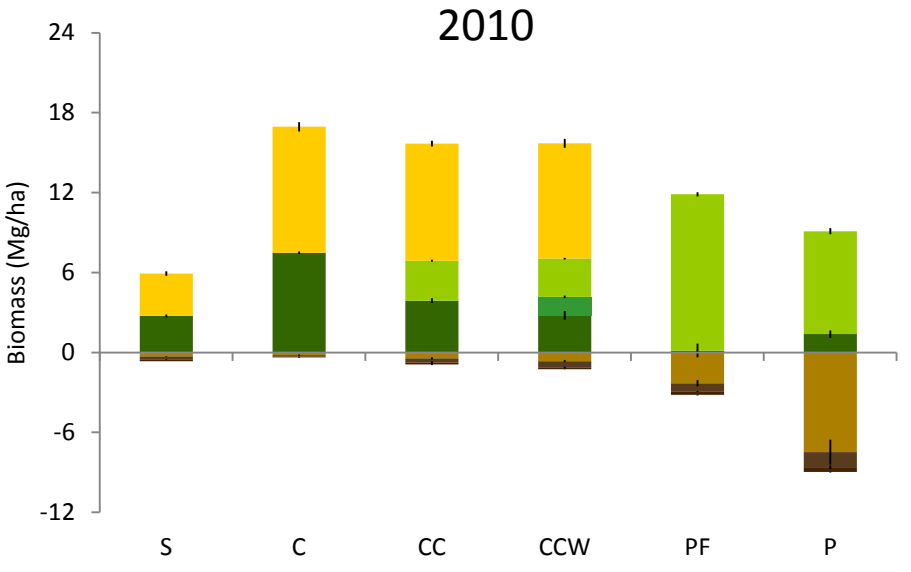
Photo credit: M. Tomka,2011

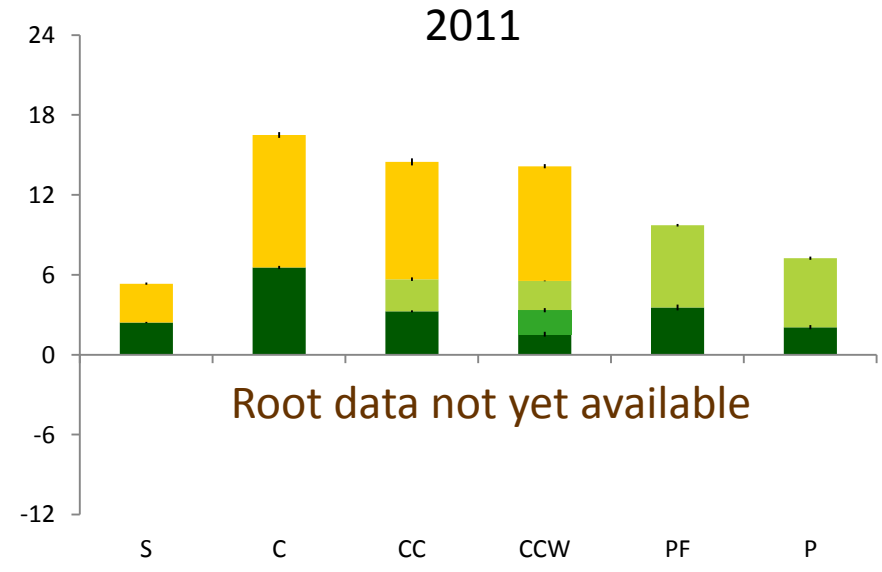
Instruments for monitoring drainage water quantity and quality

Total biomass









Multiple Performance Criteria

- Fossil fuel replacement
- Greenhouse gas emissions
- Water quality
- Energy return on investment
- Soil carbon storage
- Biodiversity
- Revenue from a marketable crop

