Connections Between Midwest Agriculture, Bioenergy, and Water Quality

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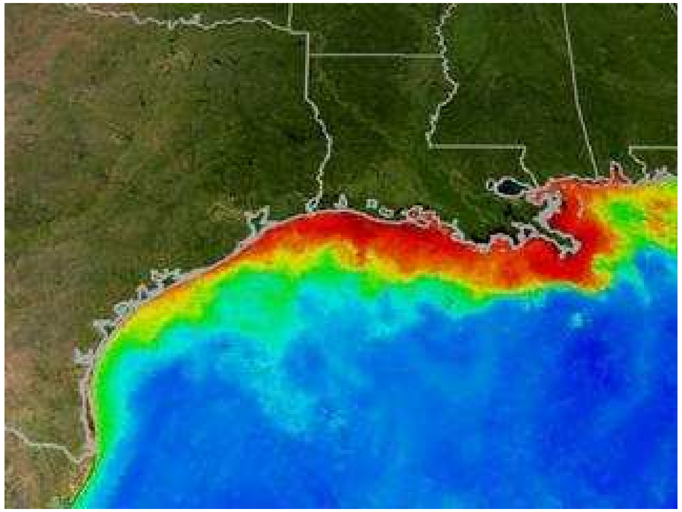


Great Lakes Bioenergy Research Center

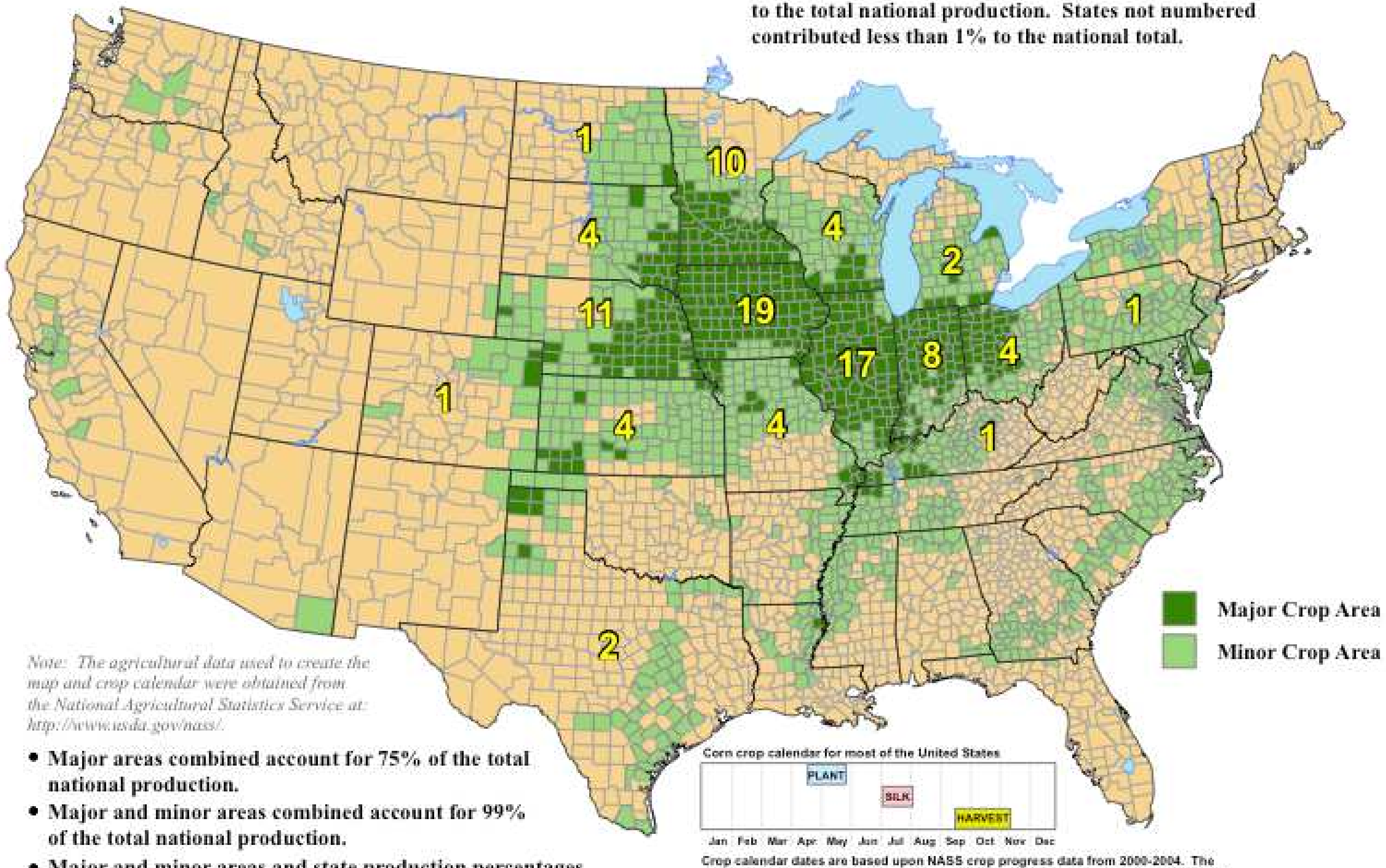
sage

COLLEGE OF AGRICULTURAL & LIFE SCIENCES
University of Wisconsin-Madison

THE NELSON INSTITUTE FOR ENVIRONMENTAL STUDIES
University of Wisconsin-Madison
Where Environmental Leadership Begins

United States: Corn

Yellow numbers indicate the percent each state contributed to the total national production. States not numbered contributed less than 1% to the national total.



Note: The agricultural data used to create the map and crop calendar were obtained from the National Agricultural Statistics Service at: http://www.usda.gov/nass/.

