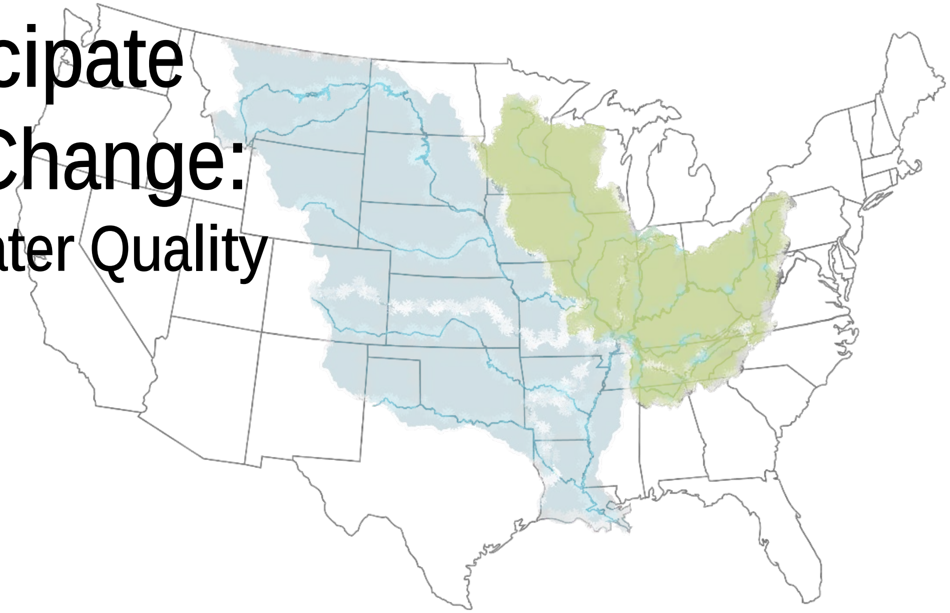
Midwestern Farmers Anticipate and Respond to Climate Change:

Impacts on the Landscape and Water Quality



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Climate Change in the Midwest

1. What will it mean for rainfall and temperature in the region?

2. How will farmers adapt to changes in weather patterns?

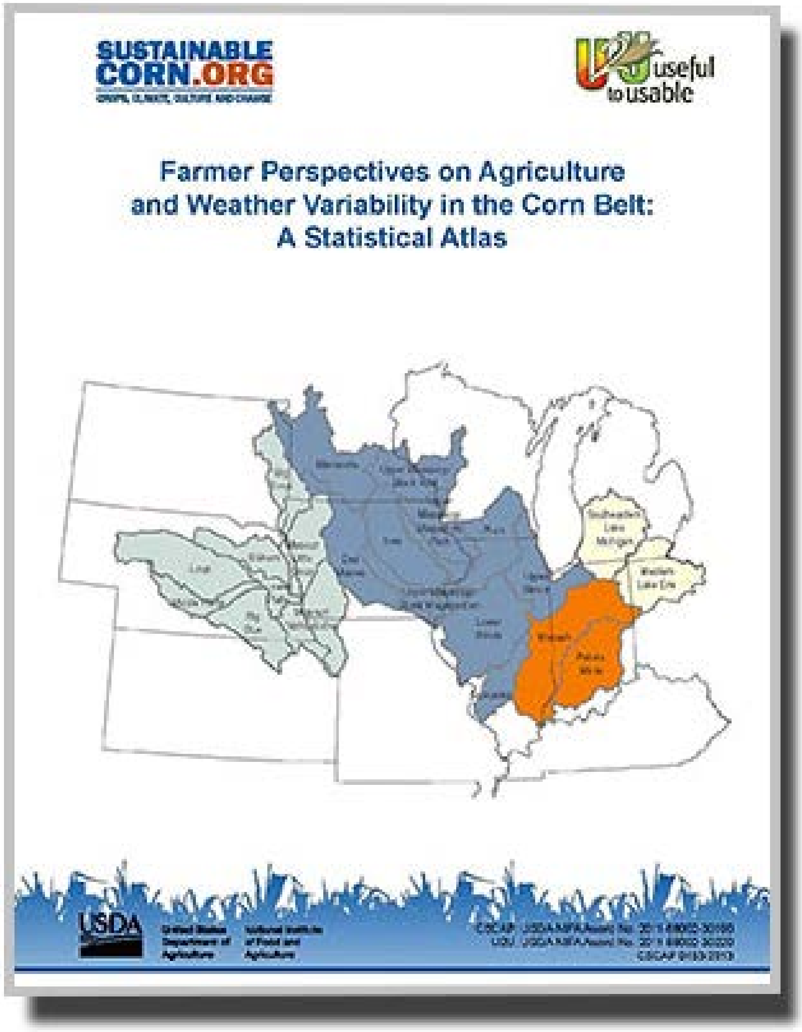
3. How will these changes, in turn, affect the landscape and water quality?

Three large data/modeling integration efforts:

1. Farmer's Perspectives on Agriculture and Weather

2. Climate Change Projections for the Midwest

3. Land Use and Water Quality Models



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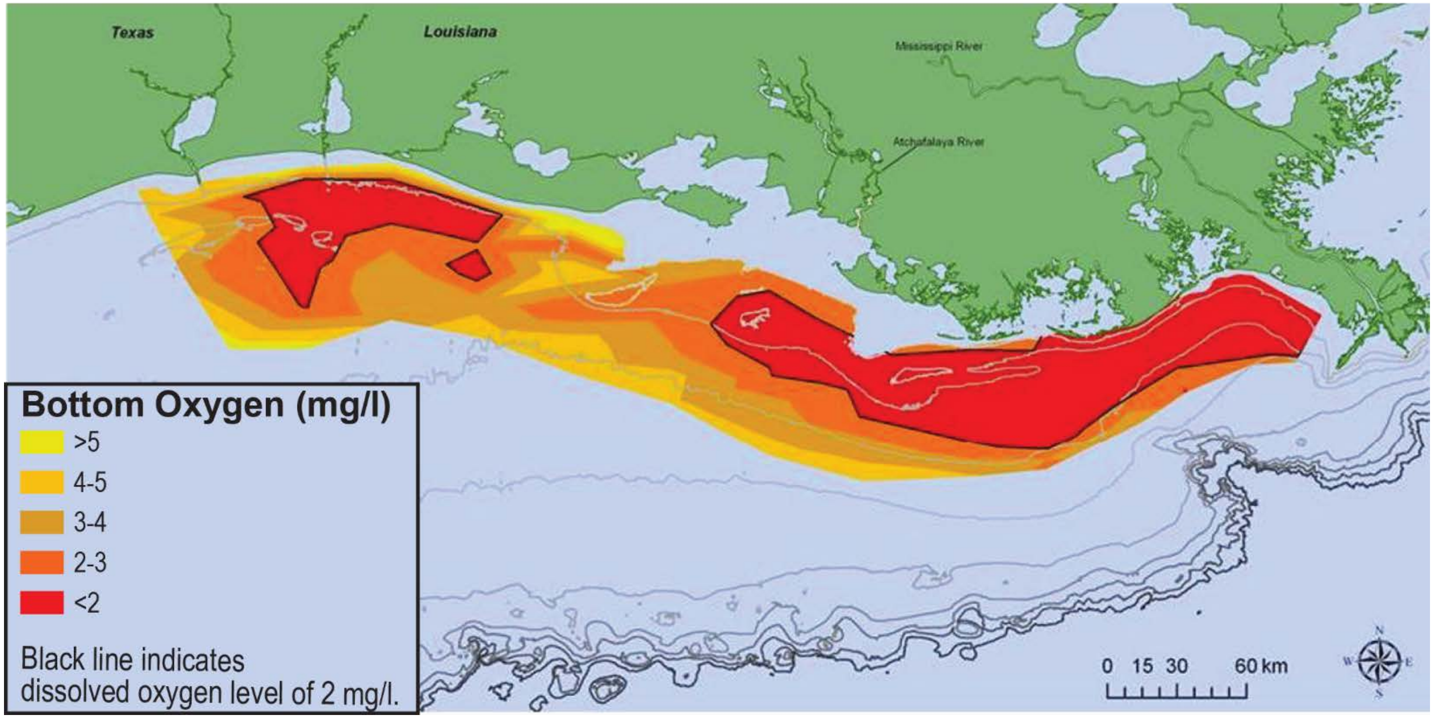
Distribution of Bottom-water Dissolved Oxygen July 27-August 1, 2014: about 5000 square miles

(west of the Mississippi River delta)



Source: Nancy NC. Rabalais, LUMCON, and R. Euguene Turner, LSU

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

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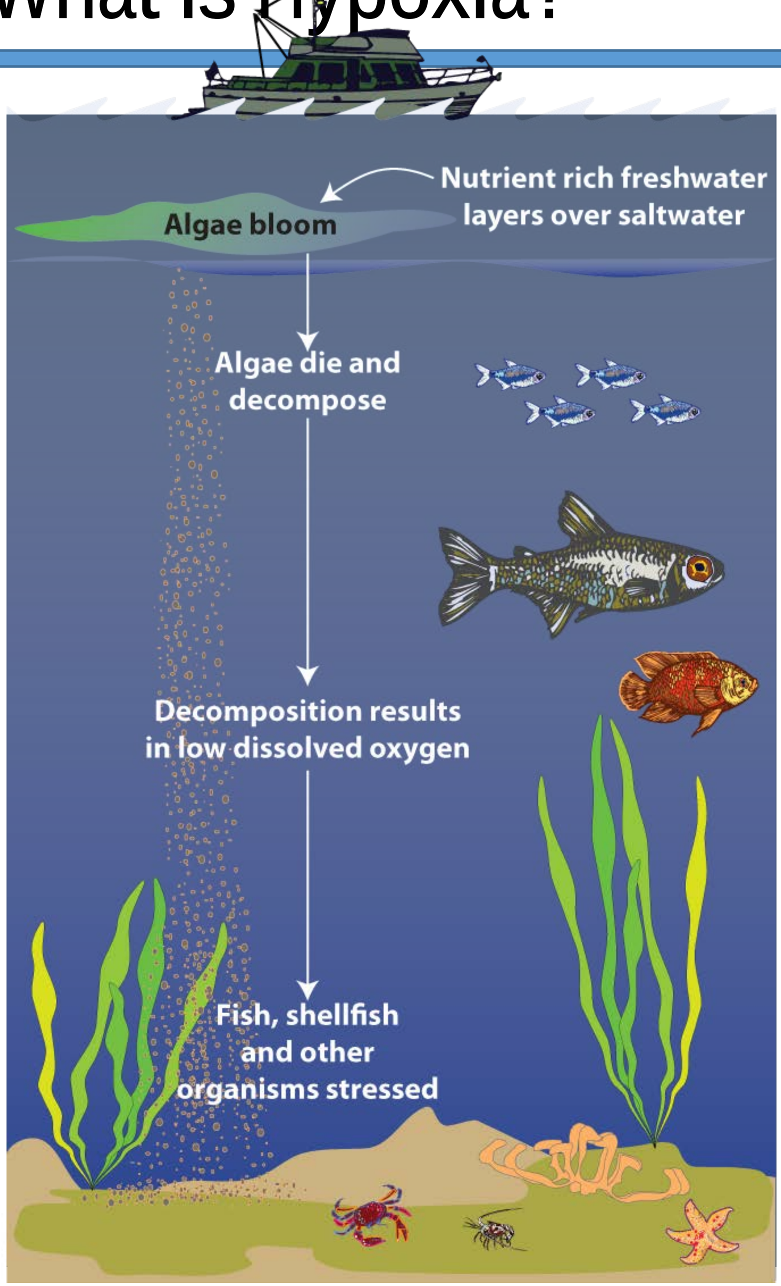
What is Hypoxia?