Corn

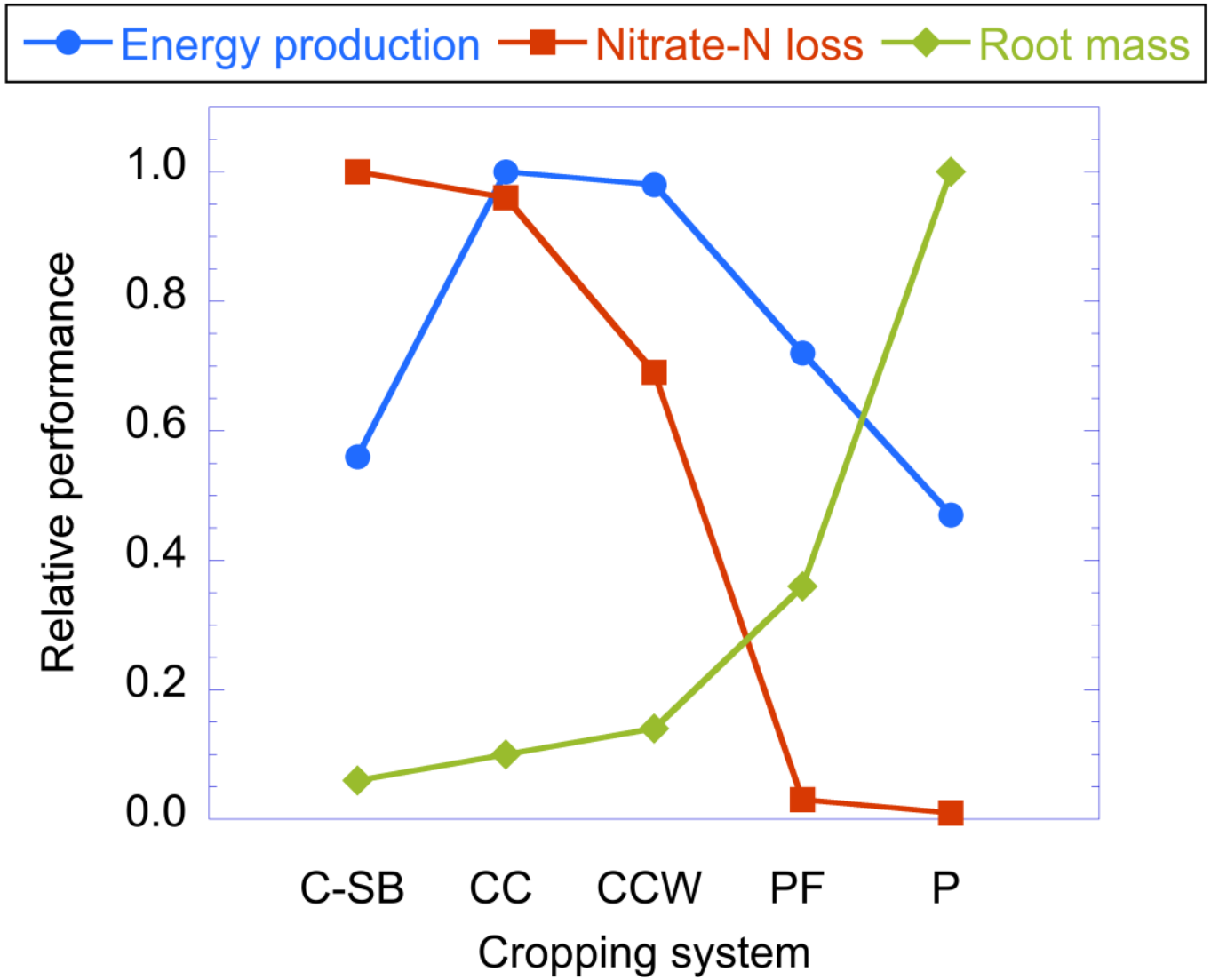
Reconstructed prairie

Three performance indicators, 2010

Cropping system	Liquid fuel production (GJ/ha)	Root mass to 1 m depth (Mg/ha)	Nitrate-N lost in tile drainage (kg NO_3-N/ha)
Corn–soybean (grain)	49.6	0.51	33.3
Corn–corn (grain + stover)	88.8	0.91	32.1
Corn–corn with cover crop (grain + stover)	87.0	1.25	22.8
Prairie + fertilizer	63.5	3.19	1.0
Prairie	41.8	8.98	0.3