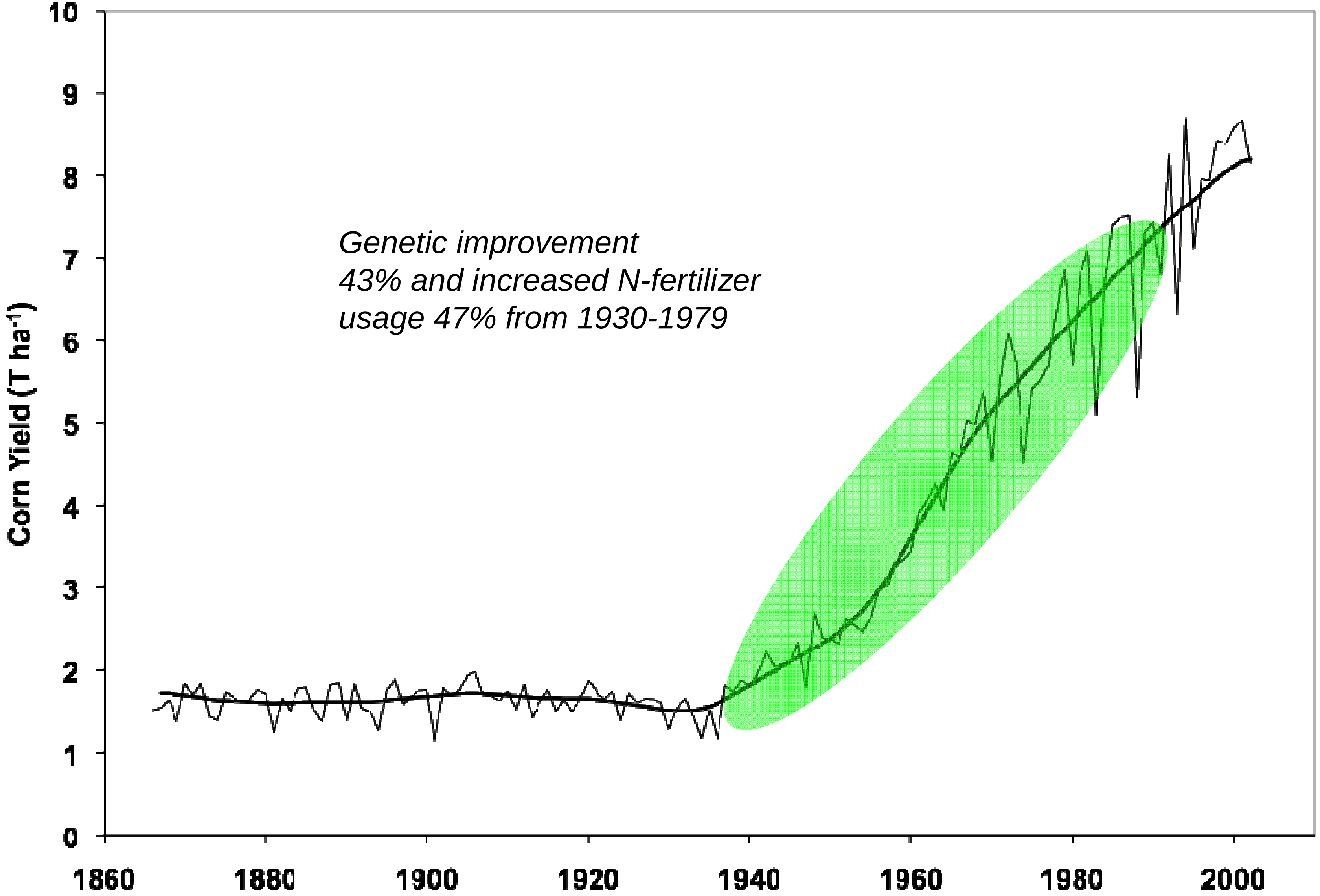
- **Major areas combined account for 75% of the total national production.**
- **Major and minor areas combined account for 99% of the total national production.**
- **Major and minor areas and state production percentages are based upon averaged NASS county-level and state production data from 2000-2004.**

Corn crop calendar for most of the United States

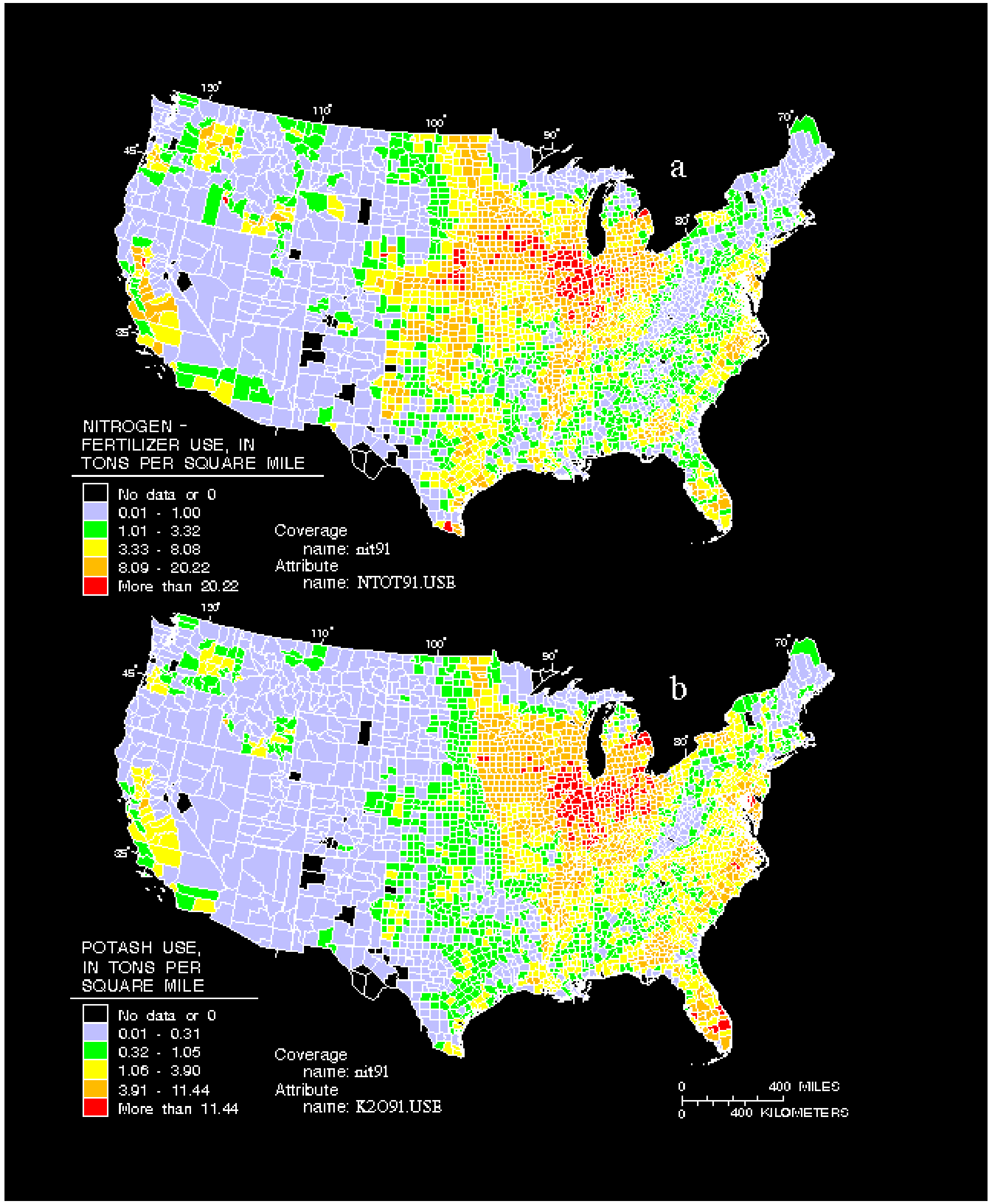
Crop calendar dates are based upon NASS crop progress data from 2000-2004. The field activities and crop development stages illustrated in the crop calendar represent the average time period when national progress advanced from 10 to 90 percent.