Over 3 mg/L =

Normal oxygen levels

Under 2mg/L =

Organisms exhibit stress

Under < 0.5 mg/L =

Mass mortality

Source: Steckbauer, et al, 2011

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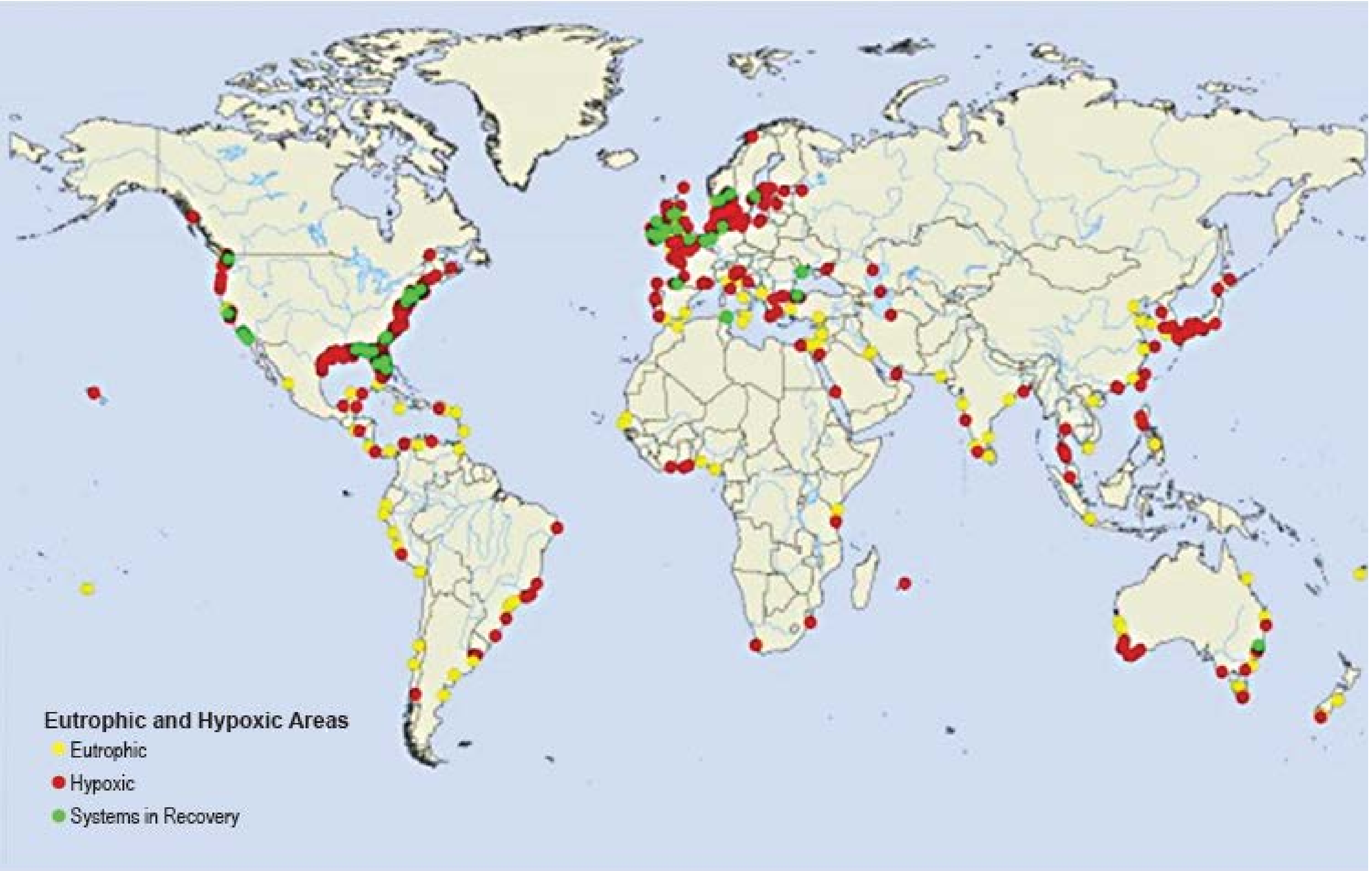
World Hypoxic and Eutrophic Coastal Areas