(Data courtesy of M. Jarchow, R. Dietzel, M. Helmers)

Trade-offs: perennials have shortcomings as well as advantages

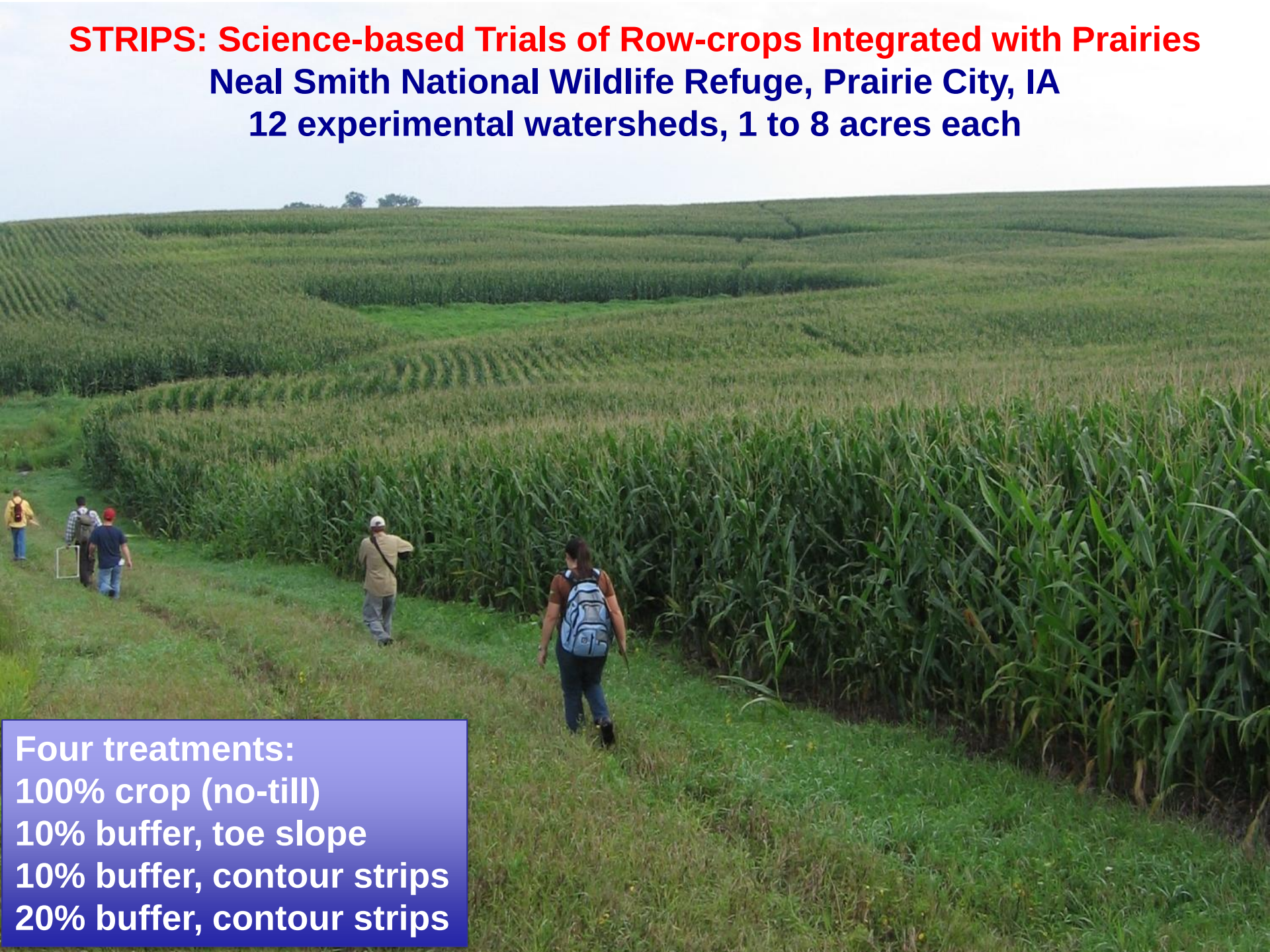


Strategic placement of perennial vegetation into row-crop systems can provide conservation benefits that are disproportionately greater than the land area occupied.

