Chris Jones, Research Engineer, IIHR Hydroscience and Engineering

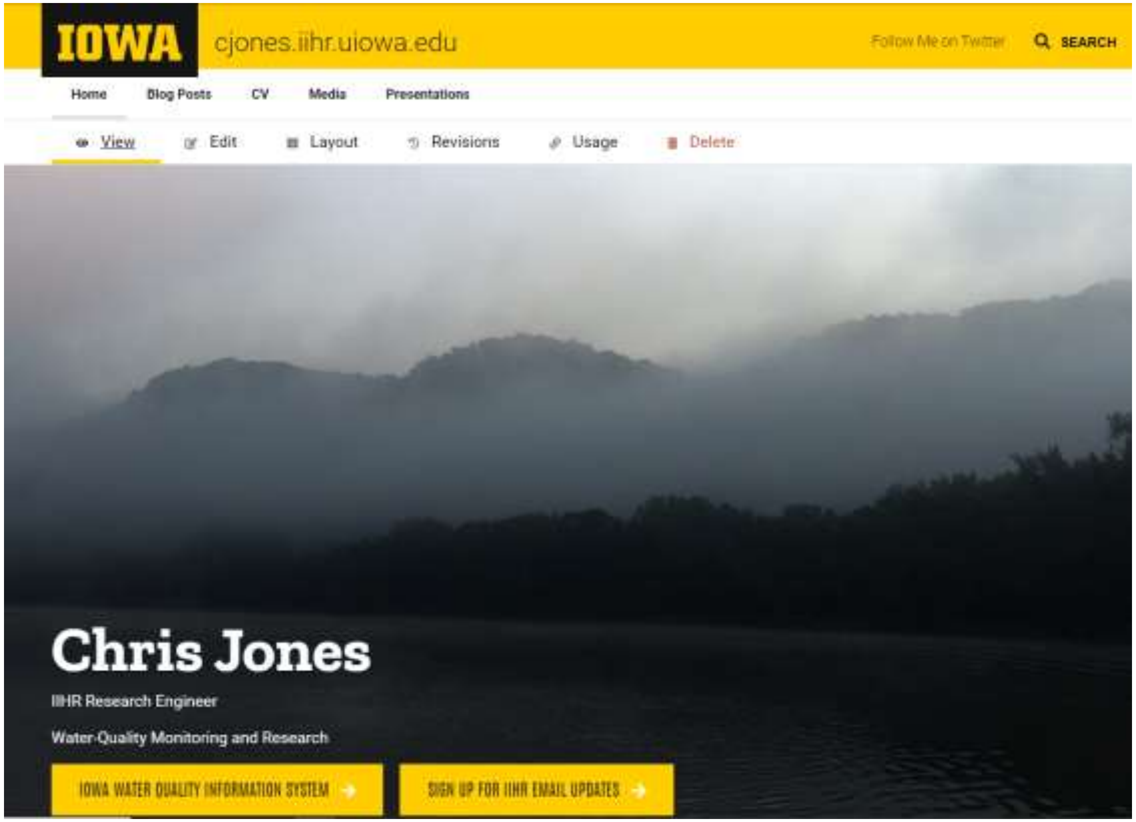
Drivers of Nutrient Pollution in the Corn-Soy-Ethanol-CAFO Production System

March 10, 2022

Graduate Seminar in Electrical & Computer Engineering, Spring 2022

Slides Available at:

https://cjones.iihr.uiowa.edu/

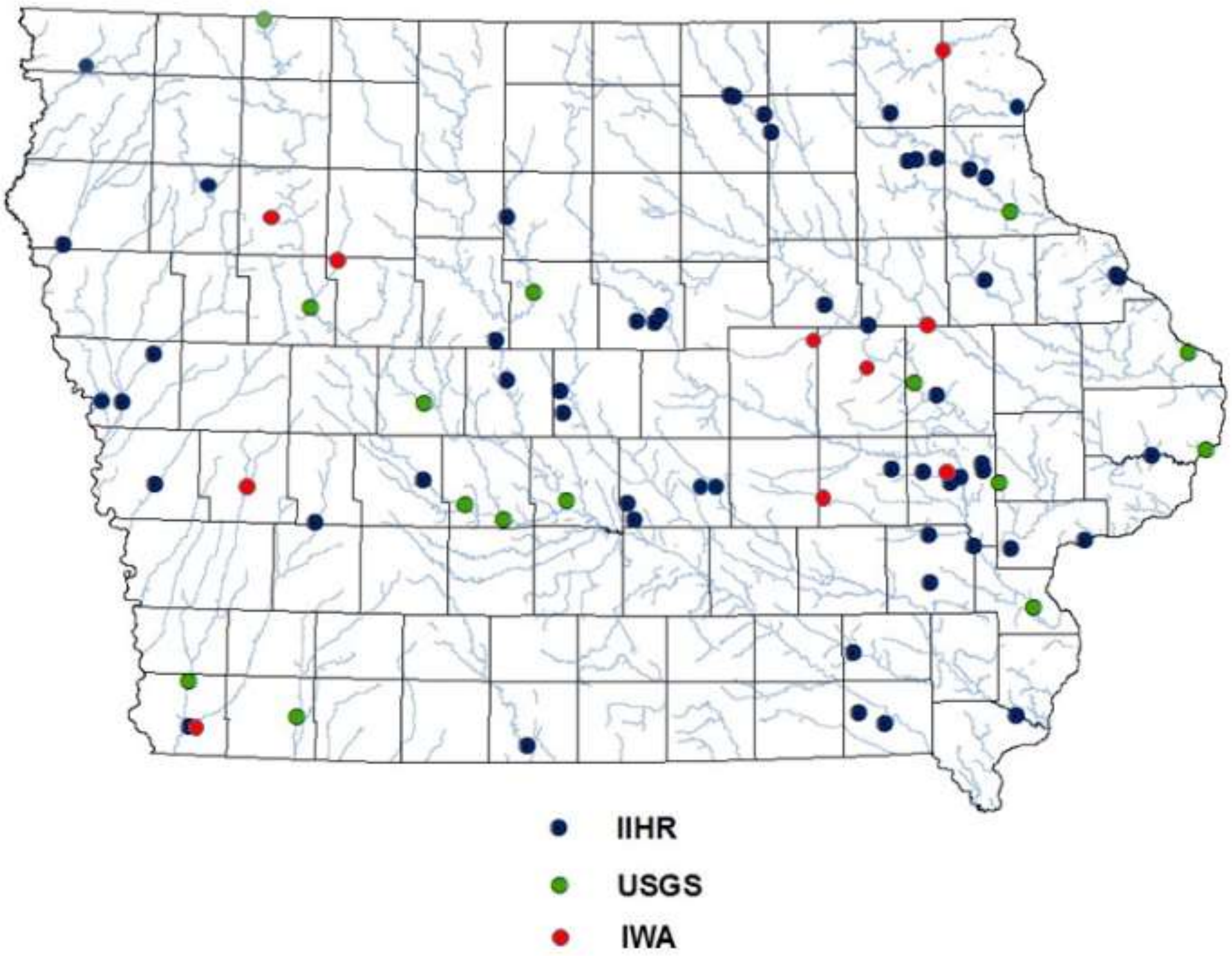


IIHR Water Quality Sensor Network

Sites

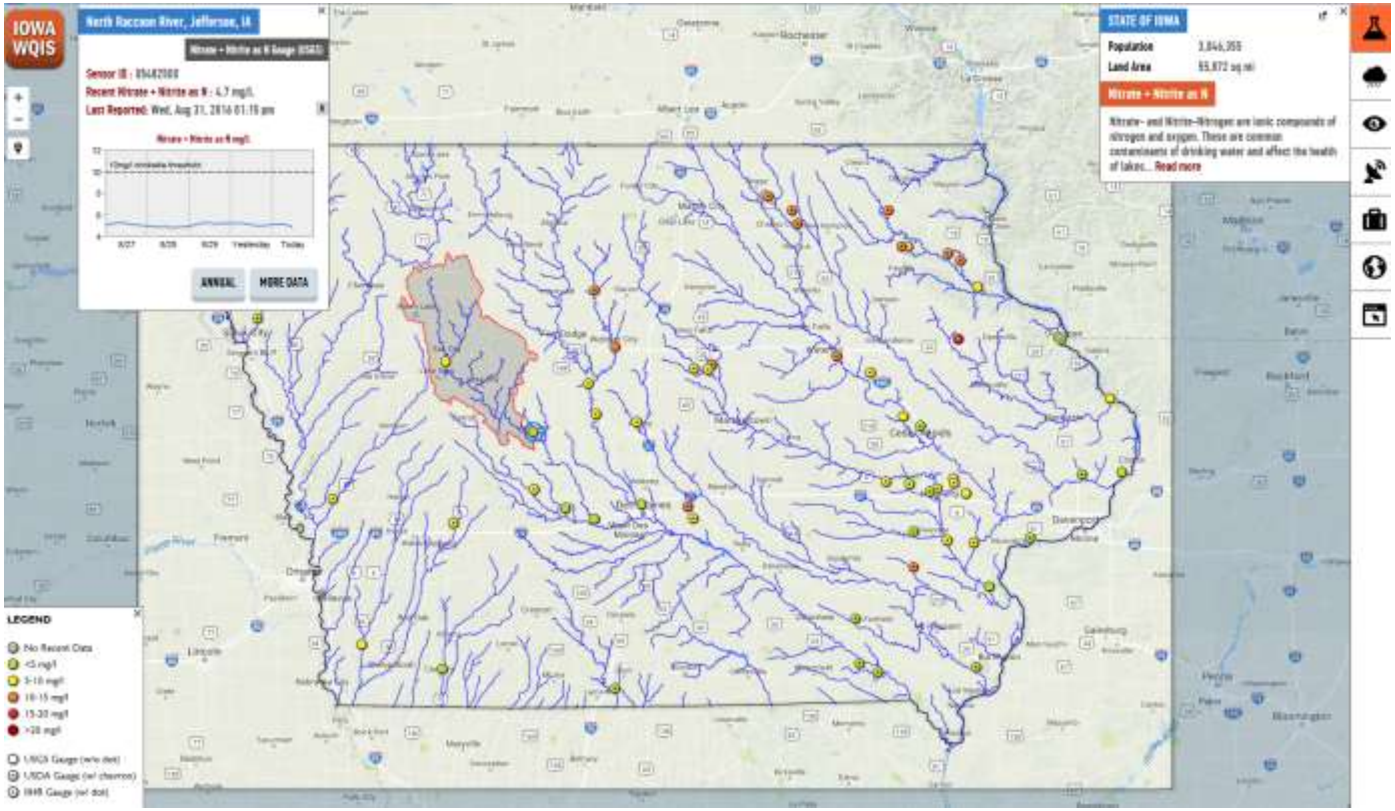