Diaz, R. and M. Selman, 2010

http://www.wri.org/resource/world-hypoxic-and-eutrophic-coastal-areas

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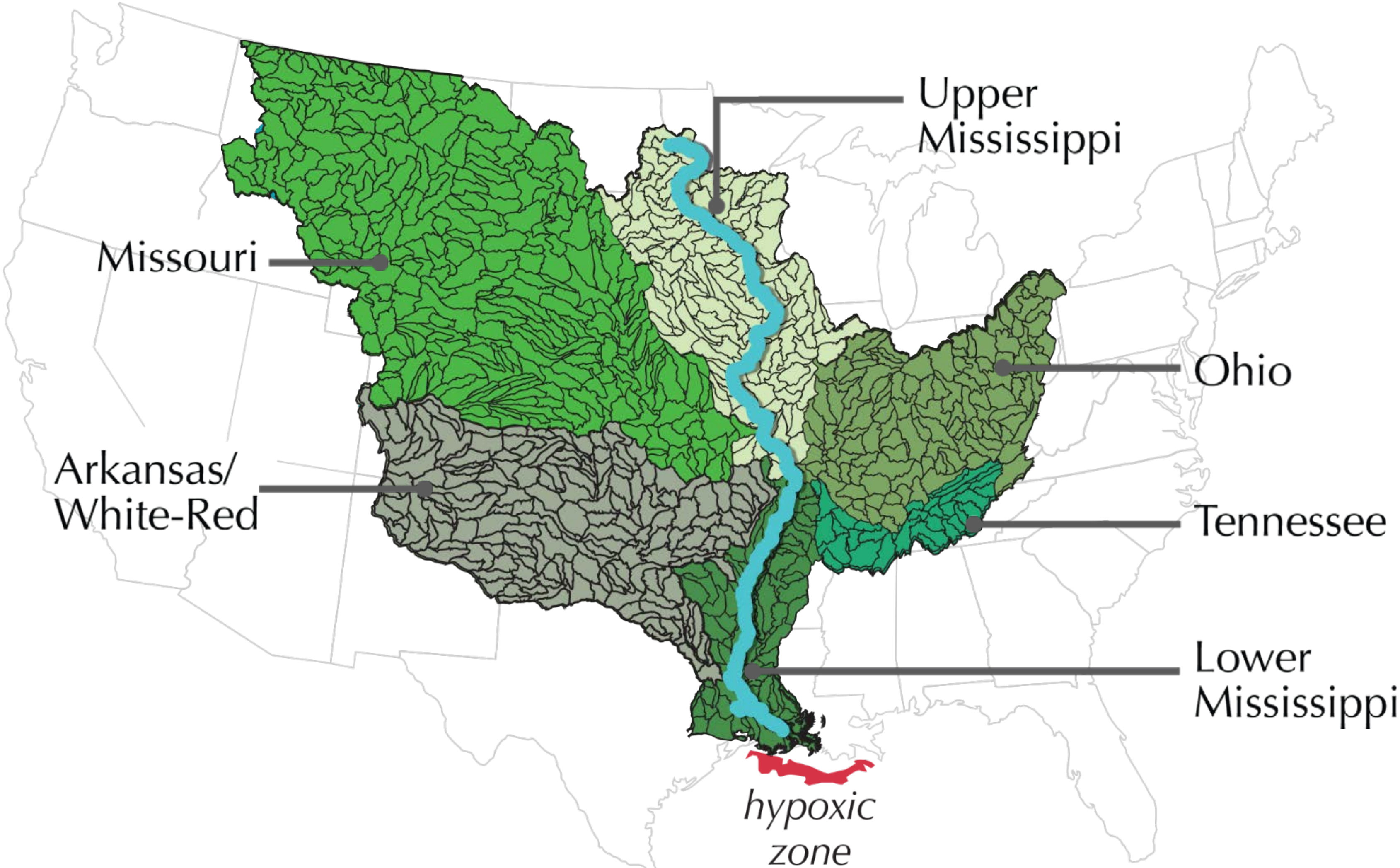
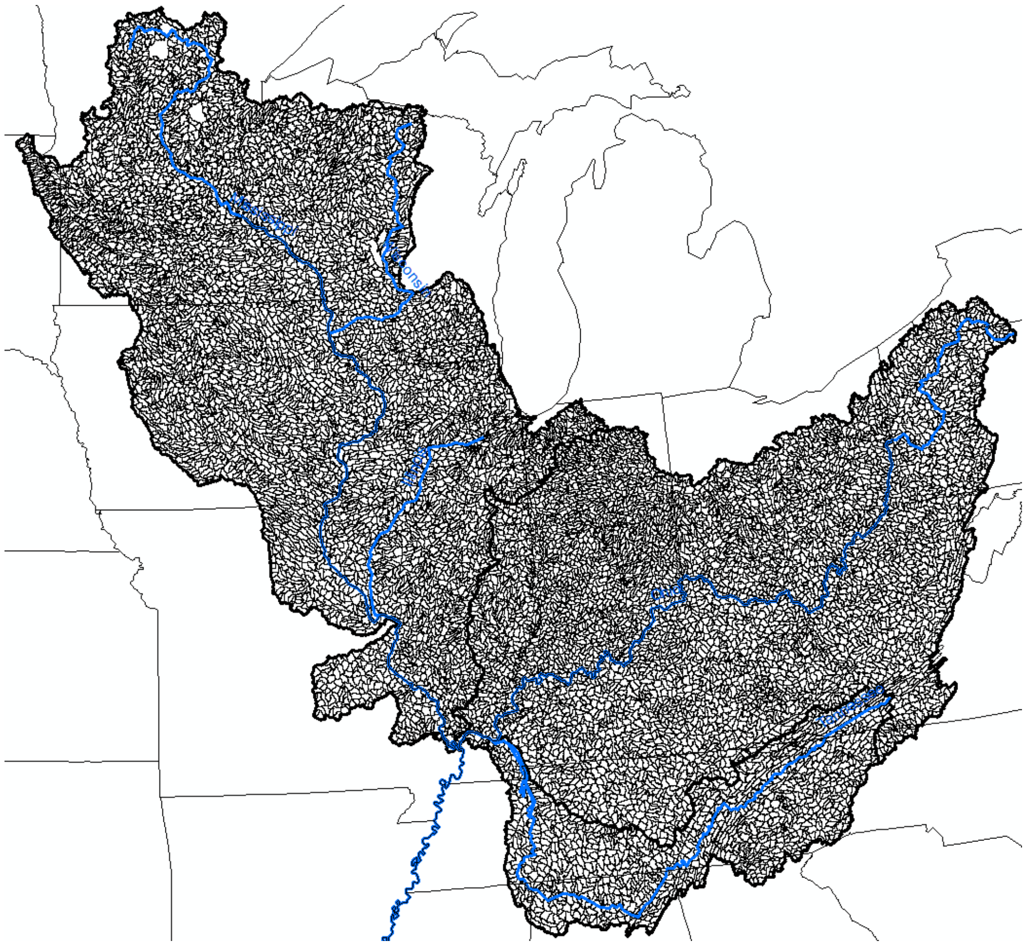
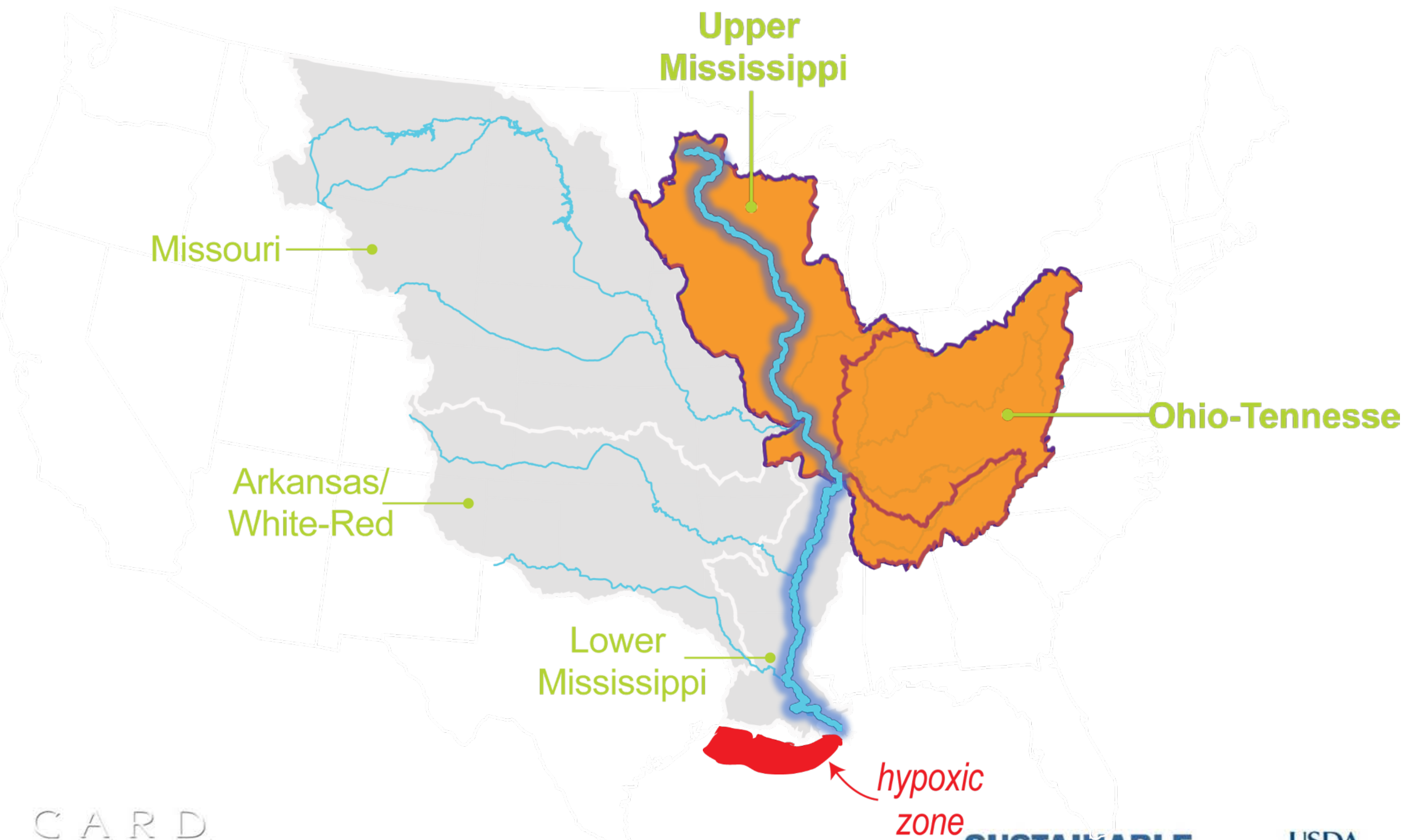

Upper
Mississippi
Missouri
Ohio
Arkansas/
White-Red
Tennessee
Lower
Mississippi
hypoxic
zone

And so on….



Change in Landuse Affects Water Quality



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The Current Landscape: Some numbers

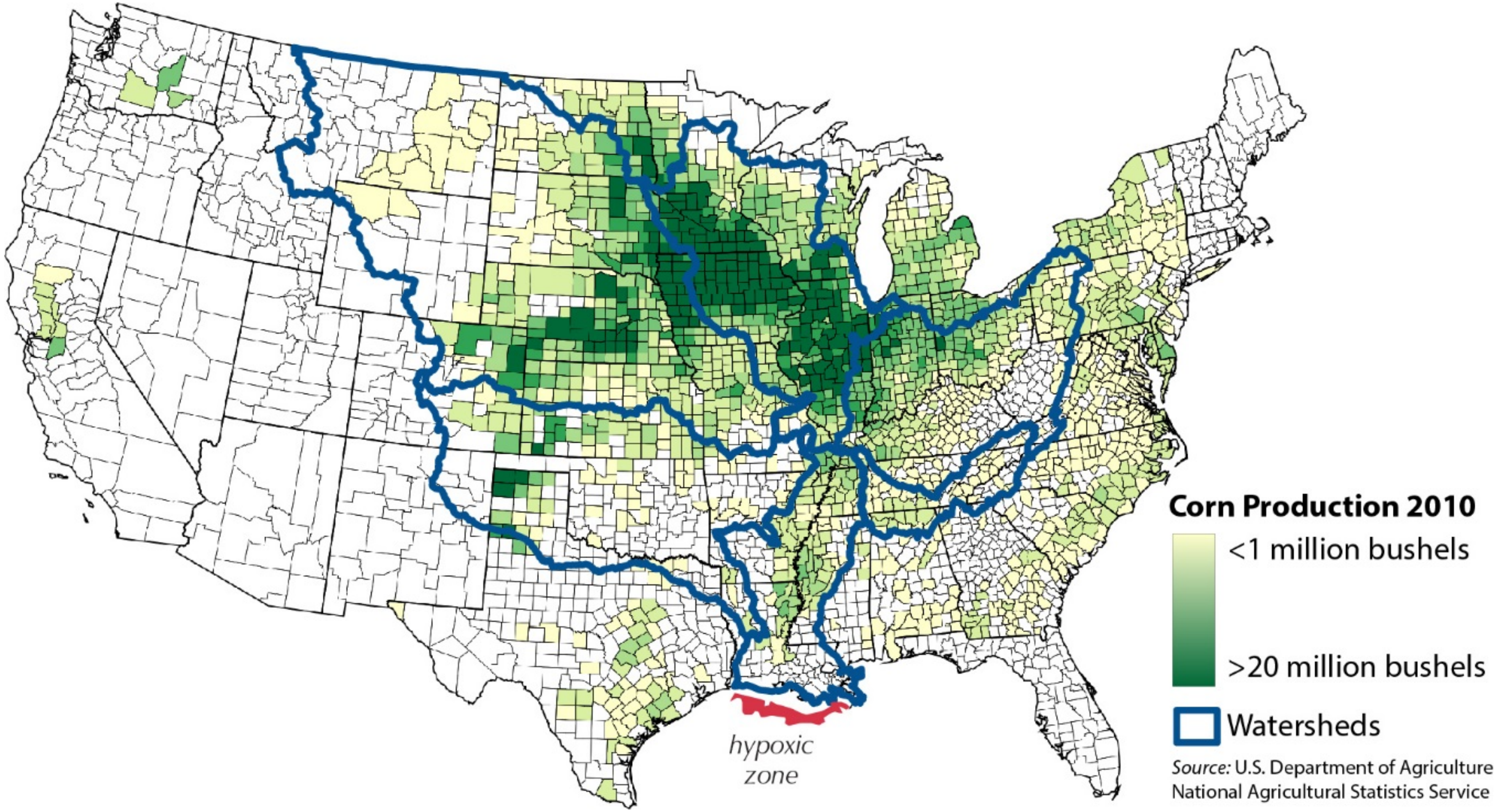
Upper Mississippi River Basin:

Land Area:	190,000 square miles
Agriculture:	cropland covers about 50%
Flat:	75% of the land has less than a 5% slope
Adequate Rainfall:	Over 35 inches of rainfall/year

Ohio Tennessee River Basin:

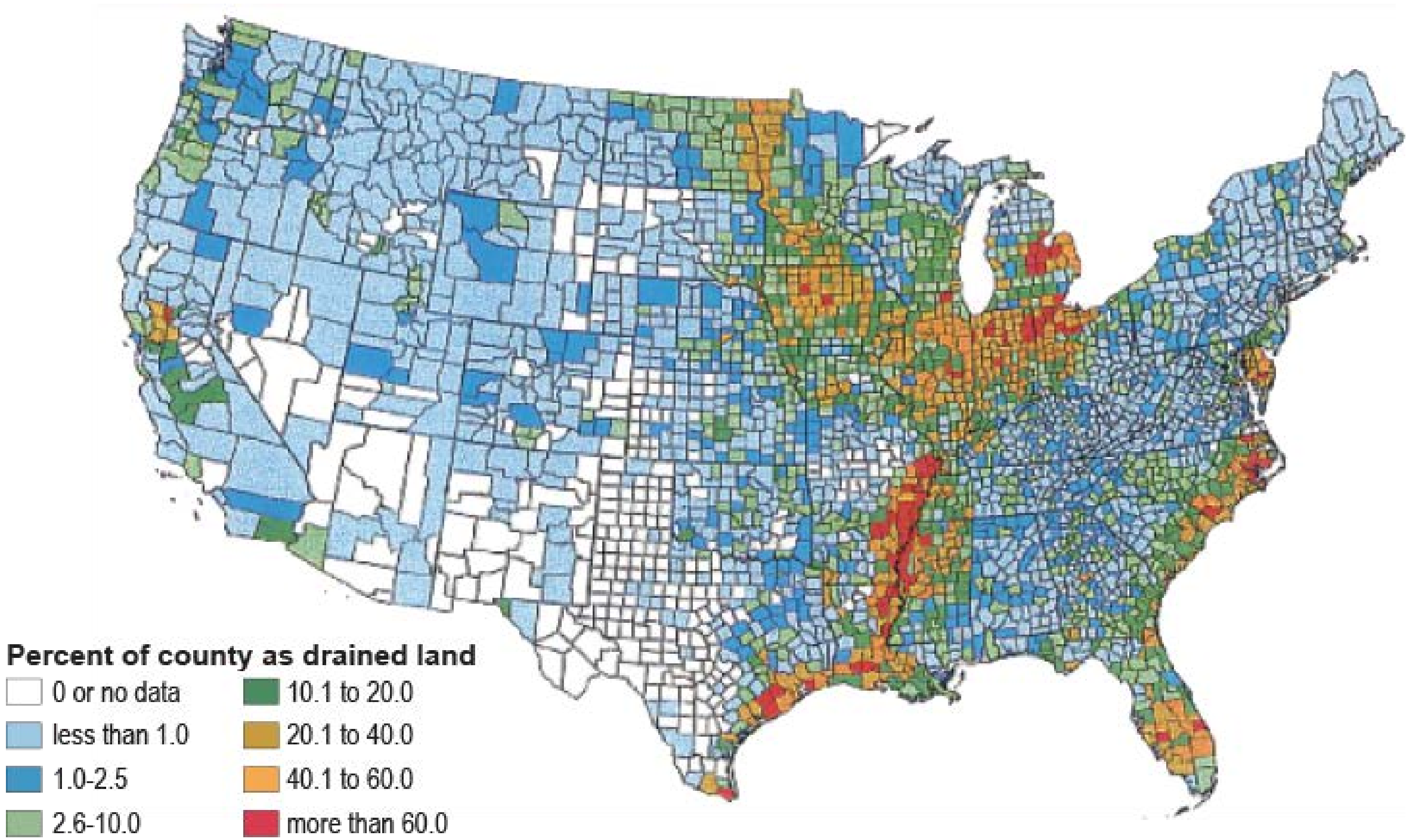
Land Area:	205,000 square miles
Agriculture:	cropland covers about 20%
Less Flat:	35% of the land has less than a 5% slope
Adequate Rainfall:	Over 45 inches of rainfall/year

The Current Landscape: Corn Production



1000s of acres per county

The Current Landscape: Tile Drainage



U.S. Department of Commerce, Bureau of the Census, 1978 Census of Agriculture. 1981. Volume 5, Special Reports, Part 5, Drainage of Agricultural Lands, AC78-SR-5.

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Water Quality: Some numbers

Rivers and Streams:

- 55-60% of the region's streams in "poor" condition (NARS, EPA)
- Phosphorous, Nitrogen pollution and poor habitat are primary problems

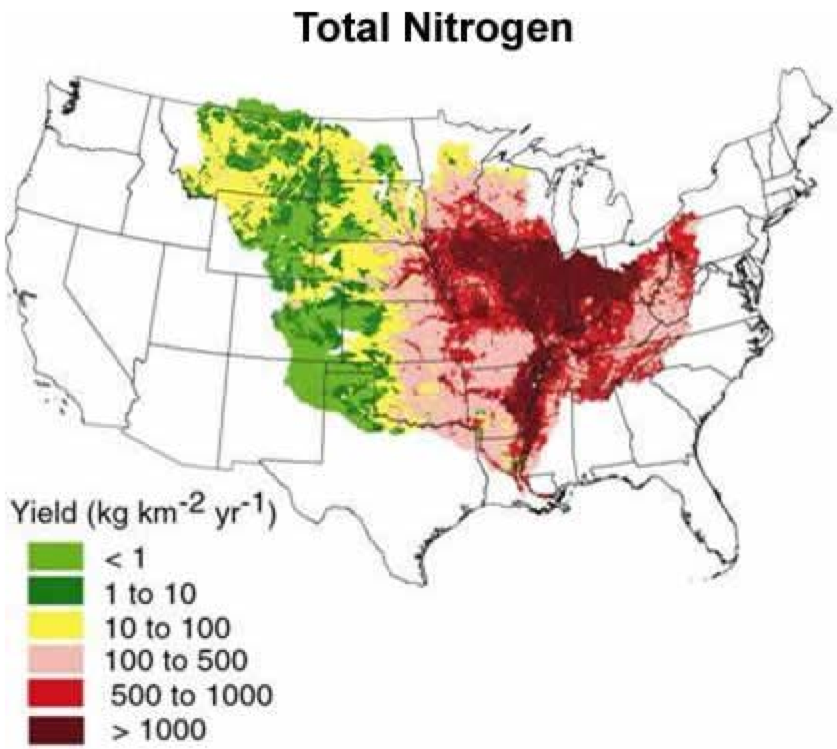
Lakes:

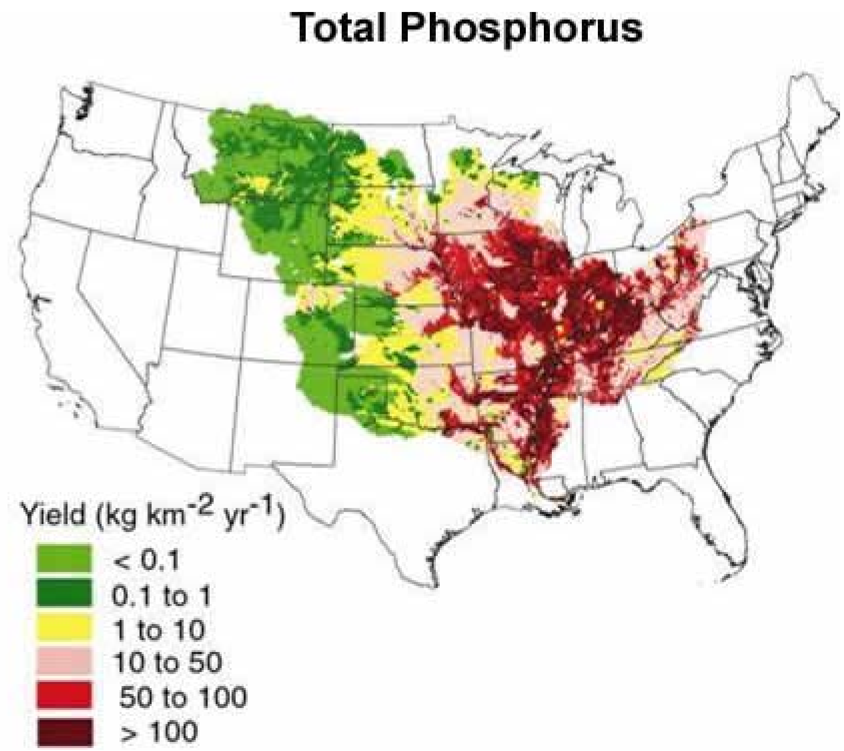
- 25% of regions lakes in "poor" condition (NLA, EPA)

Gulf of Mexico Hypoxic Zone:

- Annually recurring "dead" zone, 5 year average size = 5800 sq miles
- Three times the average goal
- 70% of Nitrogen and 80% of Phosphorus coming from agricultural land