STRIPS: Science-based Trials of Row-crops Integrated with Prairies

Neal Smith National Wildlife Refuge, Prairie City, IA

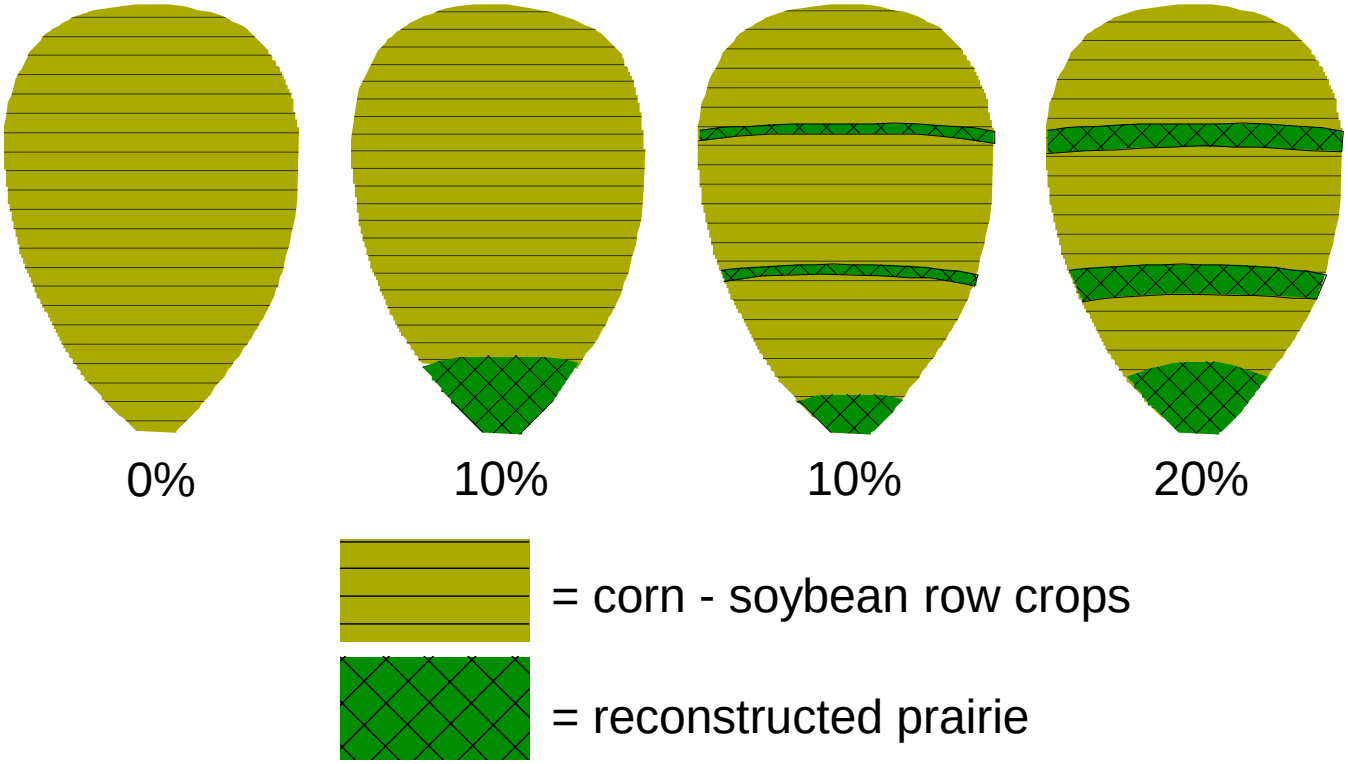
12 experimental watersheds, 1 to 8 acres each