USDA World Agricultural Outlook Board
Joint Agricultural Weather Facility

USA Corn Yield Trends



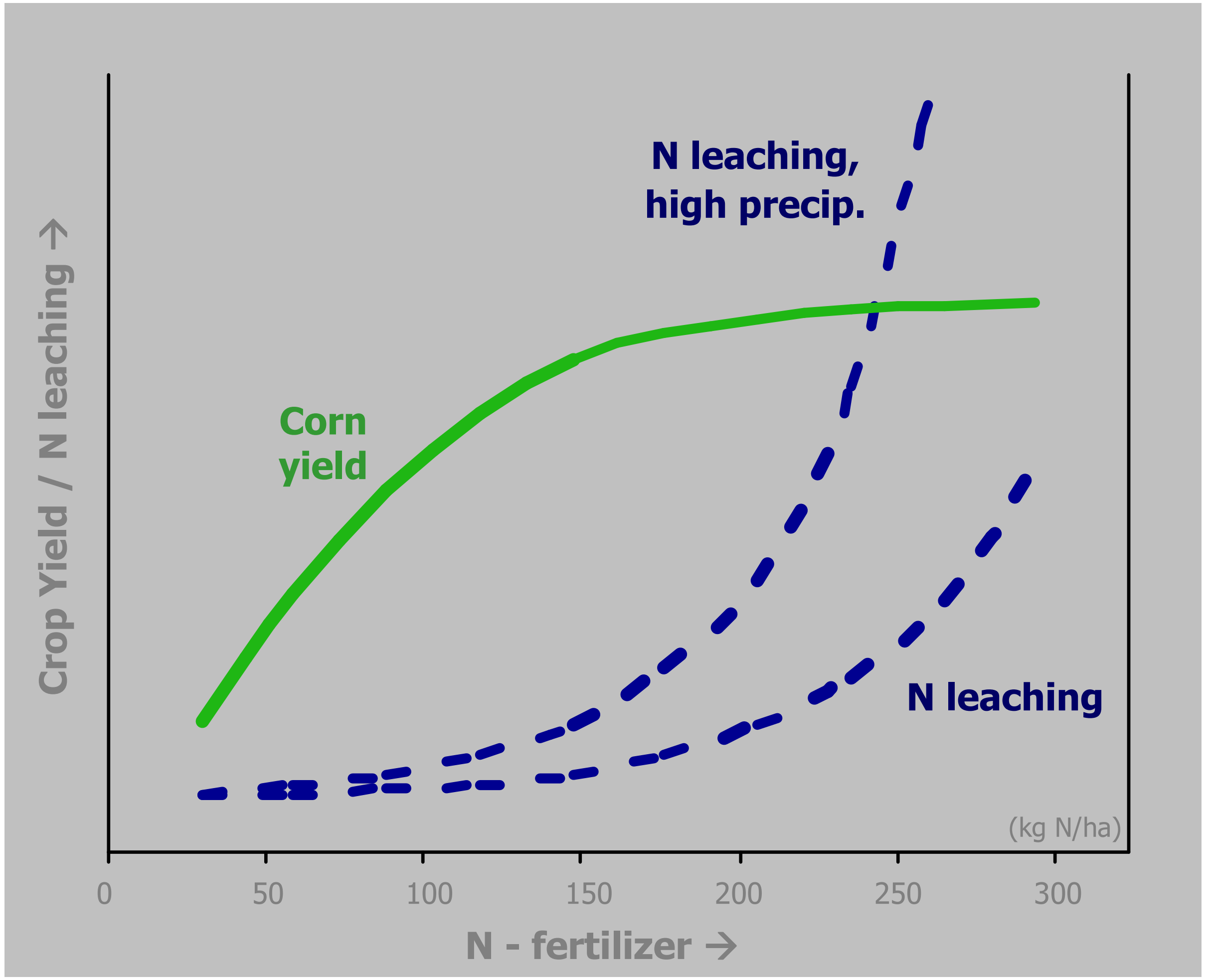
Kucharik, in prep



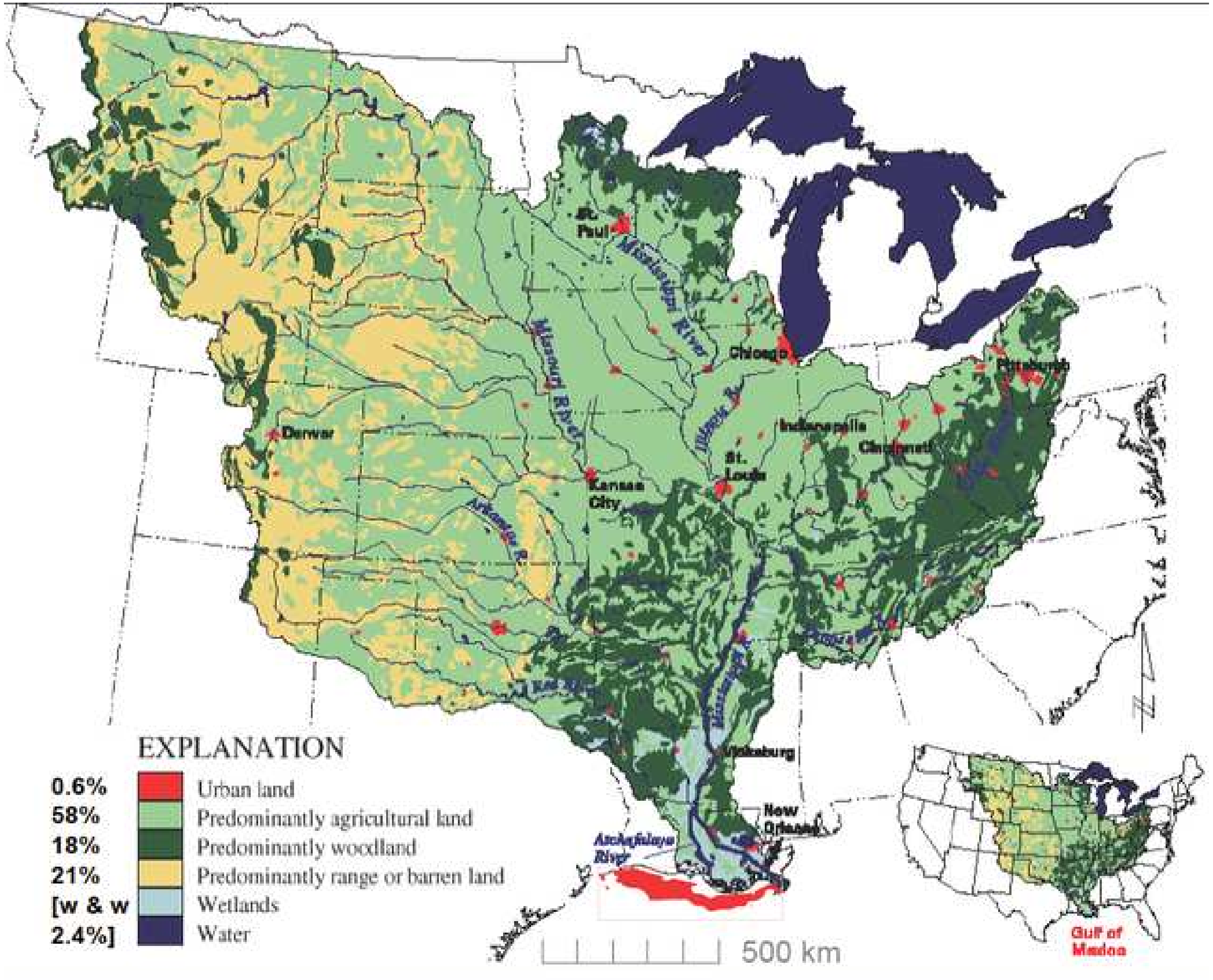
Nitrogen Applications In the "Fertilizer Belt"

