

Research Needs and Challenges in the Food, Energy and Water System: Agriculture in the Cornbelt

Presented by **Catherine L. Kling**
Iowa State University



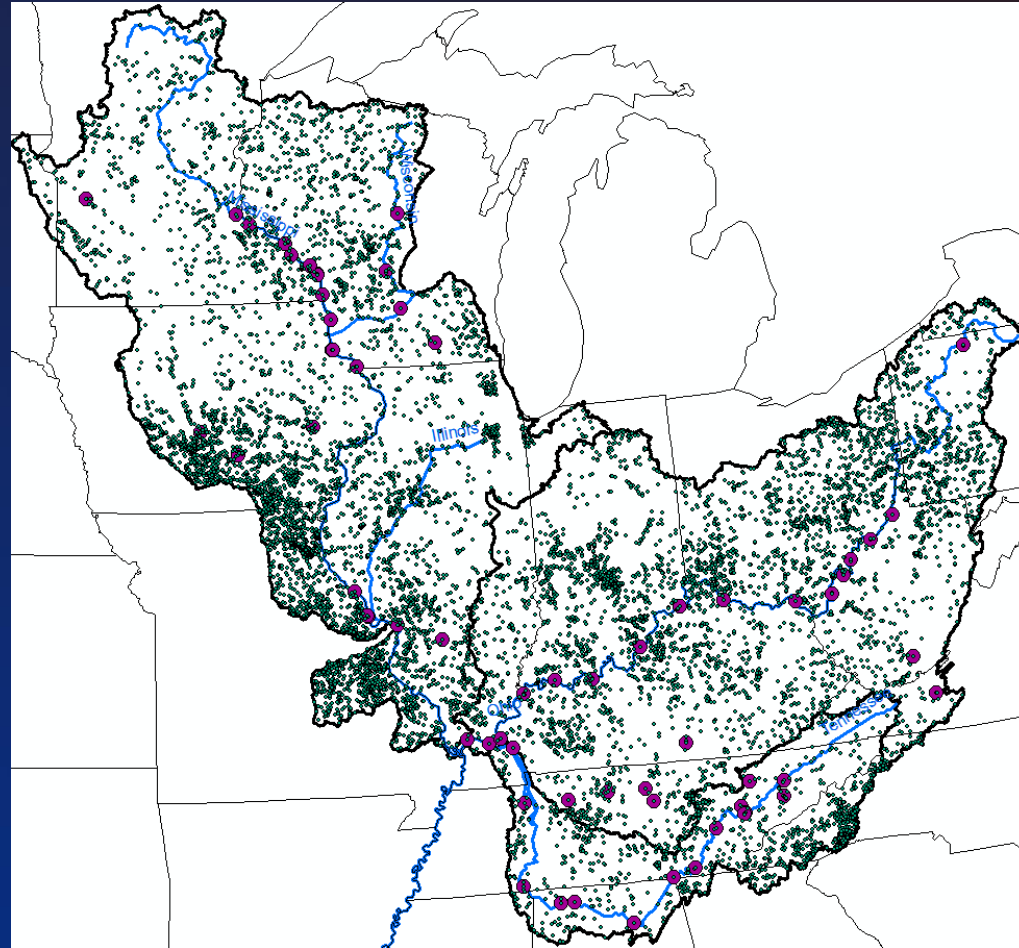
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Water quality problems in the Midwest

- What do we know?
 - Data
 - Model results
- What do we need to know? FEW workshop
- Given what we know, what actions should we be taking?