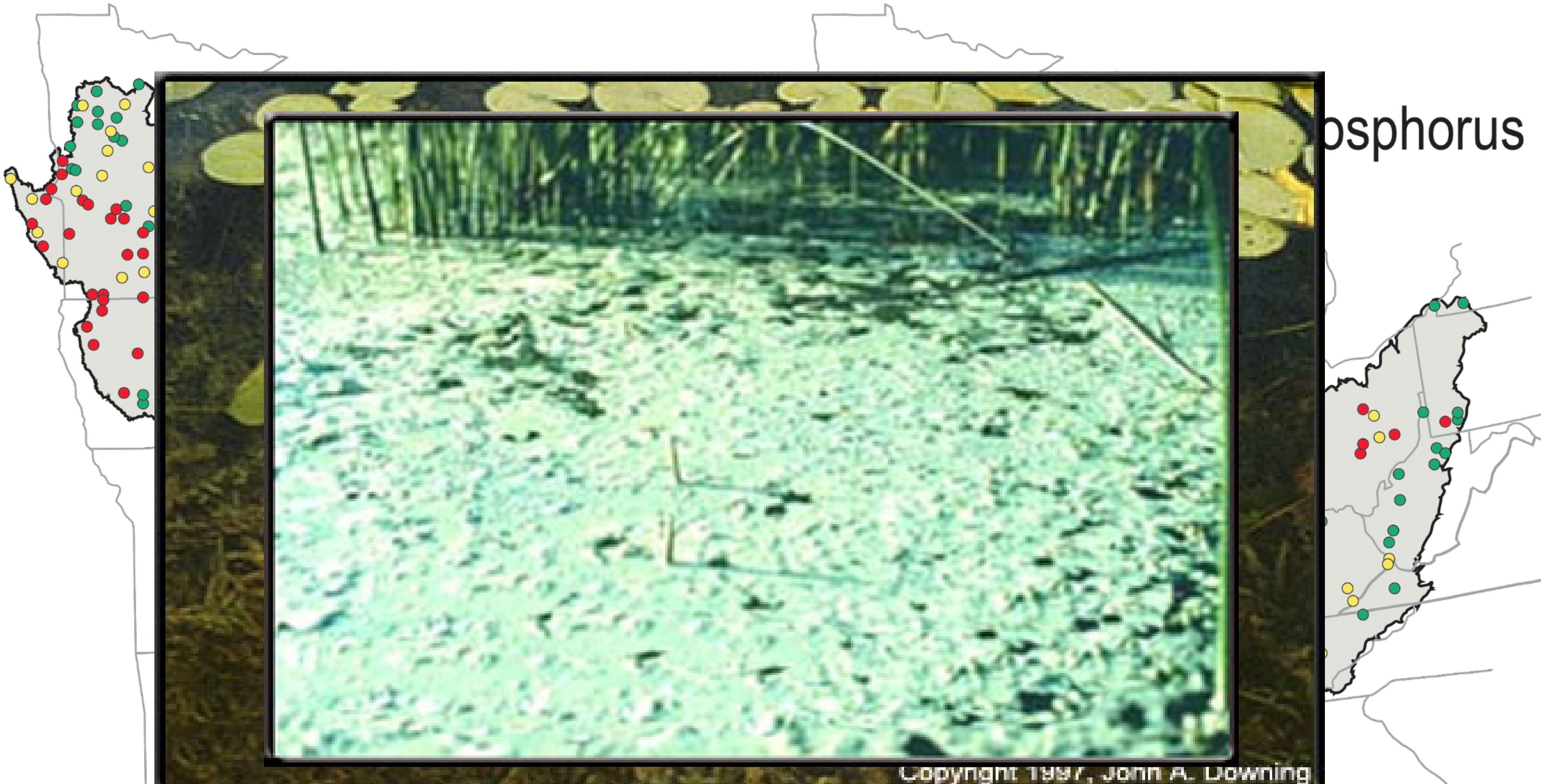
Nutrient Deliveries to the Golf of Mexico





Source: USGS

Lake Water Quality



A cyanobacteria bloom in a Midwestern lake.

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

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“Toledo bearing full brunt of Lake Erie algae bloom”

The Columbus Dispatch August 4, 2014

“Toxin leaves 500,000 in northwest Ohio without drinking water”

REUTERS August 2, 2014

“Algae blooms in Lake Erie contaminate water in Ohio and Michigan”

Pittsburgh Post-Gazette August 2, 2014

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Our Research: Climate Change in the Midwest

1. Choose one climate scenario from those available for rainfall and temperature in the region

2. Incorporate information from farmers about how they might adapt to altered climate

3. Integrate this information with spatially rich water quality model. Evaluate possible consequences for local water quality and hypoxic zone

1. Choose one climate scenario from those available for rainfall and temperature in the region

Model for Interdisciplinary Research on Climate, version 3.2 (MIROC 3.2) Global Circulation Model (GCM) (A projected future climate from mid-century (2046-2065))

- General Circulation Model (GCM) and Predicted Mid-Century Climate

- A1B scenario - greenhouse gases are assumed to increase through the middle of the 21st century - CO_2 concentrations stabilizing at 720 ppm

- Downscaling method: bias corrected with spatial disaggregation (BCSD)
- Interpolation to a 1/8 degree latitude-longitude grid. Adjustment of daily observed weather time-series (% changes in precipitation - absolute changes in T_{max}, T_{min}).

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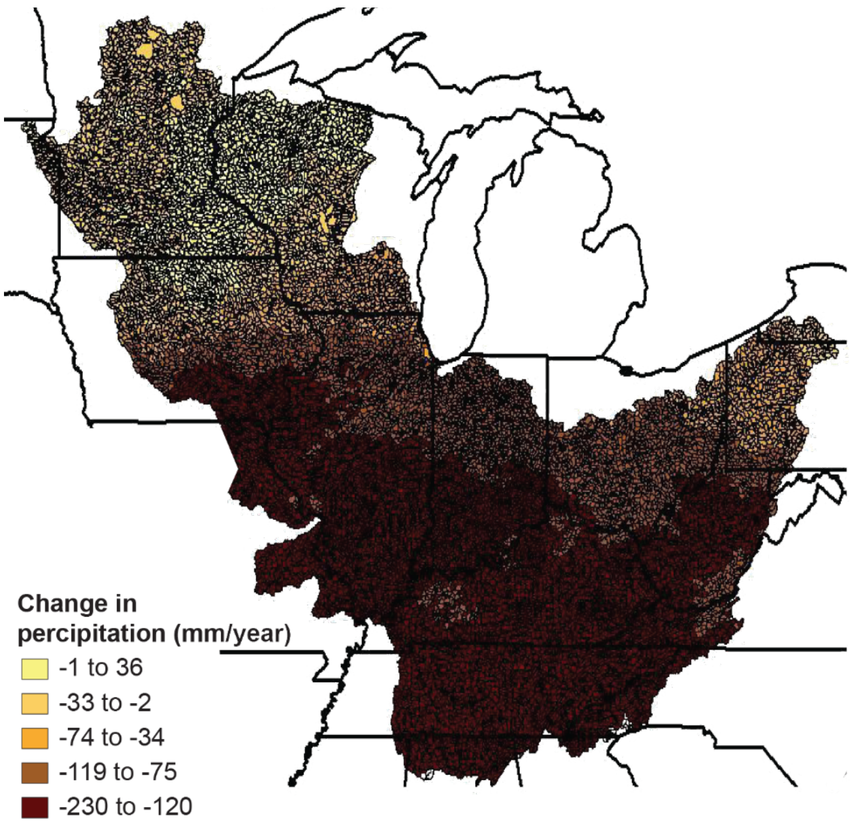
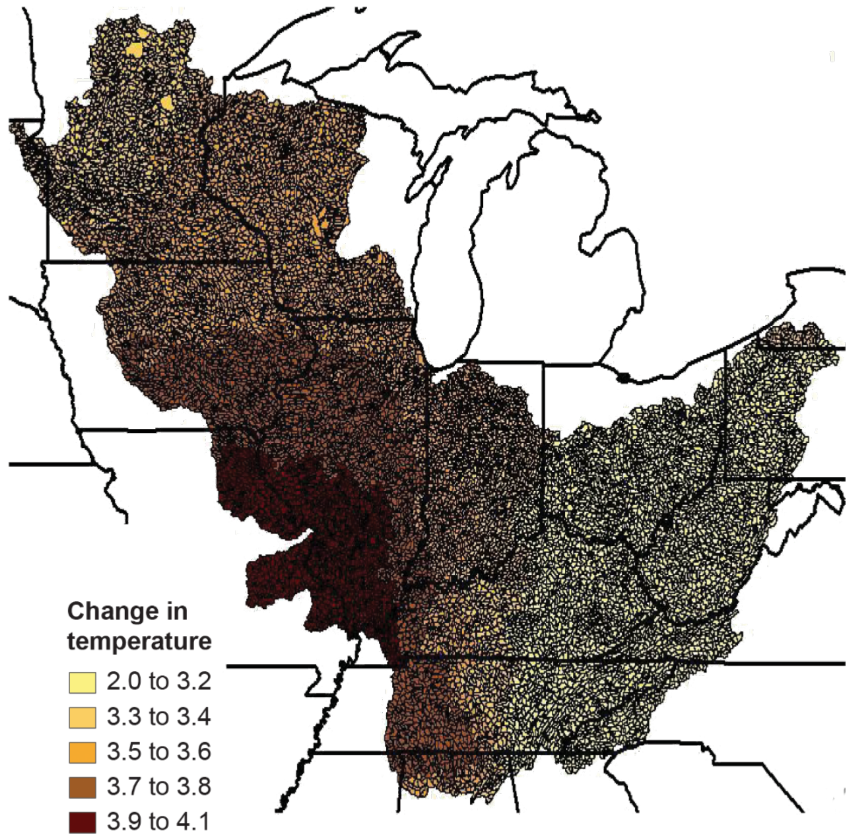
The *Global Circulation Model* indicates these changes in mean annual precipitation and temperature between baseline (1981-2000) and future (2046-2065) climate





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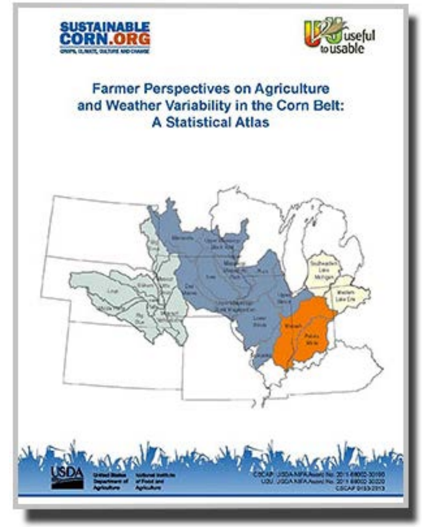
2. Incorporate information from farmers about how they might adapt to altered climate



Survey:

- Sample represents ~60% of U.S. corn production
- Larger-scale farmers: $100k+ Gross Revenue, ~80% of farmland
- Sample size 4,778 farmers (26% response rate) covering the corn belt states (11 states)
- See J. Arbuckle’s presentation for lots more insight from the survey

Partnership with U2U, Survey conducted by National Agricultural Statistics Service

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Behavioral Intentions Under Climate Change Scenario

Objective: Explore what farmers intend to do under a realistic climate change scenario.