Source: *William A. Battaglin and Donald A. Goolsby & USGS*

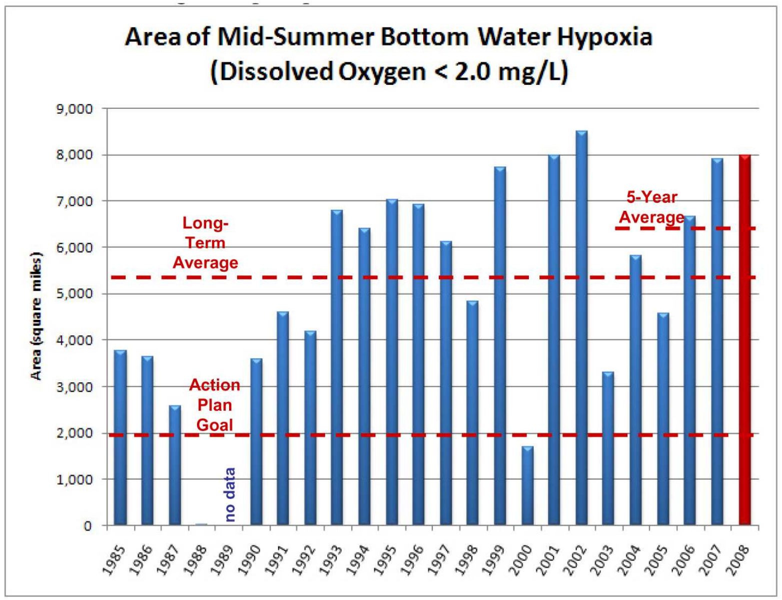
Thresholds on land



Connections between land-use and Gulf of Mexico Hypoxia

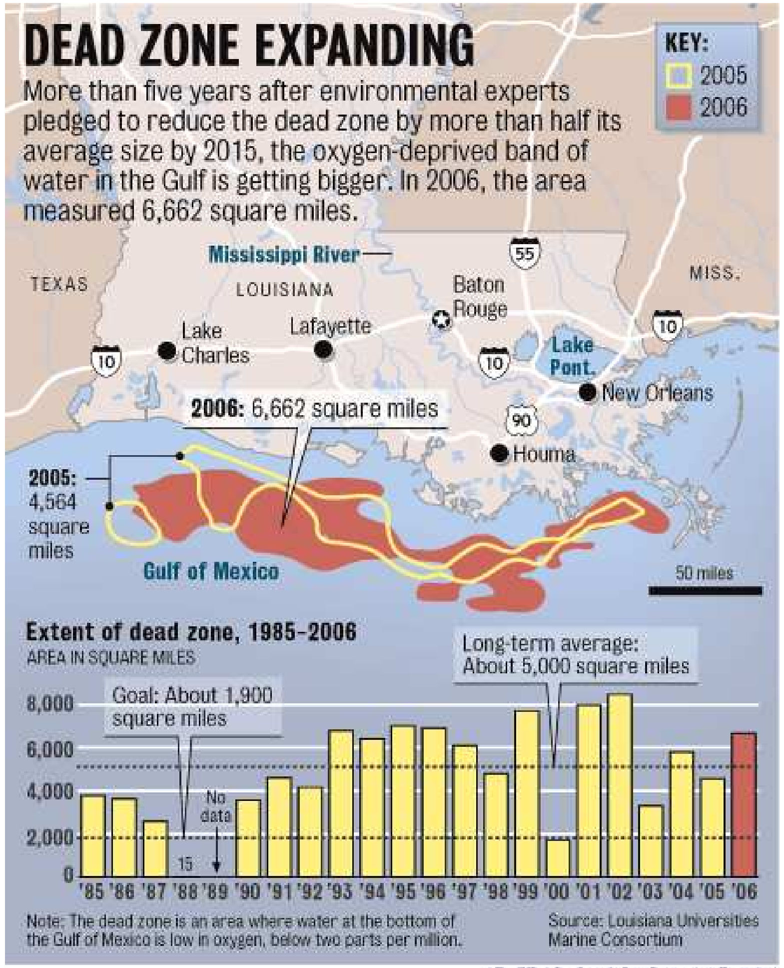


Case study: Corn Ethanol and Water Quality



Source: N. Rabalais, LUMCON

The average size of the Dead Zone over the past 5 years has been 6,600 square miles, much larger than the interagency Gulf of Mexico/Mississippi River Watershed Nutrient Task Force goal of 2,000 square miles. The long-term average is 5,300 square miles.