70+ sites
Nitrate-N

20-25 sites
- Temperature
- pH
- SC
- DO
- Turbidity



Site infrastructure

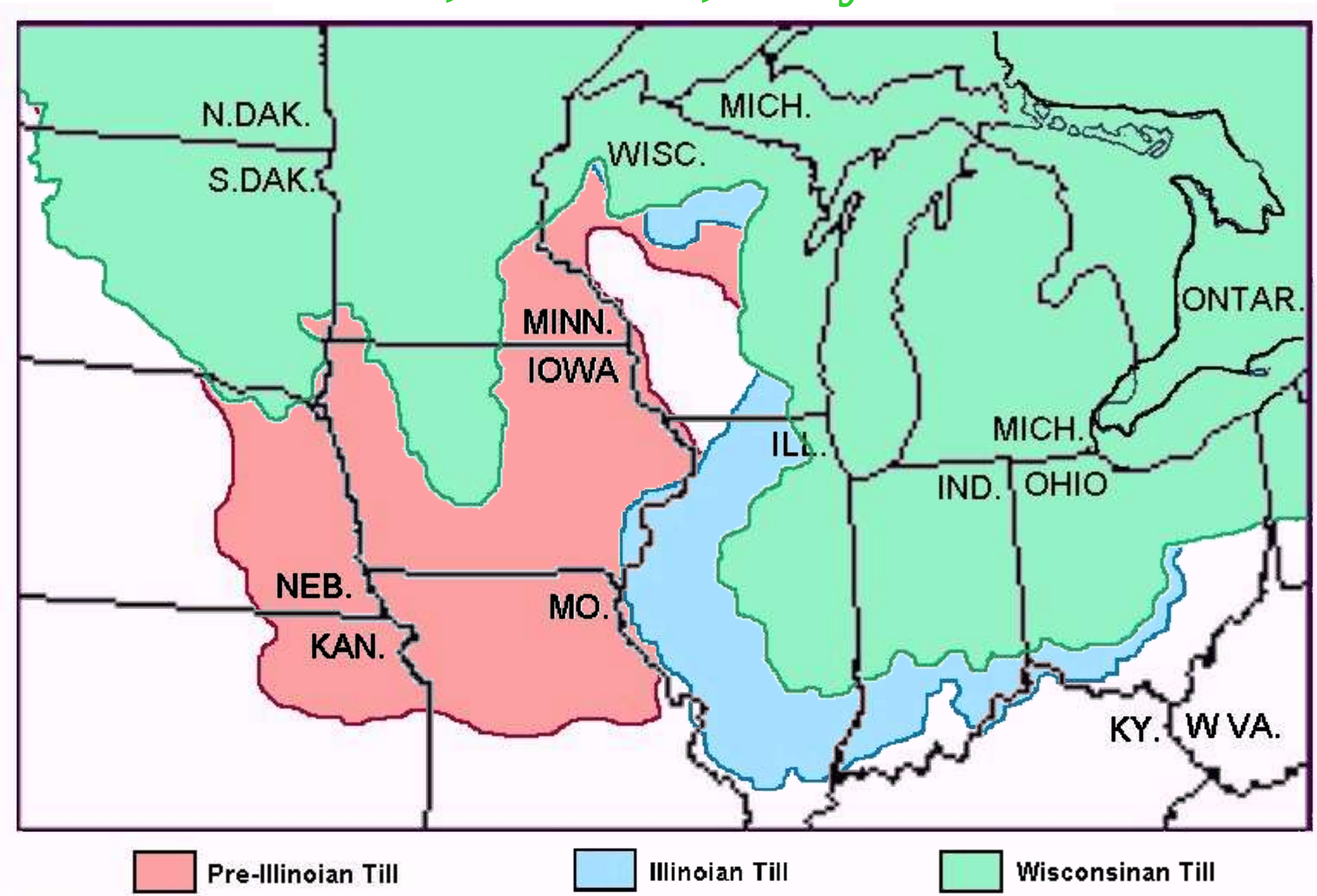