Built Dams and Reservoirs: More than 10,000 Dams and Reservoirs



Source: Army Corps of Engineers

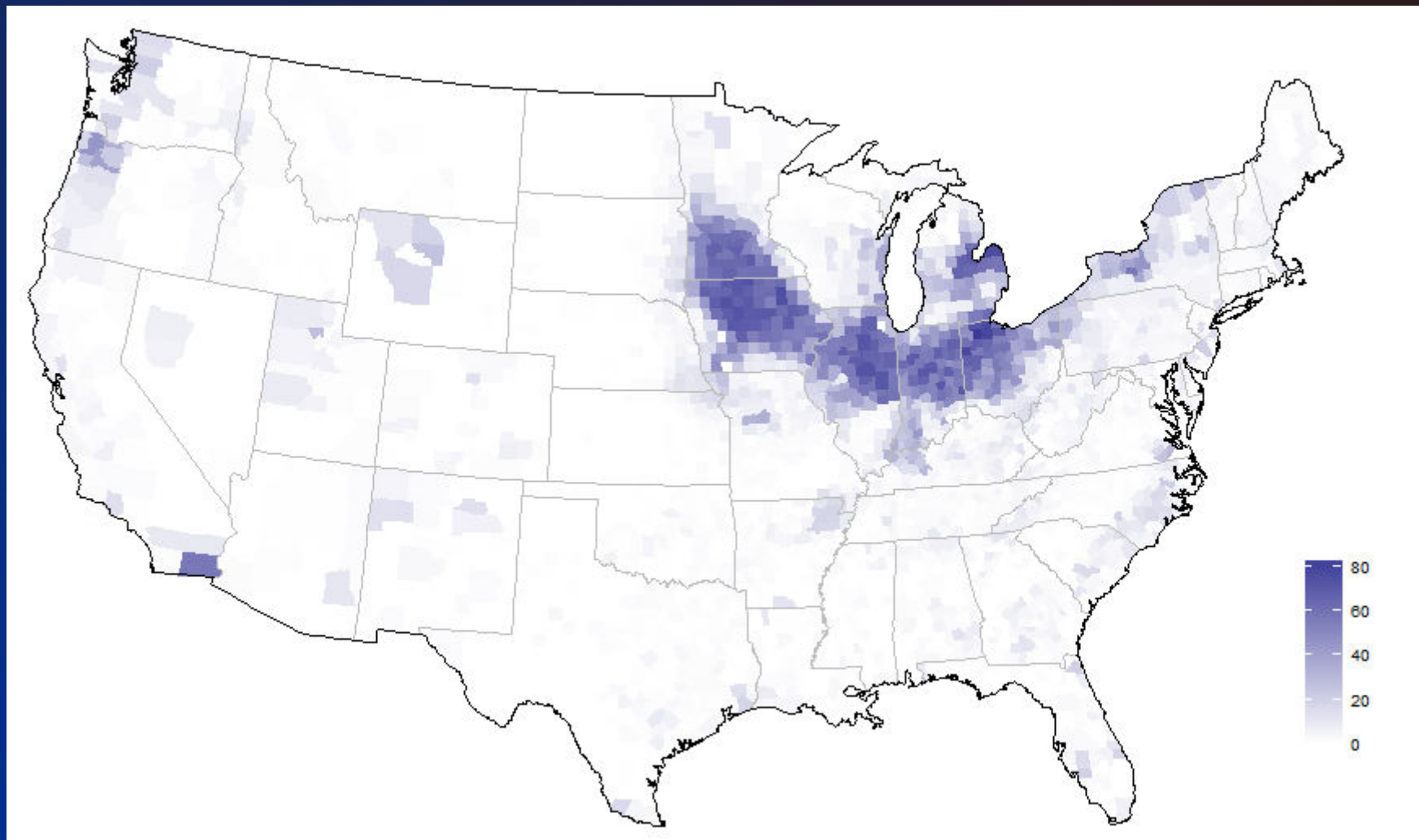


Tile Drains being installed in agricultural land



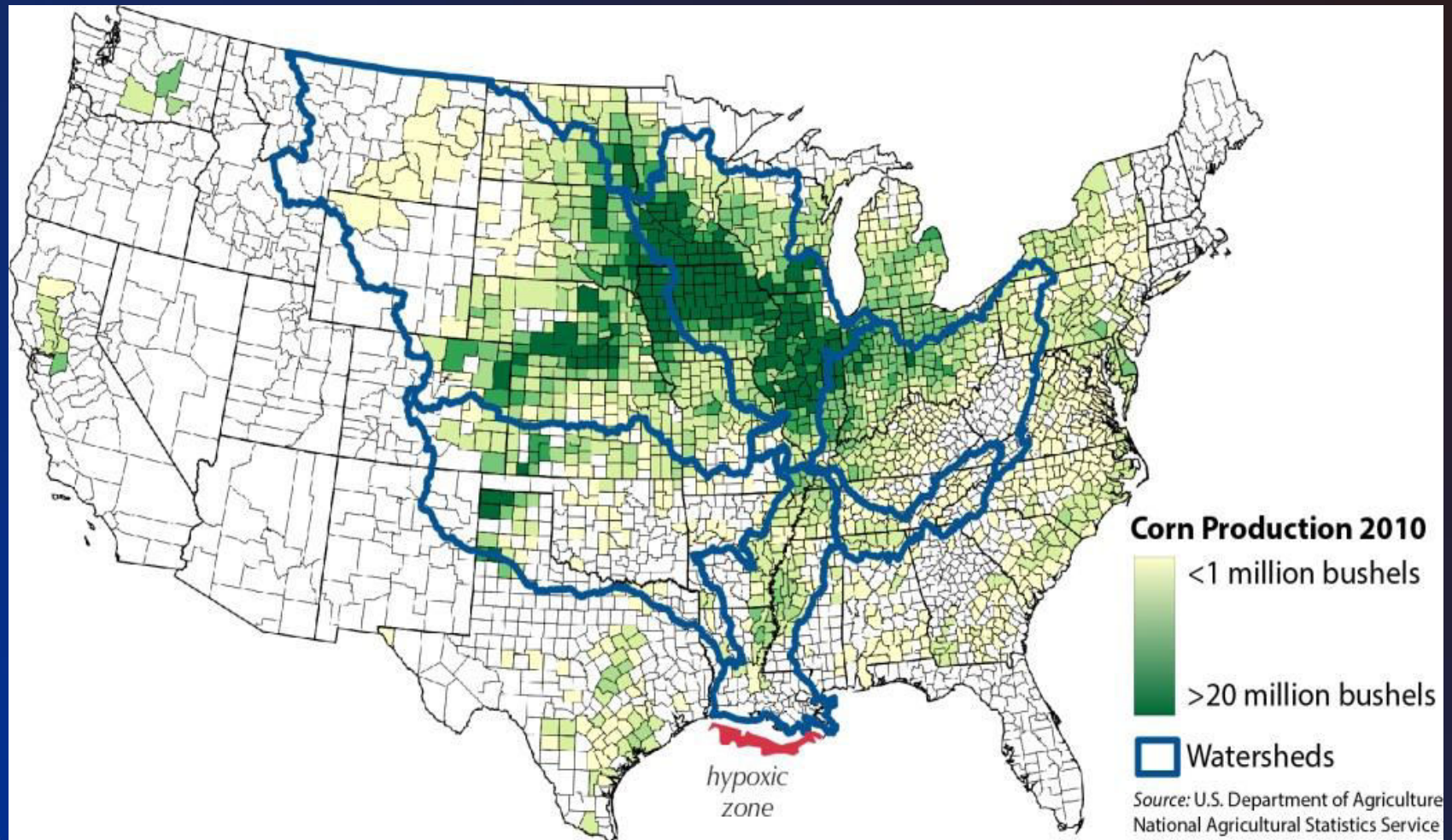