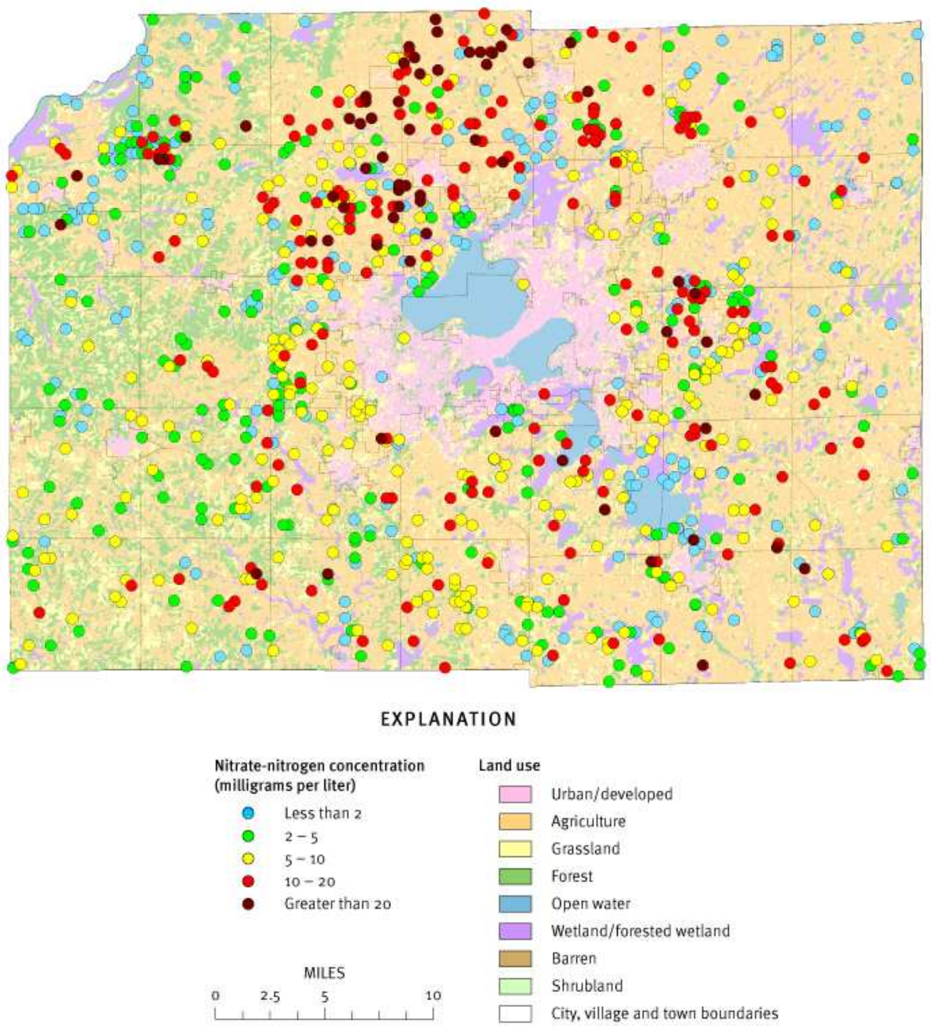


STAFF GRAPHIC BY DAN SWENSON

Local groundwater pollution is also a concern

EPA: NO_3-N > 10 ppm

Dane County – Nitrate-Nitrogen Concentrations

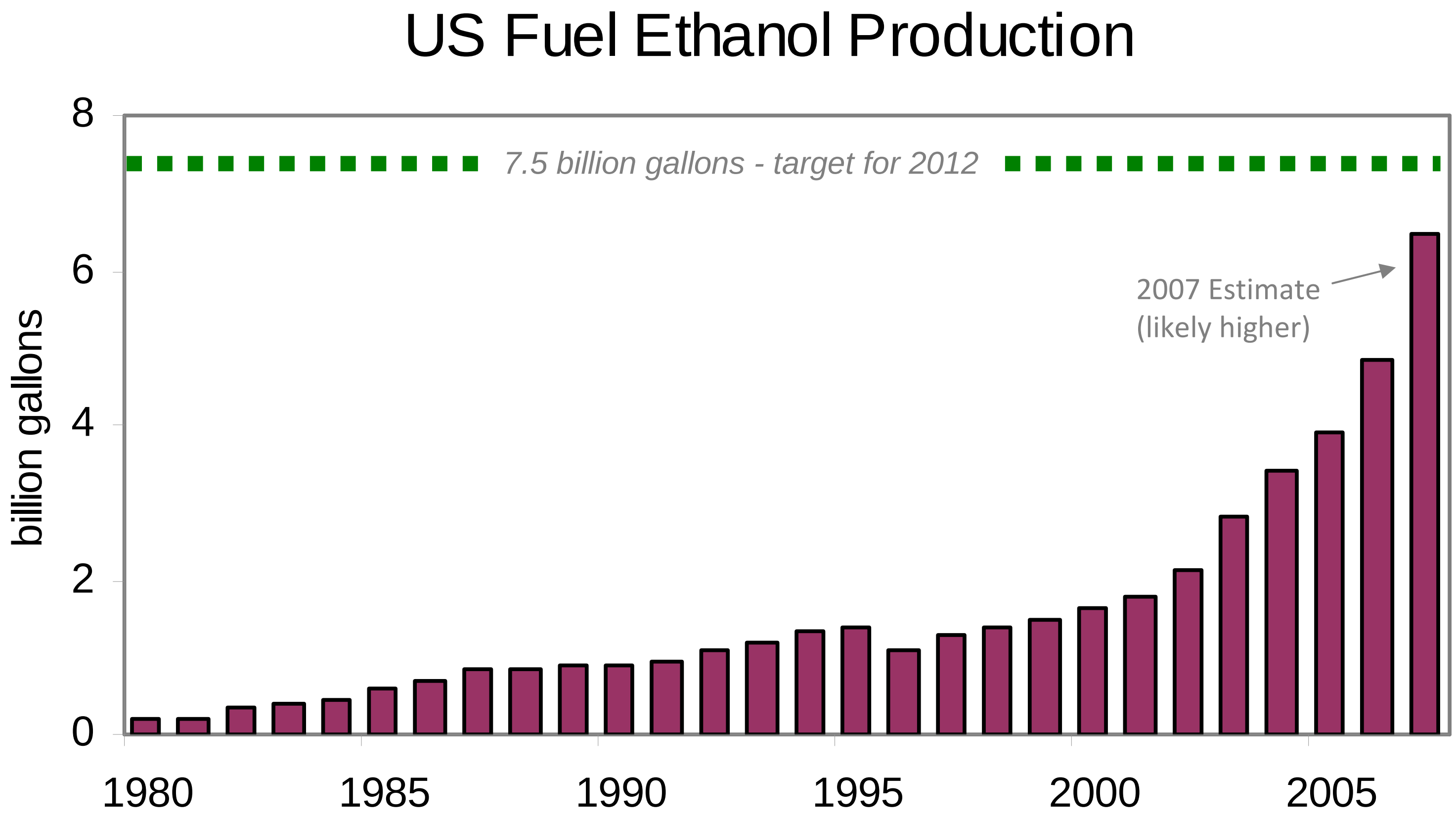


Private well nitrate-nitrogen data presented on this map should not be considered comprehensive. Data are from sampling conducted during 1985-2004 as reported by the Wisconsin Department of Natural Resources, the Wisconsin Department of Agriculture, Trade and Consumer Protection, and the Central Wisconsin Groundwater Center. Data collected at other times or by other sources are not included.