The Scenario

- Violent storms/extreme rain events will become more frequent, particularly in the spring.
- More extreme rain events will increase the likelihood of flooding and saturated soils.
- Periods between rains will become longer, increasing likelihood of drought.
- Changes in the weather patterns will increase crop insect, weed and disease problems.

The Question

If you knew with certainty that the above conditions would occur, would the following practices on the cropland you own and rent decrease, increase, or stay the same?

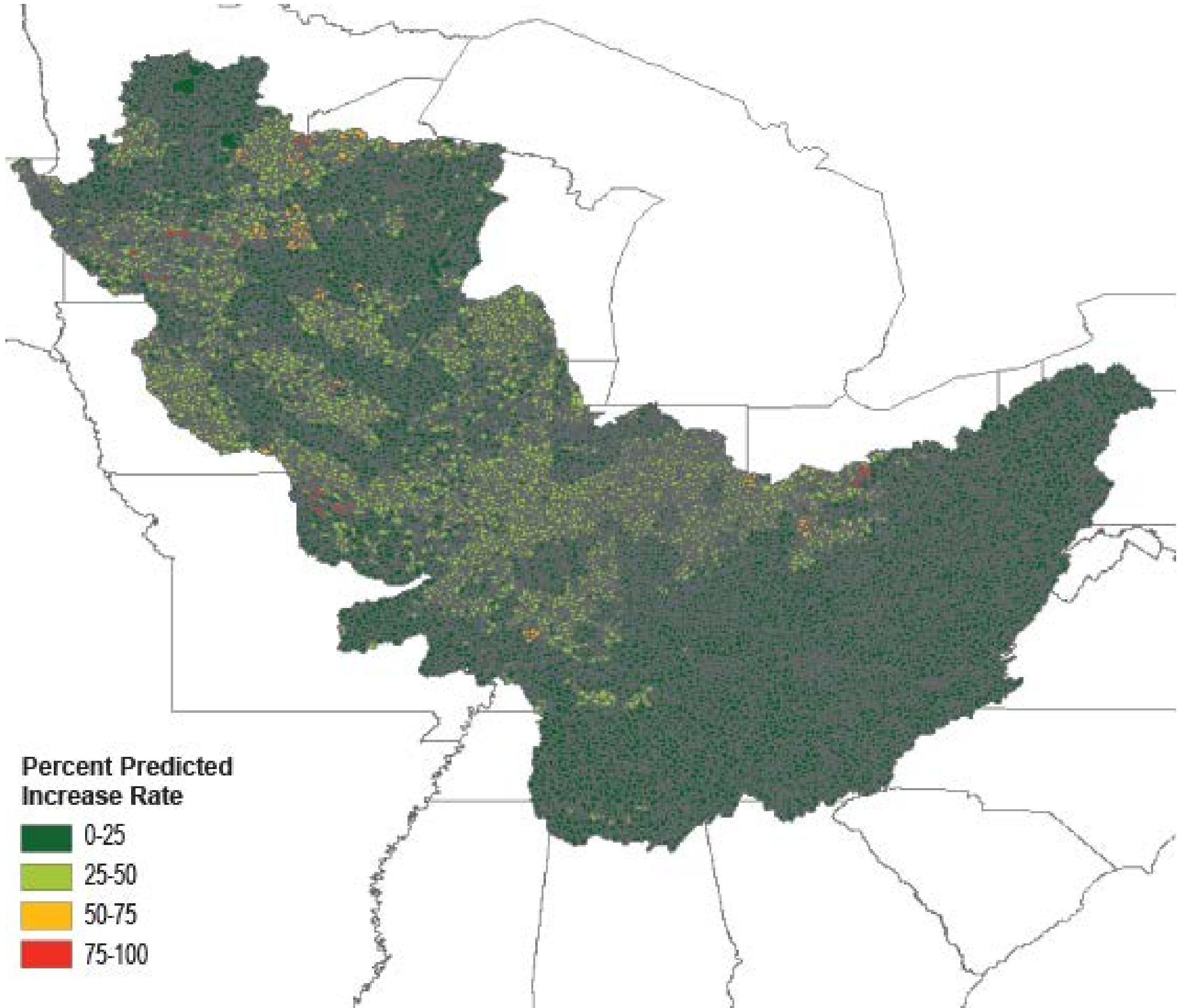
Adaptation Intentions

in Response to Increased Extremes

Practices	% Decrease	% Stay the Same	% Increase
No-till	1.6	48.0	24.4
Edge-of-field conservation (filter and buffer strips)	1.8	52.1	14.5
Reduced Tillage (strip, ridge tillage)	2.2	49.6	19.8
Cover Crops	0.9	38.0	21.7
In-field structural conservation (grassed waterways, contour buffer strips, terraces)	0.3	53.6	26.3
Subsurface tile or other drainage	1.0	31.5	43.2

Increase of Edge-of-field Conservation Practices in Future Scenario

Percentage of farmers answered increase: 22%



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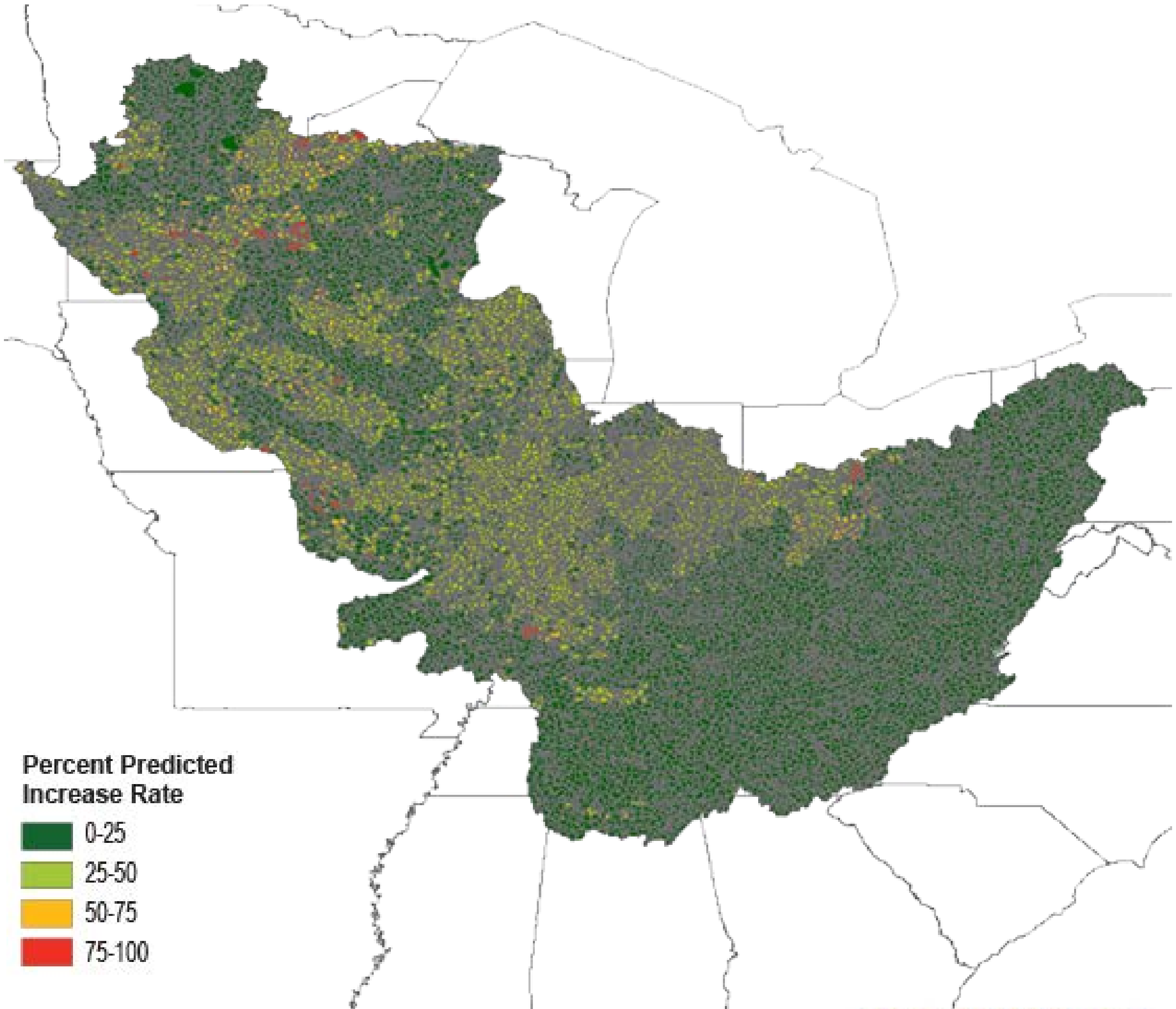
Increase of In-field Conservation Practices in Future Scenario