Photos: Matt Helmers

Installed Tile Drainage

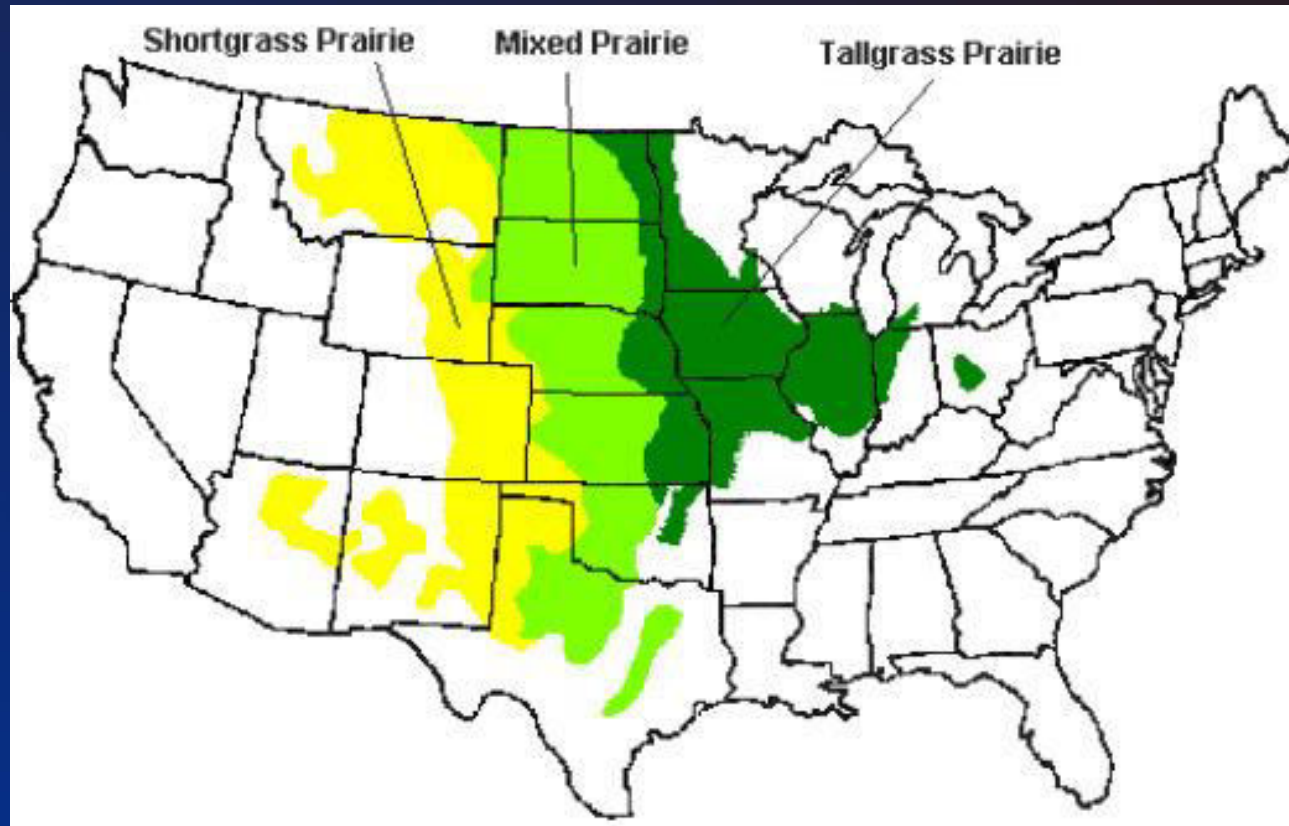


Source: 2012 US Census of Agriculture

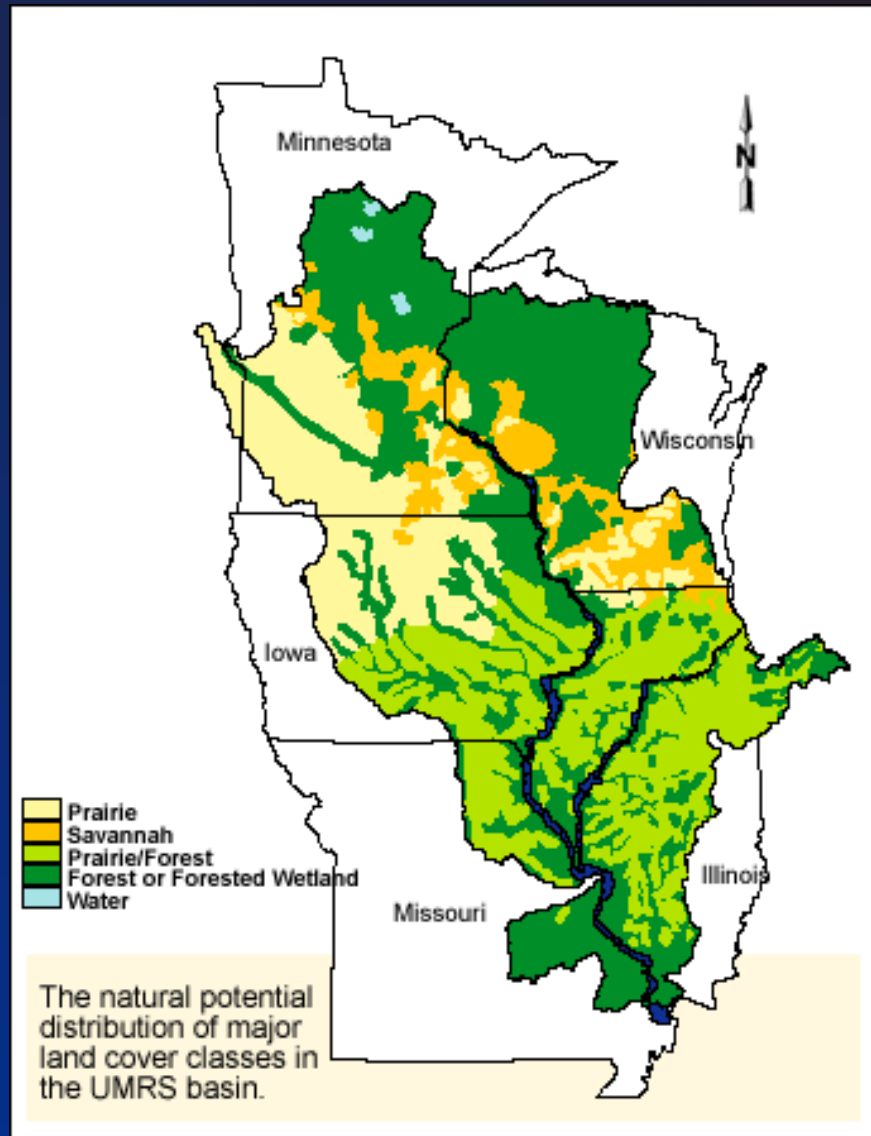
Planted an Annual Crop