Land cover data: Wisconsin Department of Natural Resources, 1998, WISCLAND land cover (WLCGW930) 1991-1993, available at *http://www.dnr.state.wi.us/maps/gis/datalandcover.html*

Figure created by Raquel Miskowski, University of Wisconsin-Stevens Point, Center for Land Use Education, for the "Protecting Wisconsin's Groundwater Through Comprehensive Planning" web site, 2007, *http://wi.water.usgs.gov/gwcomp/*

There's corn in my tailpipe



The 2007 US Senate Energy Policy calls for 36 billion gallons of renewable fuels by 2022, of which 15 billion gallons can be "non-advanced biofuels"

Renewable Fuels Association

Question

- How will increased reliance on ethanol produced from corn impact water quality and the overall biological health of the Gulf of Mexico?

Effect of increased corn ethanol production on the Gulf

We developed spatially explicit land use scenarios for meeting the Energy Policy Act goals using:

- 2004-2006 county-level crop production and yield data

- predicted corn-to-ethanol conversion rates (2.7 – 3.3 gallon/bushel)

- predicted increases in crop yields (0-1%/year)

- availability of “new” croplands (soybean land, CRP land)

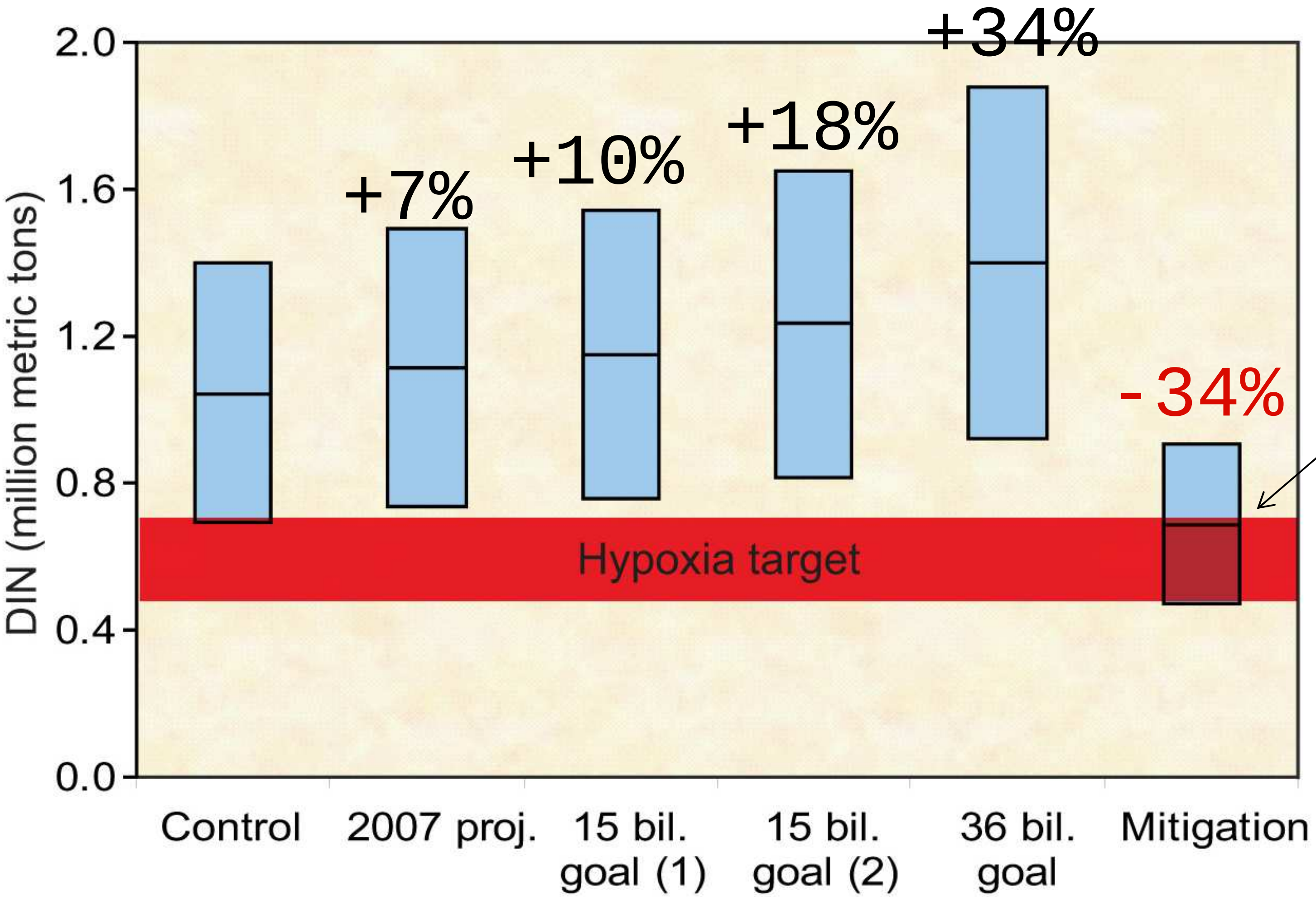
We used these constraints to develop simple “rules” – farmer decisions to convert land to corn production – that would meet the ethanol production goal. The approach was validated using 2007 data.

Donner and Kucharik, PNAS 2008

Land use scenarios

Scenario	Objective	Description
Control	2004-2006 mean crop planting by county	Describes area of corn, soybean, winter wheat and spring wheat in each grid cell for 2004-2006
Projected 2007	State-level projected plantings for 2007	Fraction of land in corn-growing counties that is planted in soybeans is shifted to corn
15 Billion Gallon (1)	Meets the goal for non-advanced biofuels in year 2022	The 2007 land use change plus conversion of some CRP land in corn-growing counties to corn
15 Billion Gallon (2)	Meets the goal for non-advanced biofuels in year 2022	A higher fraction of land planted in soybeans shifted to corn (than in 2007)
36 Billion Gallon	Meets Energy Policy Act goal for all biofuels in year 2022	Aggressive planting of corn on both CRP land and land planted in soybeans in pursuit of 2022 goal
Mitigation	Meets 15 billion gallon goal and achieves N reduction	A 50% reduction in red meat production reduces land required for feed crops; riparian wetlands constructed adjacent to corn and soybean fields

Effect of US Energy Policy on DIN export



50% drop in beef; riparian wetlands; 15 billion goal reached; 70 million acres available for other biofuels