Percentage of farmers answered increase: 33%



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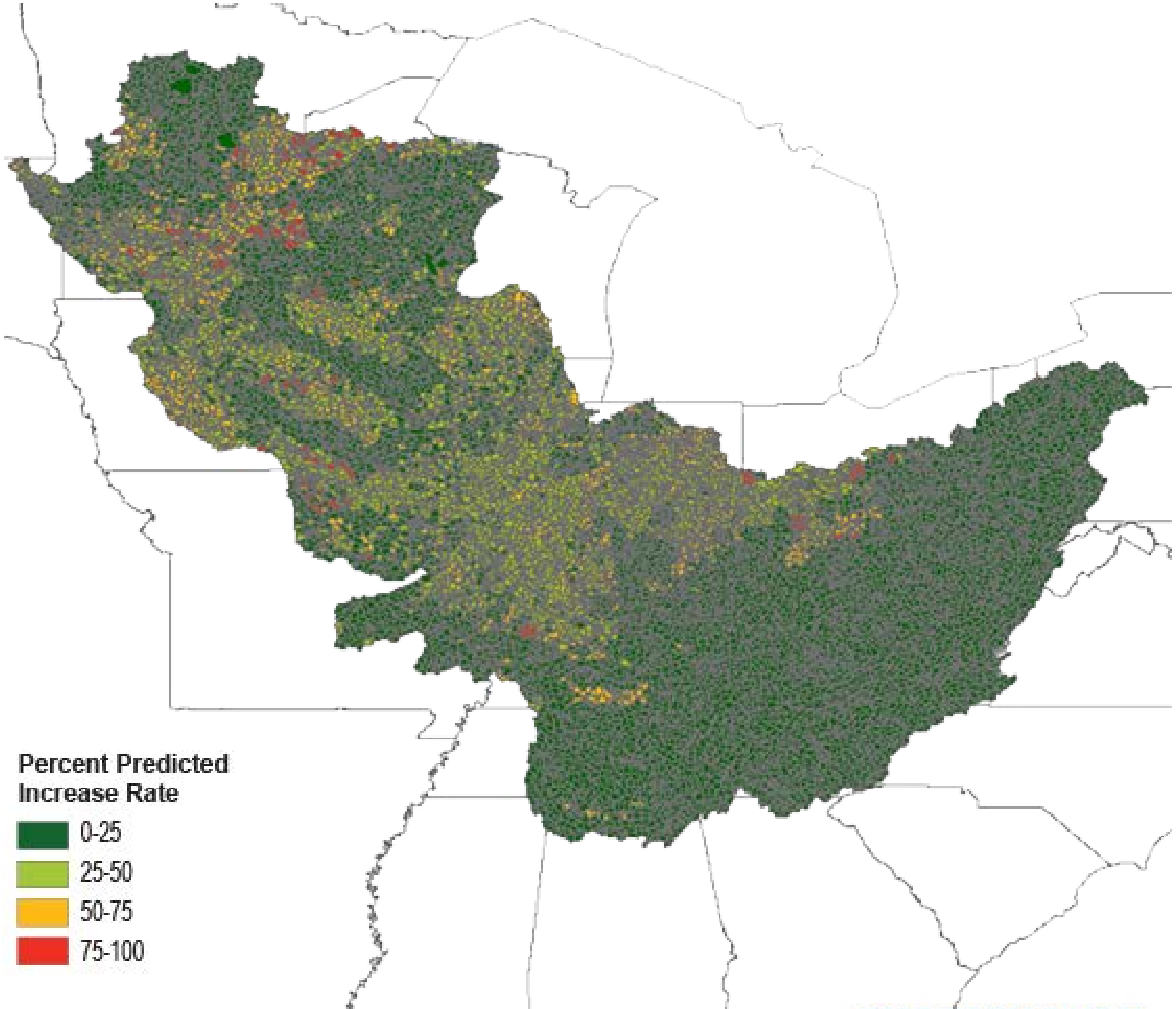
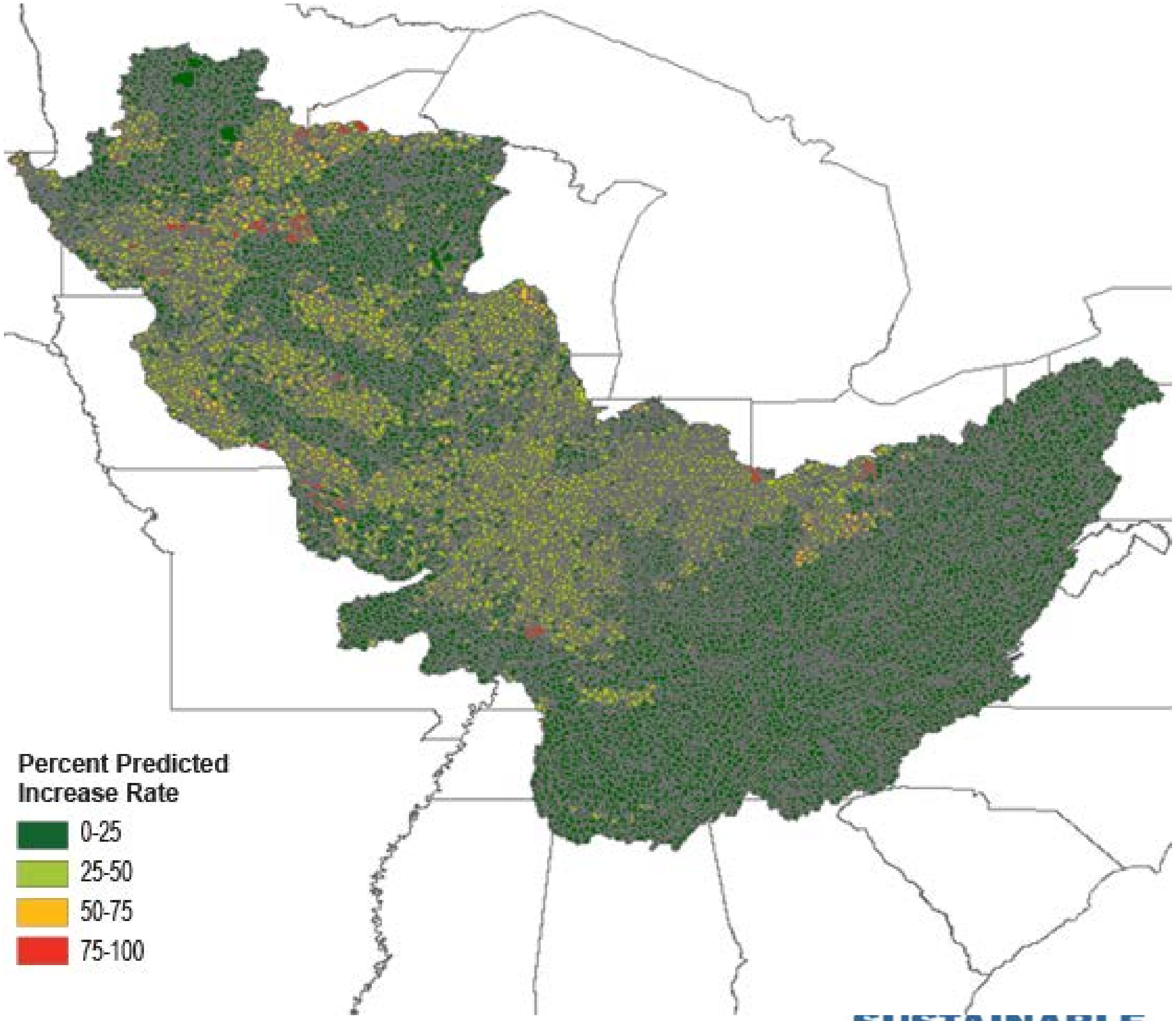
Increase of Cover Crop Practices in Future Scenario

Percentage of farmers answered increase: 36%



Increase of Conservation Tillage Practices in Future Scenario

Percentage of farmers answered increase: 34%



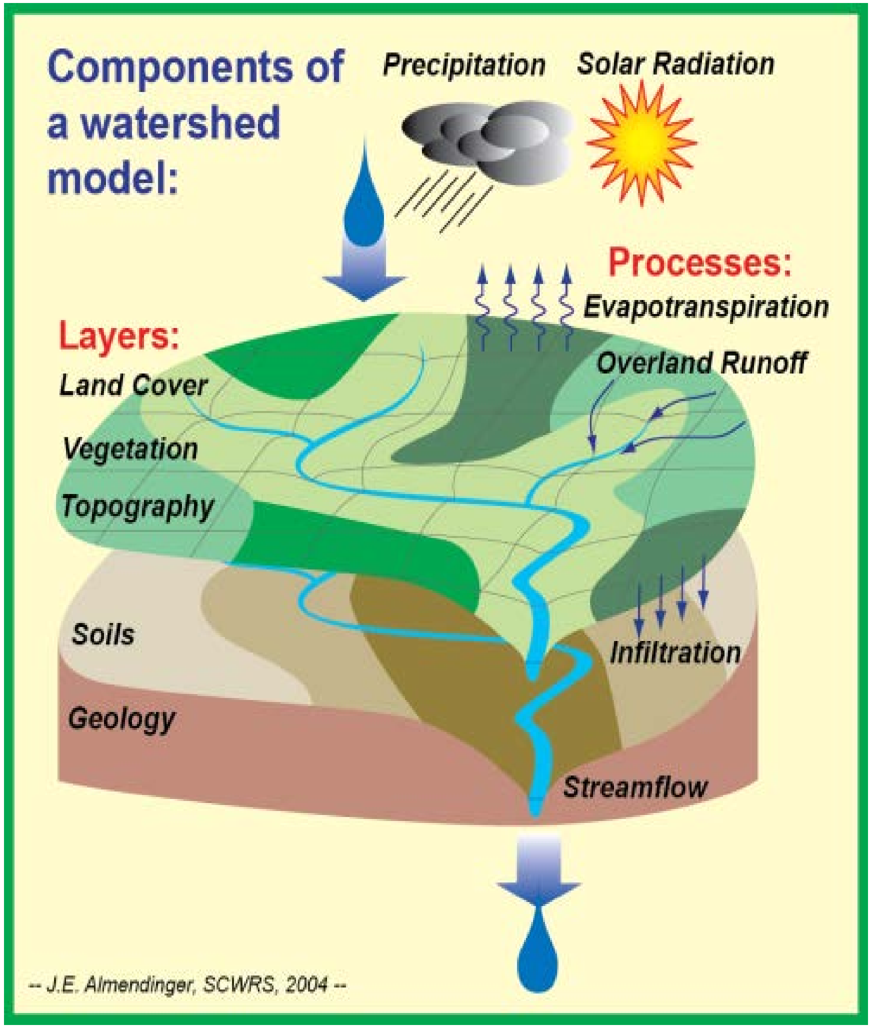
3. Integrate this information with a landuse and water quality model

Use the model to:

- Evaluate consequences of the climate scenario for
  a. water quality (nutrient loading)
  b. and yields

- Evaluate consequences of farmer adaptation for
  a. water quality (nutrient loading)
  b. and yields

Components and Key Data for the Soil and Water Assessment Tool (SWAT) Model



Gory details available in:

Arnold, J.G. et al. Large area hydrologic modeling and assessment *Journal of the American Water Resources Association*. 1998.

Gassman, P.W. et al. The Soil and Water Assessment Tool: historical development, applications, and future research directions. *Transactions of the ASABE*. 2007.

Kling, C.L. et al., Land Use Model Integrating Agriculture and the Environment: Linkages between Agricultural Land Use, Local Water Quality and Hypoxic Concerns in the Gulf of Mexico," *European Review of Agricultural Economics.* 2014.