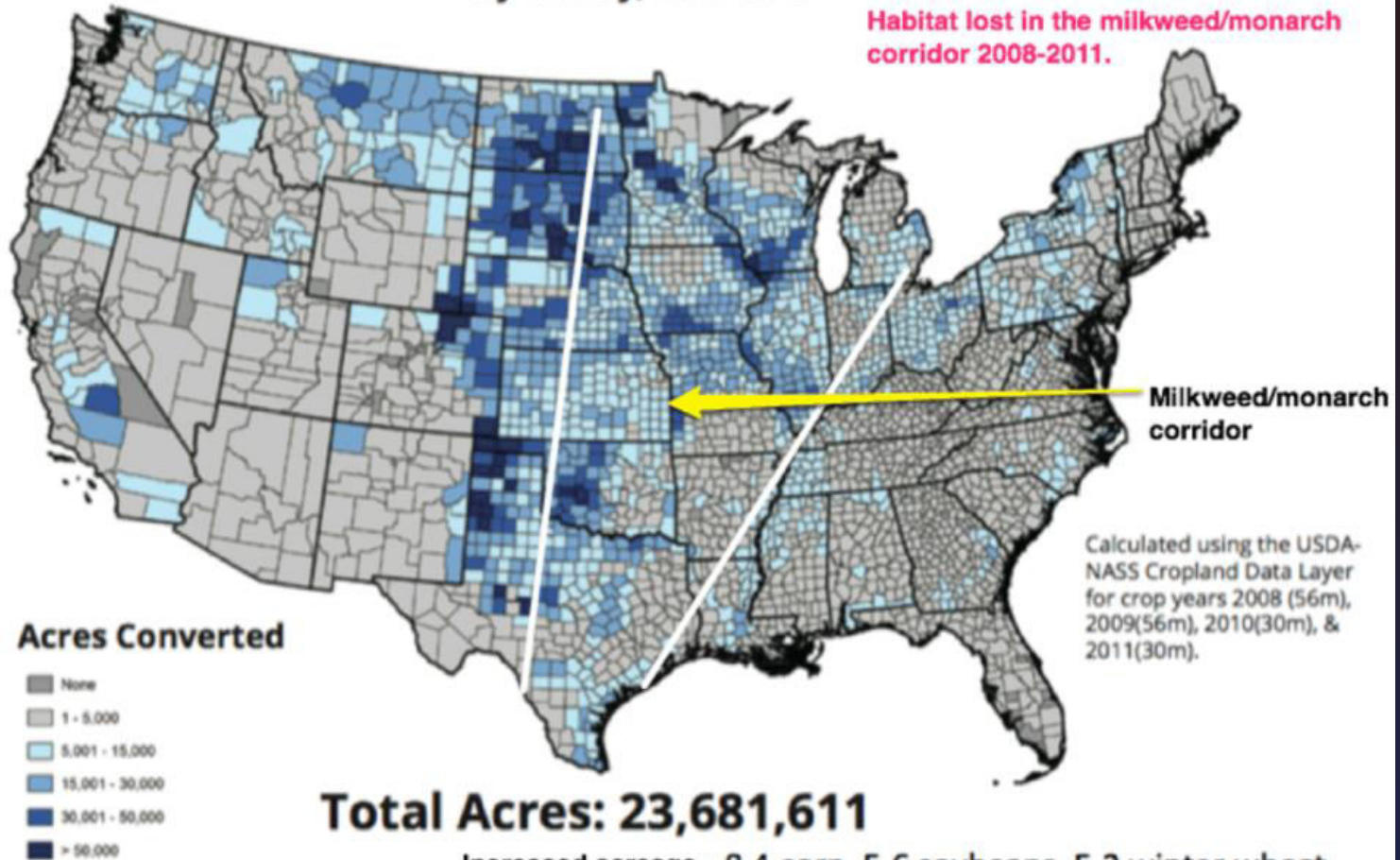
In contrast to Prairies



In Contrast to Prairies, Savannahs, and Forests

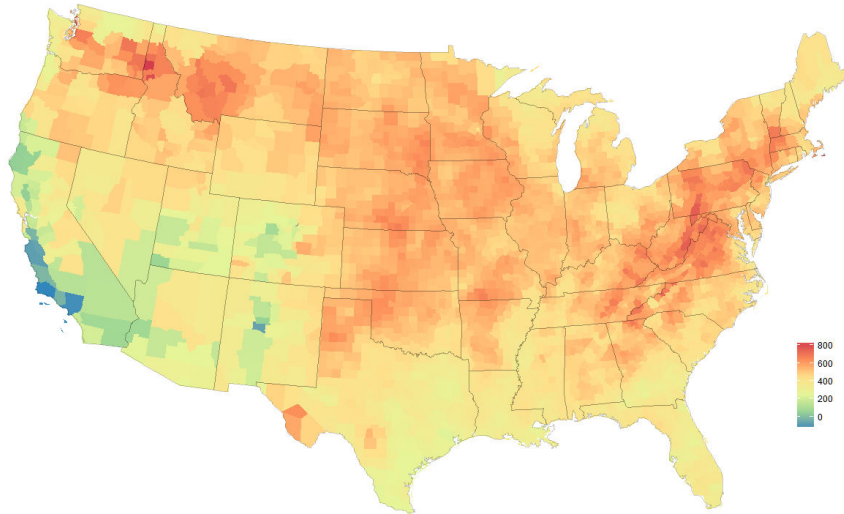


Acres of Grassland/Wetlands/Shrub Land Converted to All Crops By county, 2008-2011