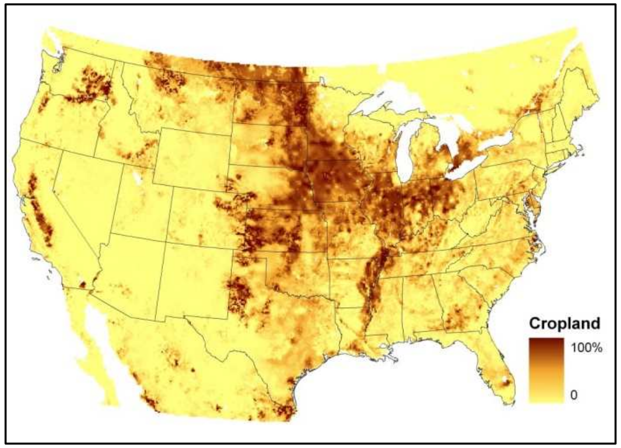
2007 change + CRP land conversion

Greater soy → corn shift

"blowout" scenario

Donner and Kucharik, PNAS 2008

Greenhouse gas implications



Global feed stock

↑ USA biofuel demand → less soybeans grown and/or more domestic corn use (USDA data)

↓

less feed exported overseas (USDA, FAO data)

↓

demand for soybeans from Brazil → ↑ Amazonian deforestation

GHG emissions

Figures courtesy of Paul Lefebvre, WHRC; Navin Ramankutty, McGill

GLBRC

Great Lakes Bioenergy Research Center

U.S. DEPARTMENT OF ENERGY

Improved Bioenergy Sustainability

Develop **economically viable & environmentally responsive ecological, agricultural & life cycle practices (WI & MI Agricultural Stations)**

High Input, Low Diversity (annuals) ◄

Continuous Corn

Corn-Soybean-Canola

Monoculture switchgrass

Switchgrass/ Legumes

Poplars

► **Low Input, High Diversity (perennials)**

Native prairie

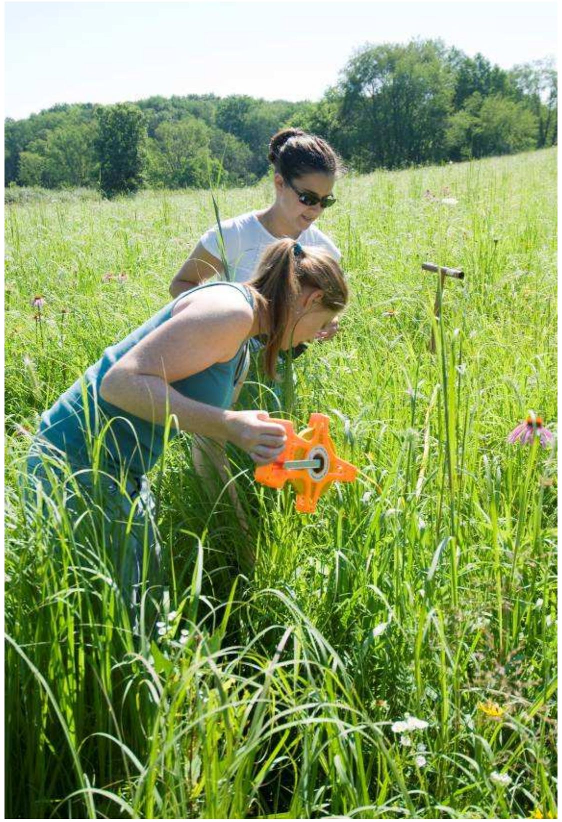
Early successional

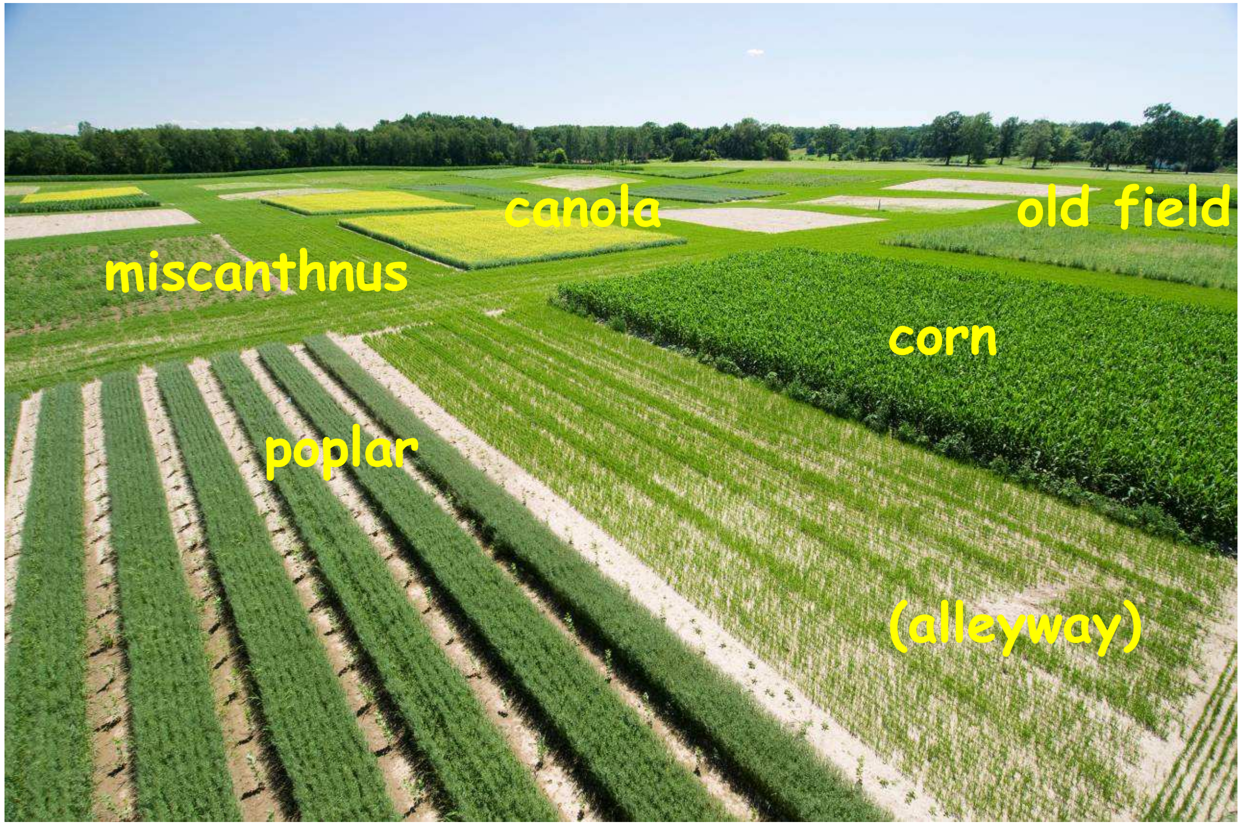
Overcome bottlenecks in agricultural, industrial, & behavioral systems to

- **Improve carbon neutrality** and **greenhouse gas mitigation** across the entire biofuel life cycle at multiple scales
- Improve **ecosystem services** in biofuel landscapes (e.g. **water, soil & air quality, biodiversity, pest suppression, land use**)

www.glbrc.org

GLBRC Field Sites - Arlington, Wisconsin (July 2008)





prairie

switchgrass

Corn Stover as a Biofuel Feedstock?