Four treatments:
100% crop (no-till)
10% buffer, toe slope
10% buffer, contour strips
20% buffer, contour strips

Experimental Watershed Treatments

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



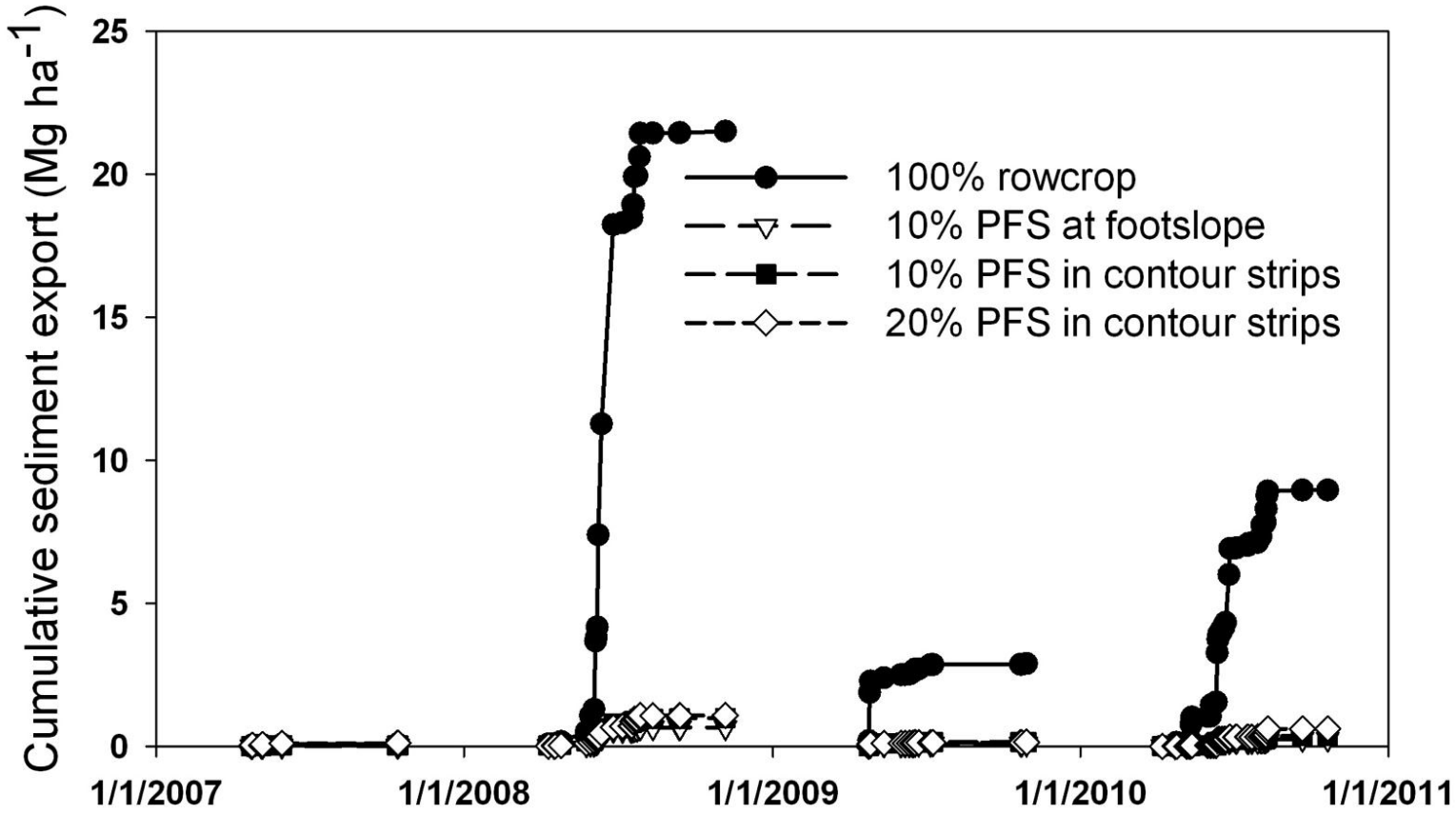
Prairie filter strips in soybean, 2009

Prairie filter strip in corn, 2010

H-flumes monitor movement of water, sediment, and nutrients

Sediment Loss in 2007-2010