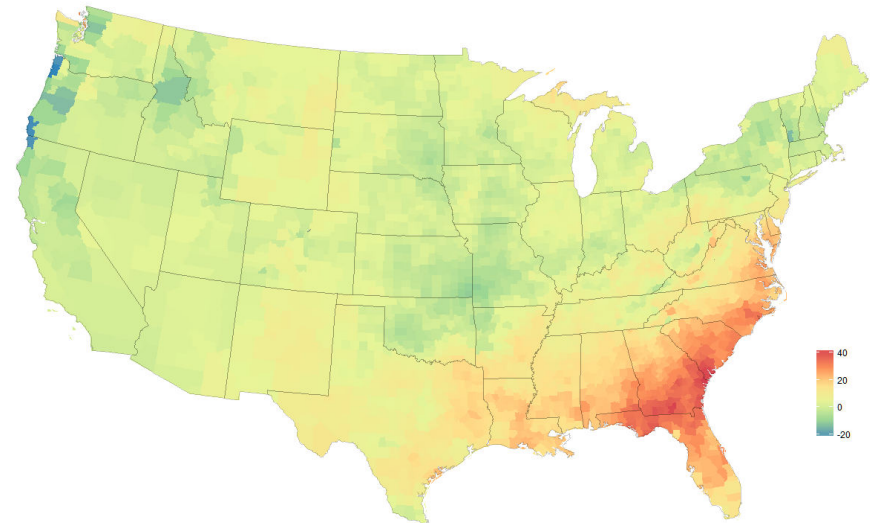


Climate Change

Change in Growing Degree Days: 2012-2099

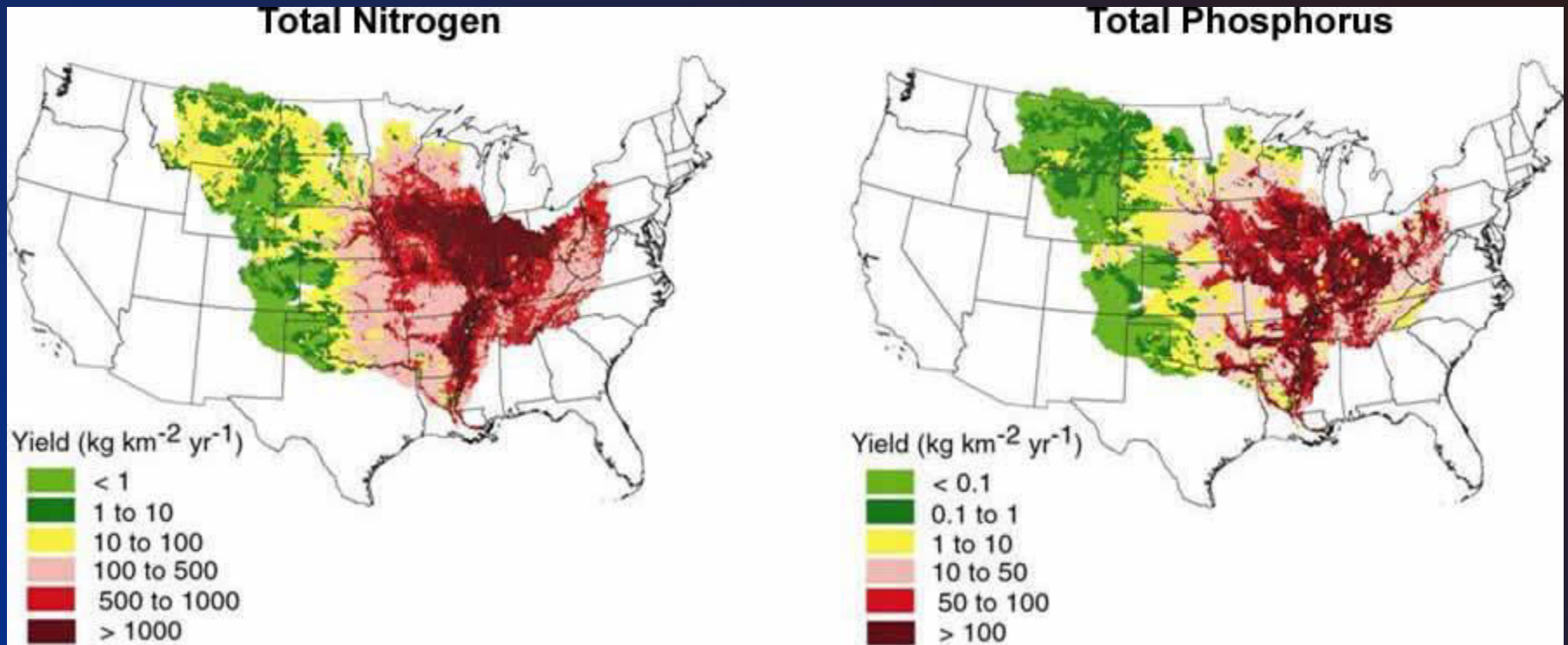


Change in Precipitation (cm.): 2012-2049



CCSM4, moderate (RCP45) scenario

We fertilize: Nutrient Deliveries to the Gulf of Mexico



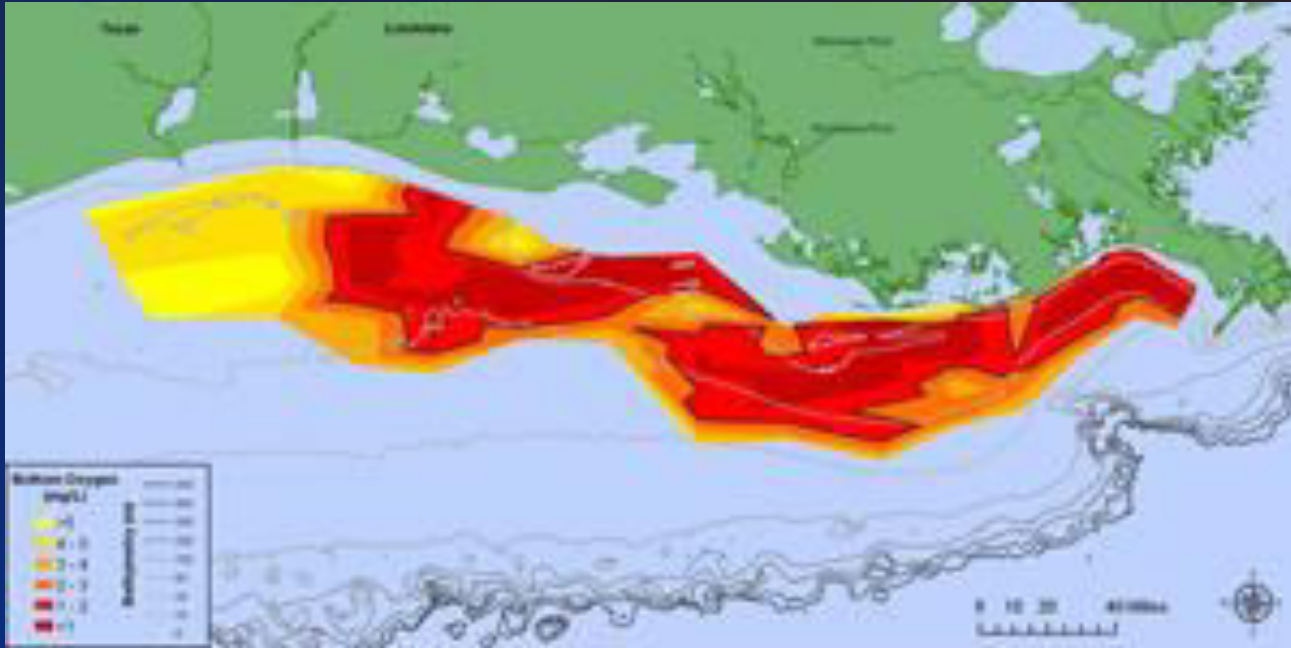
Source: USGS

52% of N from corn and soybean

Gulf of Mexico Dead Zone and Watershed, MARB

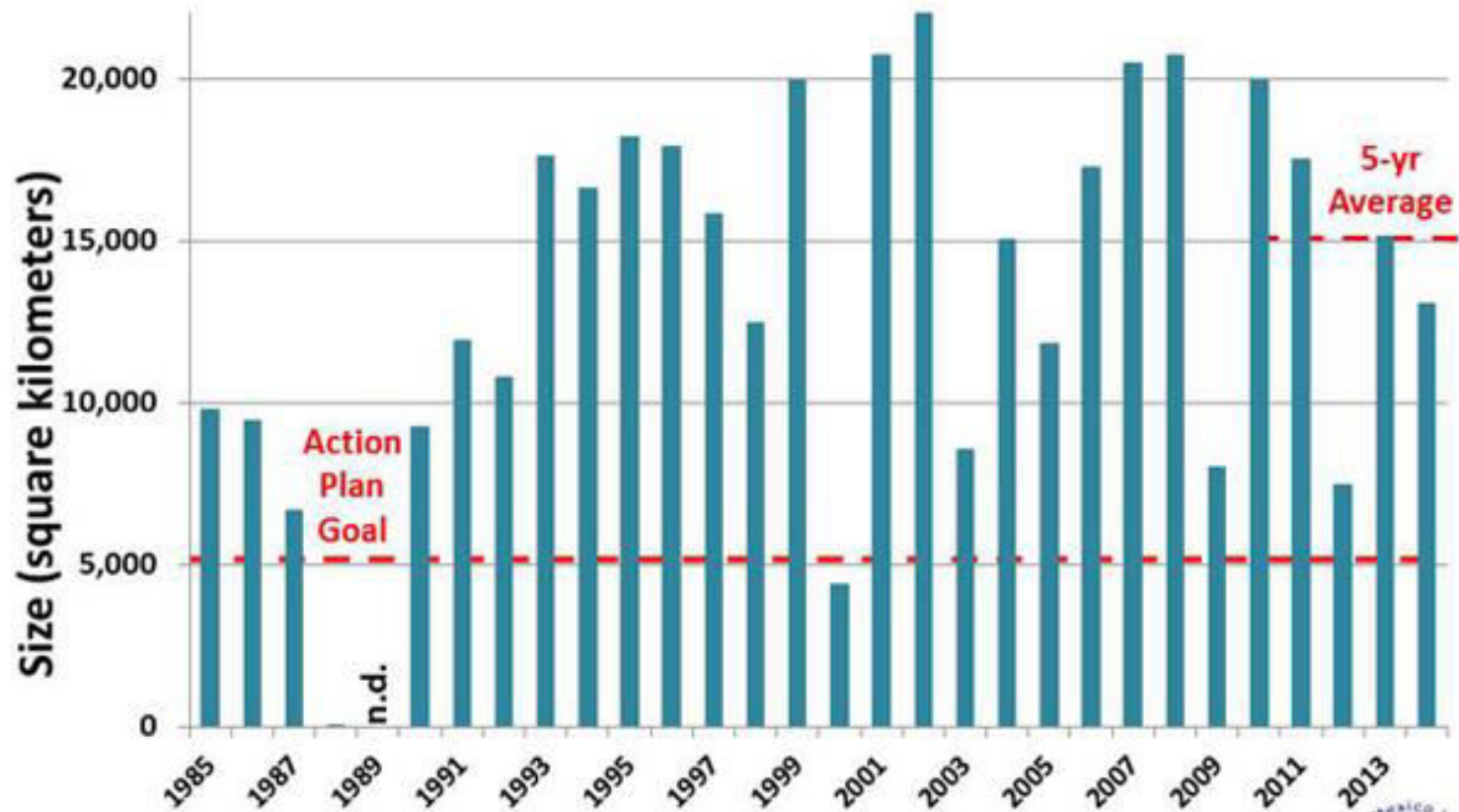


Northern Gulf of Mexico Dead Zone, 2016



Map showing distribution of bottom-water dissolved oxygen from July 28 to August 3, west of the Mississippi River delta. Black lined areas — areas in red to deep red — have very little dissolved oxygen. (Data: Nancy Rabalais, LUMCON; R Eugene Turner, LSU. Credit: NOAA)

Size of bottom-water hypoxia in mid-summer



Data source: Nancy N. Rabalais, LUMCON, and R. Eugene Turner, LSU

Funding sources: NOAA Center for Sponsored Coastal Ocean Research and U.S. EPA Gulf of Mexico Program



Altered Water Quality

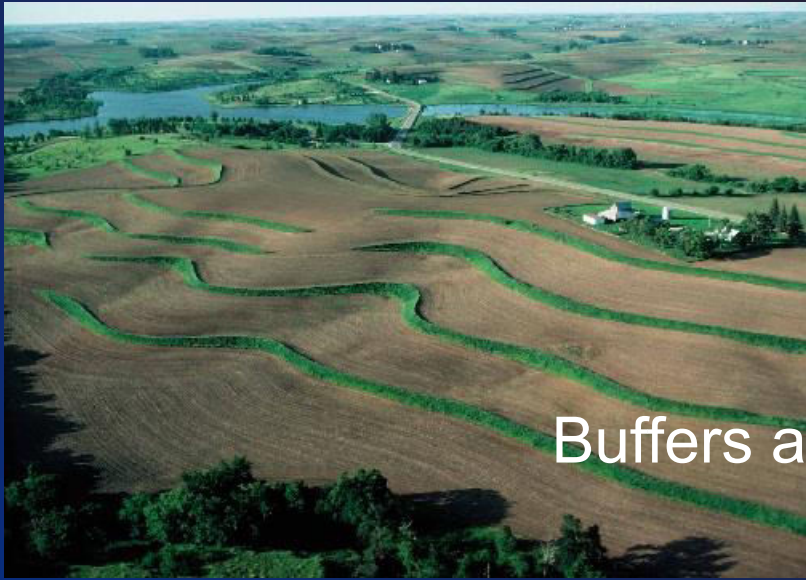


A cyanobacteria bloom in a Midwestern lake.

Copyright 1997, John A. Downing

The diverse aquatic vegetation found in the Littoral Zone of freshwater lakes and ponds.

Many Abatement Options



Buffers and Terracing



Reduced tillage



Grassed Waterways

Cost-effective targeting of conservation investments to reduce the northern Gulf of Mexico hypoxic zone

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Edited by Stephen Polasky, University of Minnesota, St. Paul, MN, and approved November 13, 2014 (received for review March 28, 2014)

A seasonally occurring summer hypoxic (low oxygen) zone in the northern Gulf of Mexico is the second largest in the world. Reductions in nutrients from agricultural cropland in its watershed are needed to reduce the hypoxic zone size to the national policy goal of 5,000 km² (as a 5-y running average) set by the national Gulf of Mexico Task Force's Action Plan. We develop an integrated assessment model linking the water quality effects of cropland conservation investment decisions on the more than 550 agricultural subwatersheds that deliver nutrients into the Gulf with a hypoxic zone model. We use this integrated assessment model to identify the most cost-effective subwatersheds to target for cropland conservation investments. We consider targeting of the location (which subwatersheds to treat) and the extent of conservation investment to undertake (how much cropland within a subwatershed to treat). We use process models to simulate the dynamics

A number of cropland conservation practices can limit the loss of N and P from cropland into waterways and include reduced tillage, terraces, and riparian buffers. Reduced fertilizer application rates, and altered timing and method of application, can also be used to control losses of N and P. A comprehensive analysis of the existing coverage and historical effectiveness of these practices in reducing N, P, and sediment loss across the Mississippi Basin has recently been completed [US Department of Agriculture Conservation Effects Assessment Project (CEAP)] (11–15).