Iowa Water Quality Information System

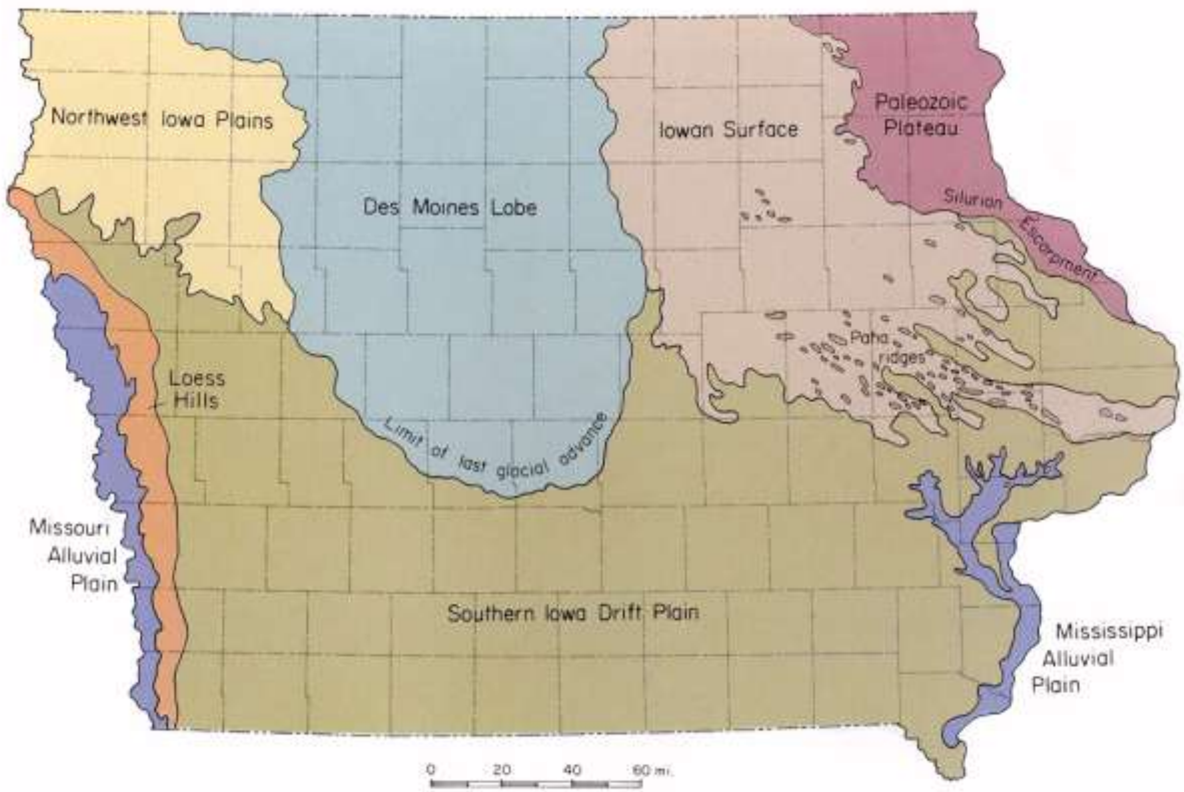


iwqis.iowawis.org/

http://iwqis.iowawis.org/app/?datetime=2017-06-06T13:00