- **8 million mT in Wisconsin annually produced**
- **Provides structural stability to soil**
  - ***Erosion prevention***
  - ***Nutrient retention***
- **Need to consider impacts to soil organic matter and productivity of cropping systems**
- **Increased residue reduces soil water loss and reduces soil temperatures**

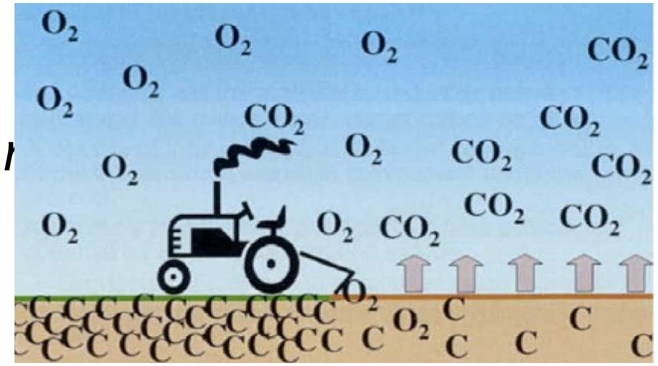
Impacts of crop residue on local climate

- Influences all components of surface energy balance
  - *Increases shortwave albedo*
  - *Lowers thermal conductivity*

- *Increasing residue density leads to*
  - *Decreased soil temperature (7-10ºC)*
  - *Reduced soil evaporation*
  - *Across large scales: climate regulation?*

Land-use change: feedbacks to climate

- *Biogeochemical*
  - *GHG emissions to atmospher*



- *Biogeophysical*
  - *Surface albedo; energy exchange*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Corn-based ethanol production compromises goal of reducing nitrogen export by the Mississippi River

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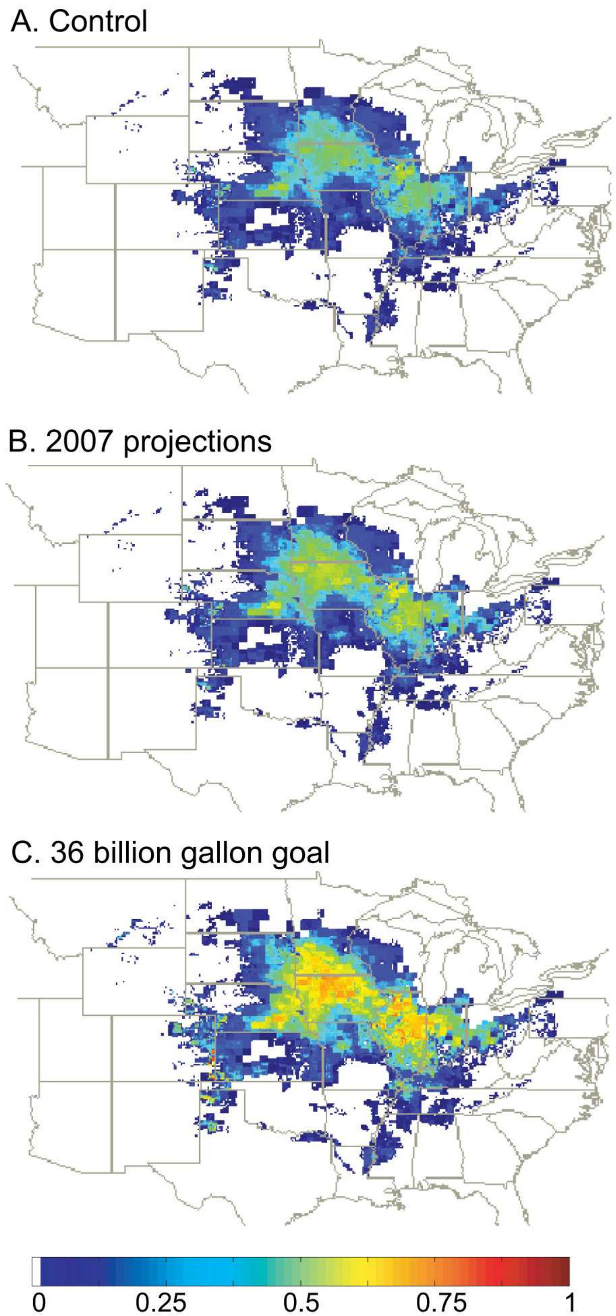
Corn cultivation in the United States is expected to increase to meet demand for ethanol. Nitrogen leaching from fertilized corn fields to the Mississippi–Atchafalaya River system is a primary cause of the bottom-water hypoxia that develops on the continental shelf of the northern Gulf of Mexico each summer. In this study, we combine agricultural land use scenarios with physically based models of terrestrial and aquatic nitrogen to examine the effect of present and future expansion of corn-based ethanol production on nitrogen export by the Mississippi and Atchafalaya Rivers to the Gulf of Mexico. The results show that the increase in corn cultivation required to meet the goal of 15–36 billion gallons of renewable fuels by the year 2022 suggested by a recent U.S. Senate energy policy would increase the annual average flux of dissolved inorganic nitrogen (DIN) export by the Mississippi and Atchafalaya Rivers by 10–34%. Generating 15 billion gallons of corn-based ethanol by the year 2022 will increase the odds that annual DIN export exceeds the target set for reducing hypoxia in the Gulf of Mexico to >95%. Examination of extreme mitigation options shows that expanding corn-based ethanol production would make the already difficult challenges of reducing nitrogen export to the Gulf of Mexico and the extent of hypoxia practically impossible without large shifts in food production and agricultural management.

and water cycling and downstream transport of nitrogen and water across the Mississippi–Atchafalaya River Basin to agricultural land use practices and climate variability (4, 10–16). First, we used USDA data to generate a series of spatially explicit land use scenarios including a control case (based on 2004–2006 mean land use and land cover); a representation of 2007 land management based on the projected plantings from the spring (1); three scenarios designed to meet the ethanol production goals in the recent Energy Bill (3); and an extreme mitigation scenario (Table 1). Second, we used the control scenario to validate the ability of the models to simulate nitrogen cycling across the Mississippi–Atchafalaya River Basin and nitrogen export to the Gulf of Mexico. Third, we evaluated the effect of the alternative land cover scenarios on nitrogen export to the Gulf of Mexico and the goal of reducing the extent of the seasonal hypoxic zone.

Results

The study focuses on the 3.2 million-km^2 Mississippi–Atchafalaya River Basin, where >80% of the total U.S. corn and soybean acreage is cultivated. The smaller Atchafalaya Basin is included in this analysis because the Old Water Control Structure north of New Orleans redistributes the combined flow of the Mississippi River

Proceedings of National Academy of Sciences, 2008



Fractional corn cover for scenarios to meet US goal of 36 billion gal of biofuels by 2022

Donner and Kucharik, 2008 P