The Mississippi Basin is often divided into five major subbasins and further delineated into more than 800 subwatersheds (these are identified as “HUC-8’s” according to the US Geologic Survey nomenclature; ref. 16). Of those subwatersheds, 557 have significant agricultural cropland and are therefore included in our study. If the Hypoxia Task Force’s goal is to be met, sig-

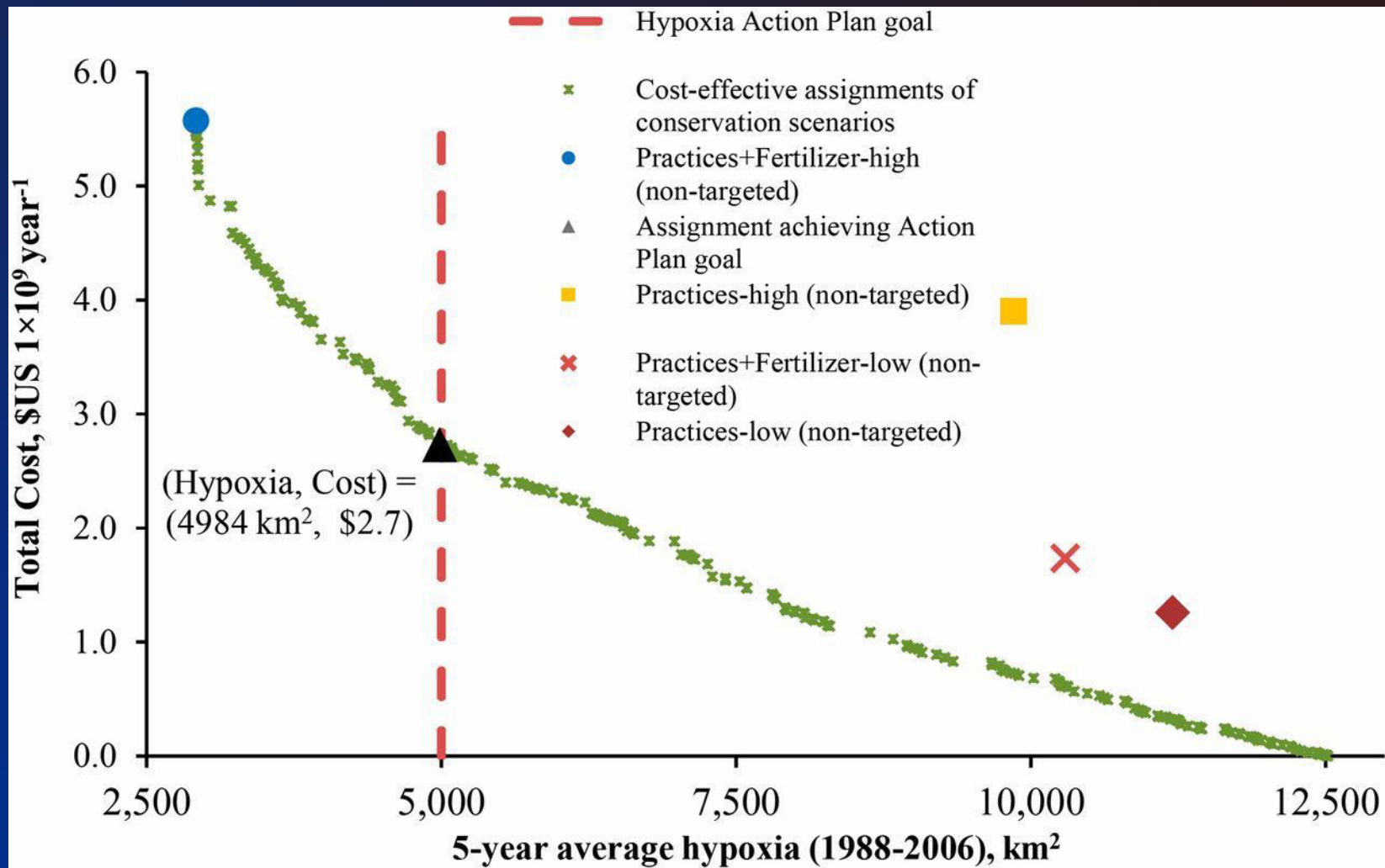
Three key model components:

1. Landscape scale watershed-based model of agricultural land use
 - How do changes in agricultural practices change nutrient runoff at each location
 - How much of these nutrients get to the gulf
 - How much do these practices cost