30,000 – 10,500 years





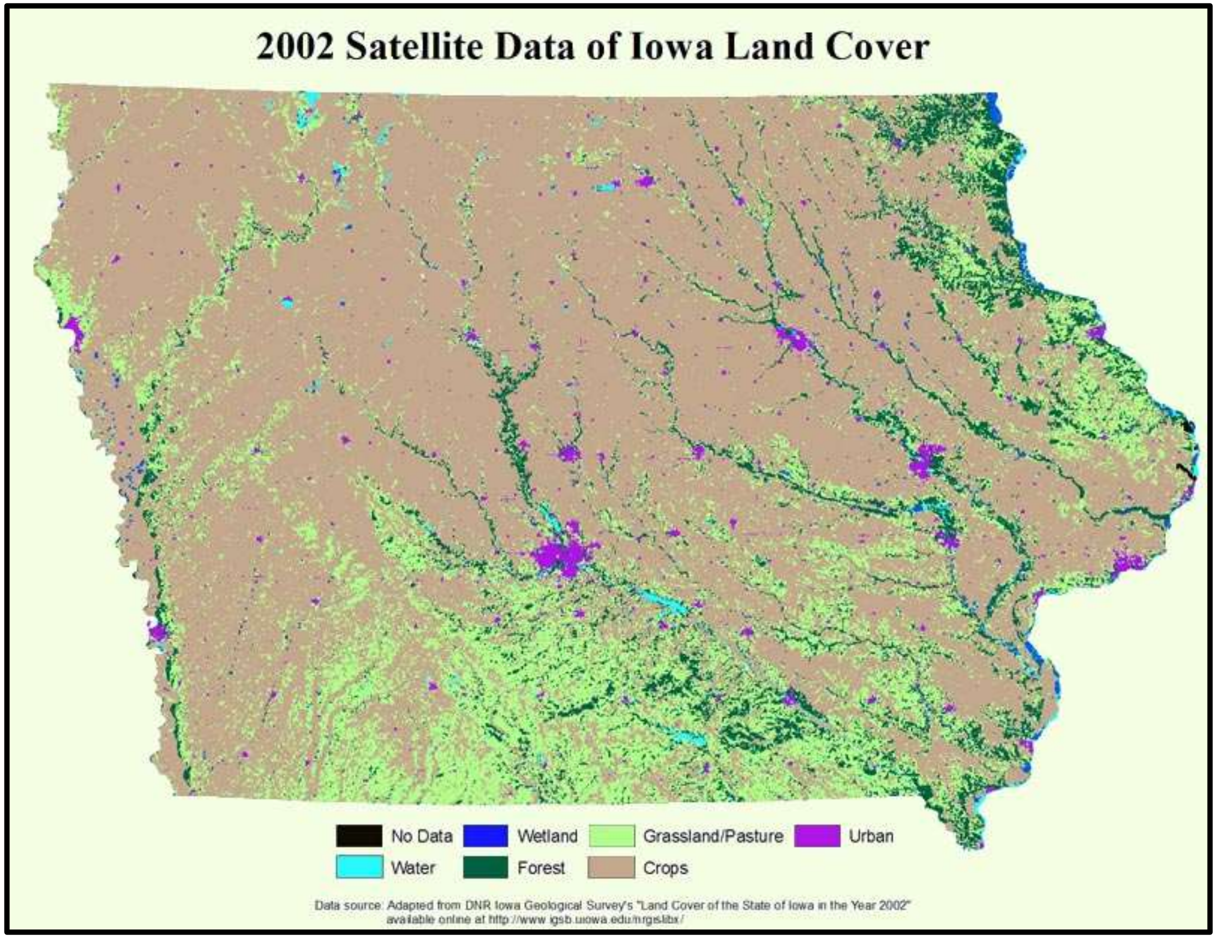
Landform Regions of Iowa


Wetland: 20% of Iowa, 7.6 million acres