Panagopoulos, Y. et al. Surface water quality and cropping systems sustainability under a changing climate in the U.S. Corn Belt region. *Journal of Soil Water Conservation.* 2014.

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Data Sources for UMRB-OHTB SWAT model

Data layer	Description of data layer	Primary data sources
Daily climate	Daily precipitation and maximum and minimum temperature; other data generated in model	NCDC-NOAA (2012)
Soil map / layer data	1:250,000 soil map; pertinent soil layer attributes included for each soil type	USDA-NRCS (1994; 2012b)
Major dams / reservoirs	Key reservoirs on main channels of the Ohio and Mississippi Rivers, and major tributaries	USACE (2012)
Topographic	30 m digital elevation model (DEM) data used to characterize slopes and slope lengths	USGS (2006)
Land Use	Assignment of crop rotations or other landuse to each subwatershed; dominant rotations were 2-year sequences of corn and soybean	USDA-NASS (2012)
Point Sources	N and P discharged from thousands of waste treatment plants and other point sources across the two study regions	Maupin and Ivahnenko (2011); Robertson (2013)
Subsurface tile drainage	Installed at assumed depth of 1.2 m in poorly drained and relatively flat soils (< 2% slope)	Sugg (2007); Neitsch et al. (2009)
Tillage practices	Notill, mulch till, reduced till, and conventional till practices represented as a function of tillage passes and residue cover, and other parameters	Baker (2011); Neitsch et al. (2009)
Fertilizer and manure	Nitrogen and phosphorus rates applied in inorganic fertilizer and manure; average rates used for landscapes located within each state	IPNI (2010)
Other conservation practices	Proxy approach used to represent terraces, contouring, and other practices as a function of slope and slope length	USDA-NRCS (2012a); Arabi et al. (2008); Neitsch et al. (2009)

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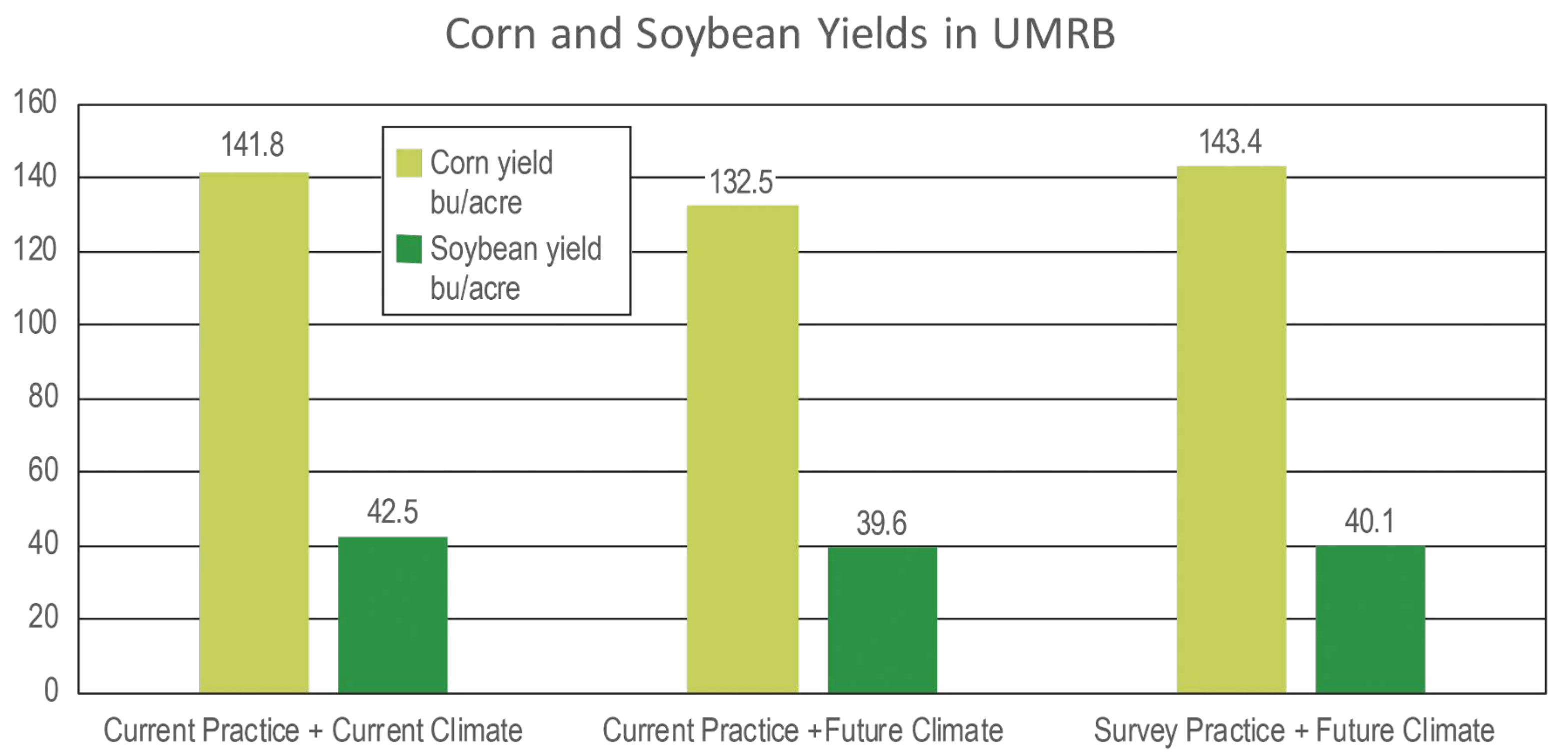
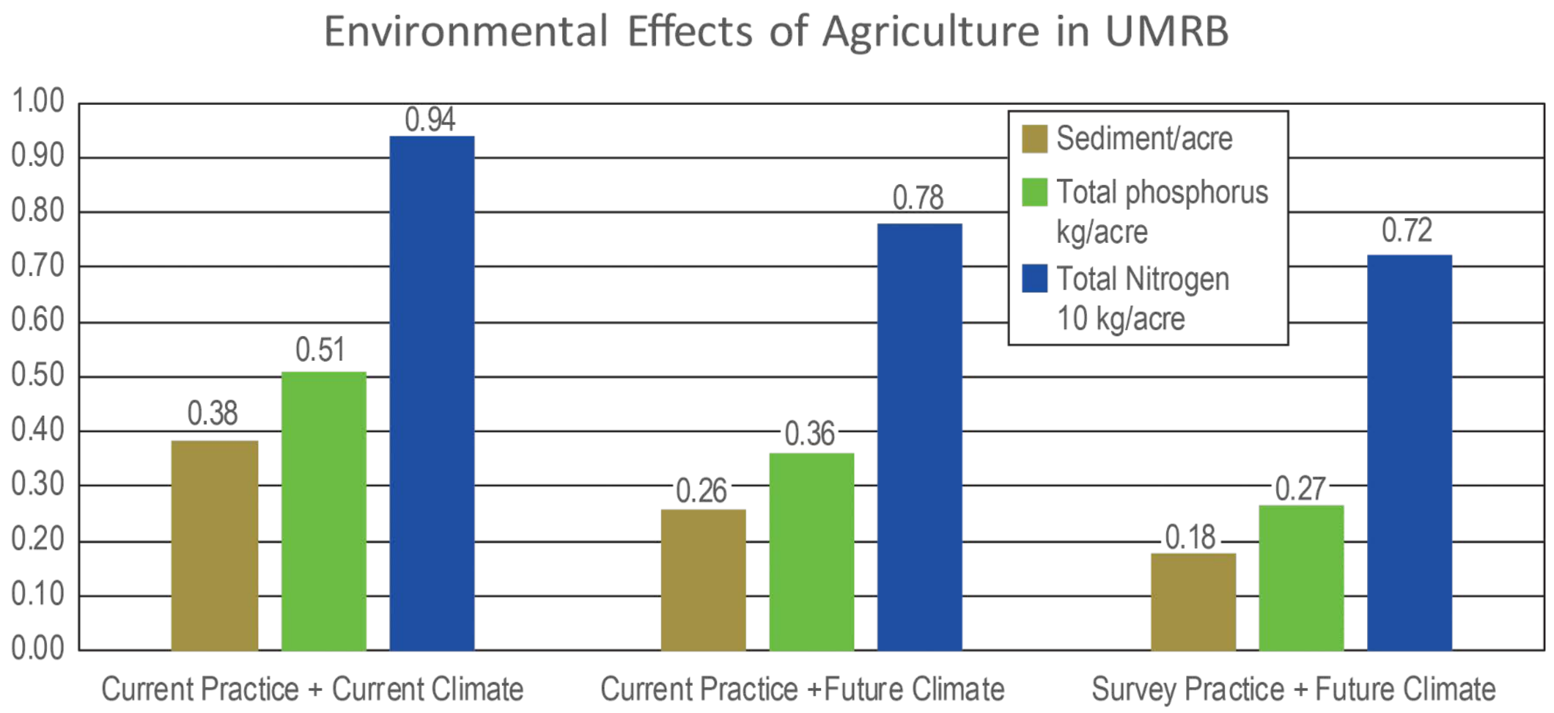
Scenario Findings for Yields



Scenario Findings for Sediments and Nutrients



Caveats

1. Only a single GCM used, storm events not well represented.
2. Many assumptions made in going from survey answers to SWAT model assumptions (e.g., definition of practices, extent of coverage of changed practices)
3. Spatially rich SWAT model has been developed but will continue to be improved as additional data and CSCAP results become available.
4. Many other adaptation strategies are possible and not considered here.

Takeaways

1. Agriculture in the central U.S. is expansive in scope with wide ranging effects on water quality and the environment
2. Climate change will alter that relationship, probably with general trends becoming increasingly known, but not specifics
3. Farmer's have the knowledge to make on the ground changes to adapt to changing climate and indicate that they plan to do so
4. These changes will affect their bottom line (yield) and the environment around them (water quality)

In addition to substantial funding from the USDA-NIFA, Award No. 2011-68002-30190, "Climate Change, Mitigation, and Adaptation In Corn-Based Cropping Systems," additional support was provided by USDA-NIFA Award No. 2011-68005-30411 and from the National Science Foundation, Awards No. DEB1010259 and WSC1209415

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