National CEAP Assessments: Major NRCS/USDA effort

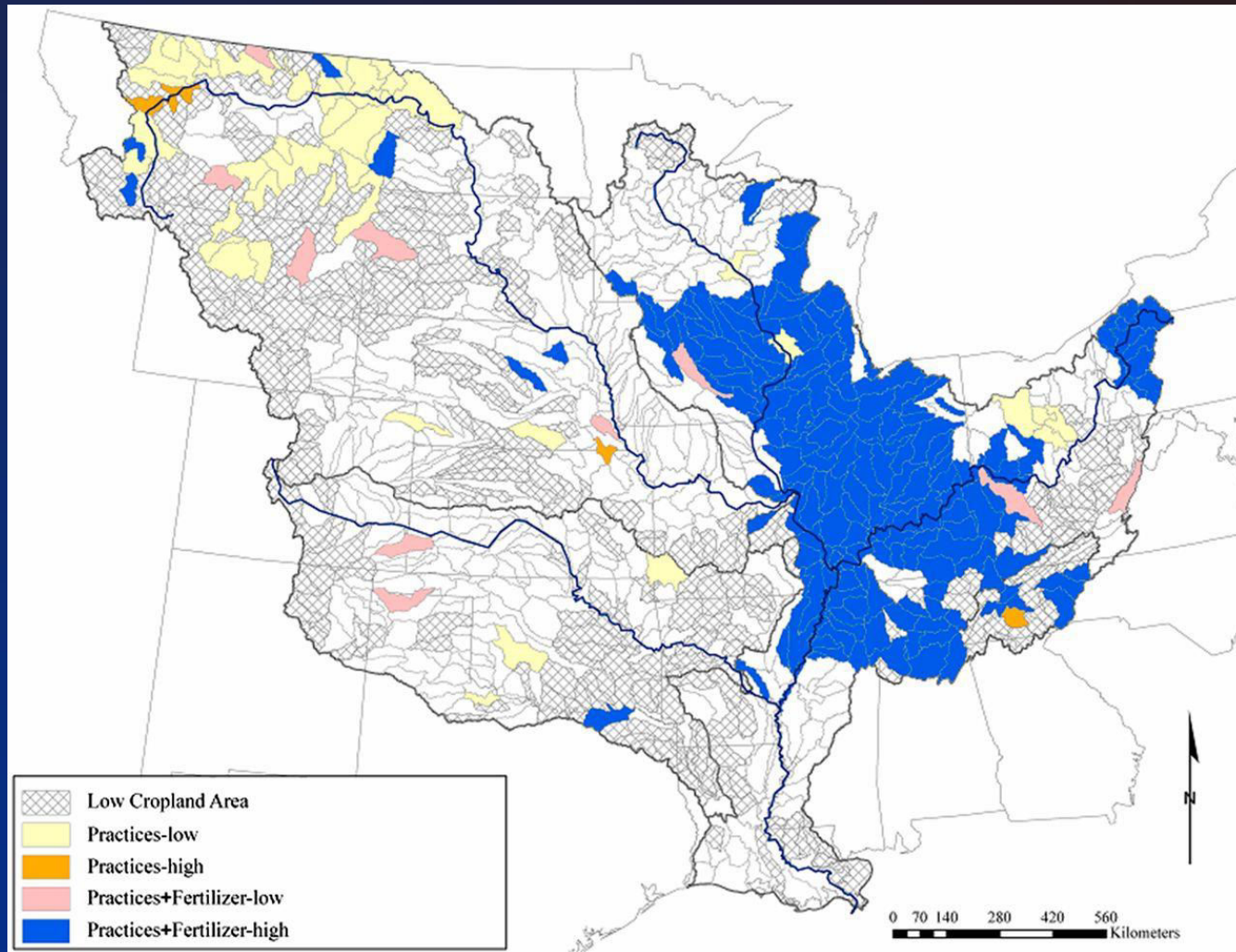
2. Hypoxic zone model
3. Evolutionary Algorithm: simulation-optimization framework – what is least cost way to achieve hypoxia reduction goal

Cost-hypoxia tradeoff frontier consisting of specific placements of cropland conservation scenarios across subwatersheds



Sergey S. Rabotyagov et al. PNAS 2014;111:18530-18535

An identified solution for a 60% reduction in the mean 5-y average hypoxia size (achieves the Action Plan goal, on average).



Sergey S. Rabotyagov et al. PNAS 2014;111:18530-18535

Results: What do we know?

1. Conservation investments can be effective in reducing the size of Gulf hypoxia
2. Targeting can lower costs a lot
3. Agricultural production can be maintained and hypoxia addressed but costs not trivial

What do we need to know?



**Coupling Economic Models with Agronomic, Hydrologic, and Bioenergy Models
for Sustainable Food, Energy, and Water Systems**

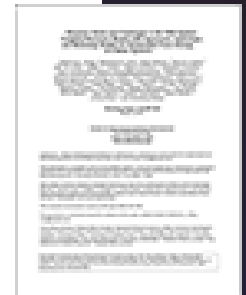
NSF supported workshop • October 12 & 13, 2015 • Ames, IA

Organizers: Catherine Kling, Raymond Arritt, Gray Calhoun, and David Keiser

The white paper is now available:

**[Research Needs and Challenges in the FEW System:
Coupling Economic Models with Agronomic, Hydrologic,
and Bioenergy Models for Sustainable Food, Energy, and
Water Systems](http://www.card.iastate.edu/few/)**

<http://www.card.iastate.edu/few/>



Research needs and challenges in the FEW system: Coupling economic models with agronomic, hydrologic, and bioenergy models for sustainable food, energy, and water systems

Working Paper 16-WP 583

March 2016

Catherine L. Kling, Raymond W. Arritt, Gray Calhoun, David A. Keiser, John M Antle, Jeffery Arnold, Miguel Carriquiry, Indrajeet Chaubey, Peter Christensen, Baskar Ganapathysubramanian, Philip Gassman, William Gutowski, Thomas W. Hertel, Gerrit Hoogenboom, Elena Irwin, Madhu Khanna, Pierre Mérel, Dan Phaneuf, Andrew Plantinga, Paul Preckel, Stephen Polasky, Sergey Rabotyagov, Ivan Rudik, Silvia Secchi, Aaron Smith, Andrew Vanloocke, Calvin Wolter, Jinhua Zhao, and Wendong Zhang.¹

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¹ The authors and the workshop benefited enormously from the contributions of Maria Jimena Gonzalez-Ramirez, Hocheol Jeon, Yongjie Ji, Fangge Liu, Kevin Meyer, Xianjun Qiu, Adriana Valcu, and Jennifer West. Excellent support from Curtis Balmer, Nathan Cook, Karen Kovarik, Michael Long, Becky Olson, and Deb Thornburg is also much appreciated.



Humans are essential components

1. Decisions
2. Value and products

HUMAN SYSTEM (Decision making)

Economic Models

- Agricultural land use and Management decisions
- Market signals
- Policy

Biophysical Models

- Natural and Physical (FEW Biophysical System)
- Climate
- Water quantity and hydrology
- Soil health
- Water quality
- Crop production
- Biomass production
- Wildlife biodiversity and habitat

HUMAN SYSTEM (Value and Products)

Economic Models

- Value of marketed goods (prices of food and fuel)
- Nonmarket valuation of ecosystem services (willingness to pay for public goods and externalities)

Feedback between Human Systems

Research Needs

1. Increased modeling capacity to represent a wide set of land use options, biophysical processes, crops and environmental impacts

Relevance to Gulf Hypoxia and PNAS research?

Full suite of ecosystem services, perennial crops, other water quality measures, wetlands, new conservation methods, butterfly production, etc!

Alternatives for Tile-drained Landscapes?

Nutrient-Removal Wetland



Bioreactor



Research Needs

2. Economic land use models to incorporate adaptation behavior

Gulf work: tile drains, changing crops, changing locations, changing irrigation, etc.

Research Needs

3. Models to incorporate dynamic and non-neoclassical economic behavior that are tractable for integration with other models

Our work completely ignored.

Research Needs

4. Models to incorporate national and international market responses into regional analysis

Price response, supply shocks, market conditions elsewhere, etc

Research Needs

5. Methods for assessing model accuracy and characterizing multiple sources of uncertainty in findings of model output



What do we know enough to do now?

1. Reduce N and P, we are far over targets and goals!
2. Monitor and measure as we do so we can learn about effectiveness of groups of programs
3. Better target existing funding (Conservation Reserve Program, EQIP, etc)