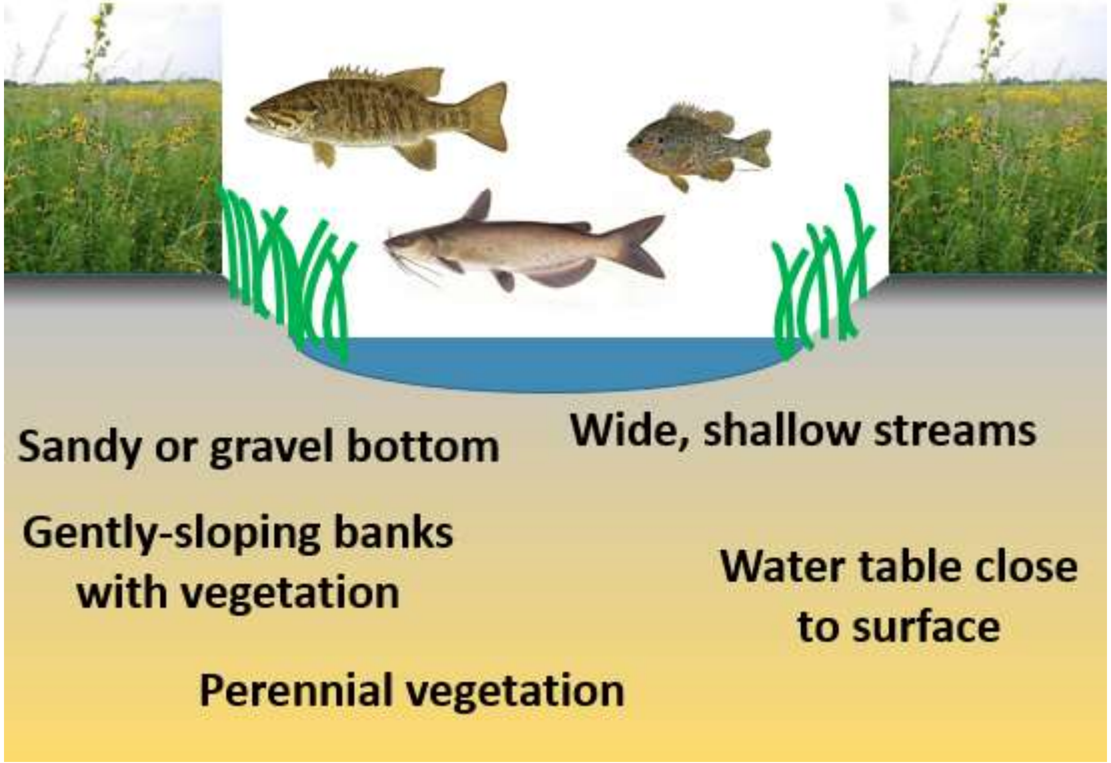

Oak Savannah: ~5%, < 1% remains


Prairie: 70%, 0.1% Remains

Iowa Land Cover



Pre-European Settlement Streams