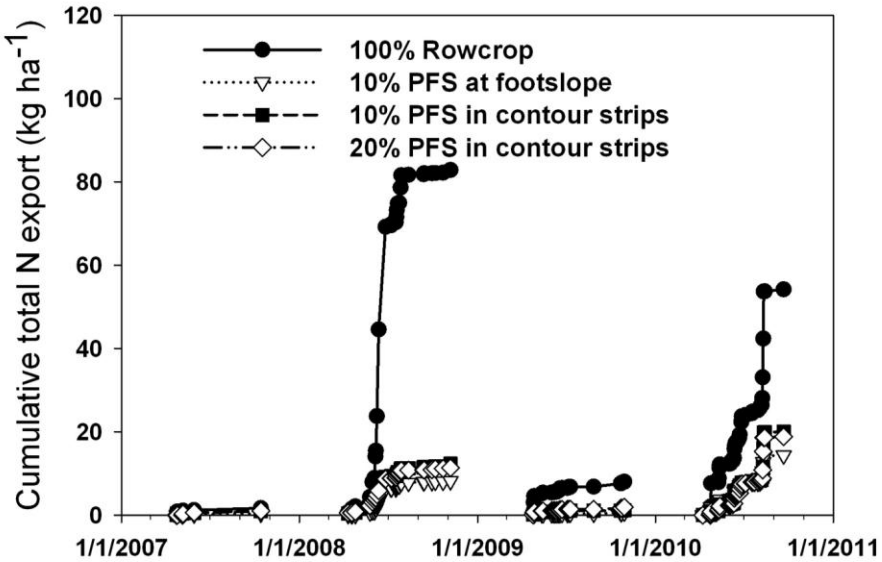
Placing 10% of a watershed into perennial cover strongly reduced soil erosion (>95%), even with no-till crop production. PFS = prairie filter strip.

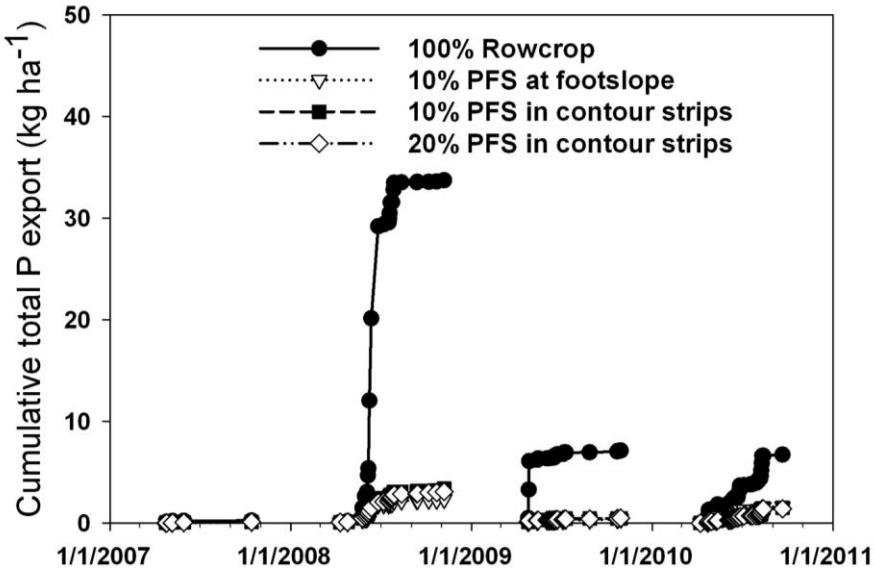


Helmers et al., in review

N and P Losses in 2007-2010

Large reductions in sediment loss were accompanied by large reductions in N and P losses. PFS = prairie filter strip.





Helmers et al., unpublished data

Balancing food, biofuel, and conservation

photo credit: J. Sellers

Two scenarios for 1000 acres

- ***(1) Food, feed and fuel:*** 500 acres of corn, 500 acres of soybean, 25% of each crop used to produce ethanol or biodiesel
- ***(2) Food, feed, fuel and conservation:*** 450 acres of corn and 450 acres of soybean used for food and feed, plus 100 acres of perennial grass targeted to sensitive locations and used for cellulosic ethanol
- Assume 170 bu/acre corn, 50 bu/acre soybean, 4 tons/acre grass

Products and Services from 1000 Acres

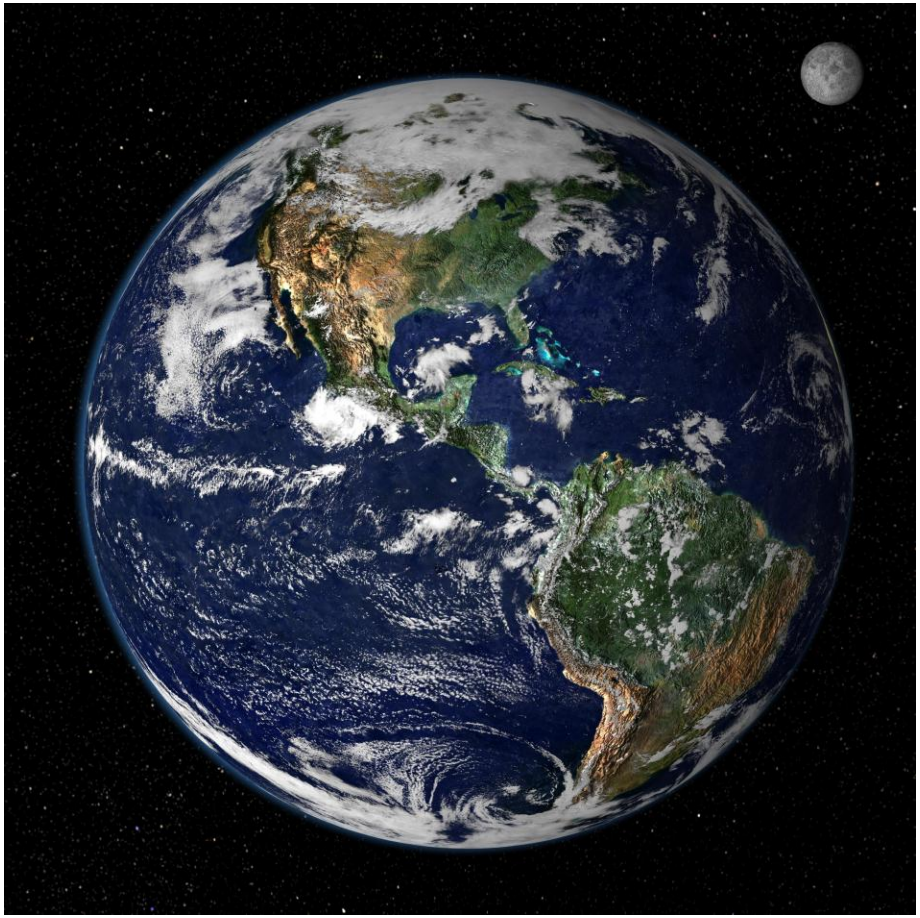
	Food, feed, fuel	Food, feed, fuel, conservation
Corn (tons)	1785	2142
Soybean (tons)	563	675
Energy (barrels of oil equivalent)	984	417
Soil, water, and wildlife conservation	?	+++

Summary

Agriculture faces increasing demands for food, feed, and fuel production, as well as environmental protection. Constraints due to resource depletion and waste assimilation are now part of the picture.

Climate change is likely to make meeting these multiple demands with existing cropping systems more difficult.

The targeted use of perennial species as biofuel feedstocks at particular locations within agroecosystems could provide important services, including soil, water, and nature conservation, while complementing food and feed production.



From an 'empty world' to a 'full world' -- Daly and Farley (2004)