Hydrological Modification: 1860s-1910s

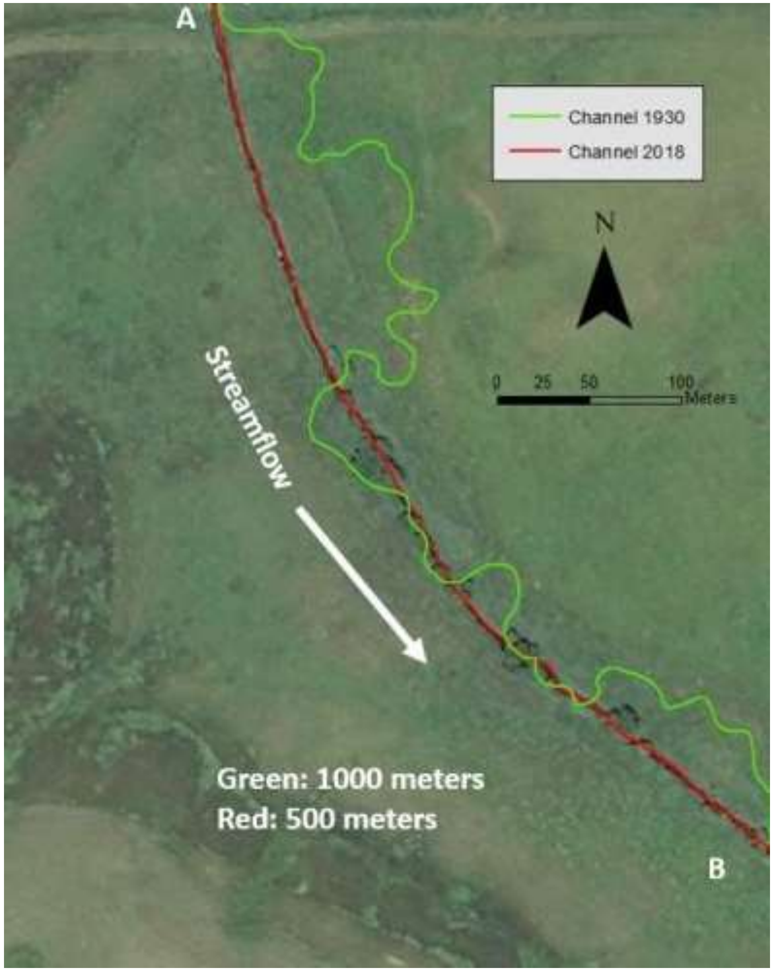
Excavating a large ditch using steam power, circa 1910.

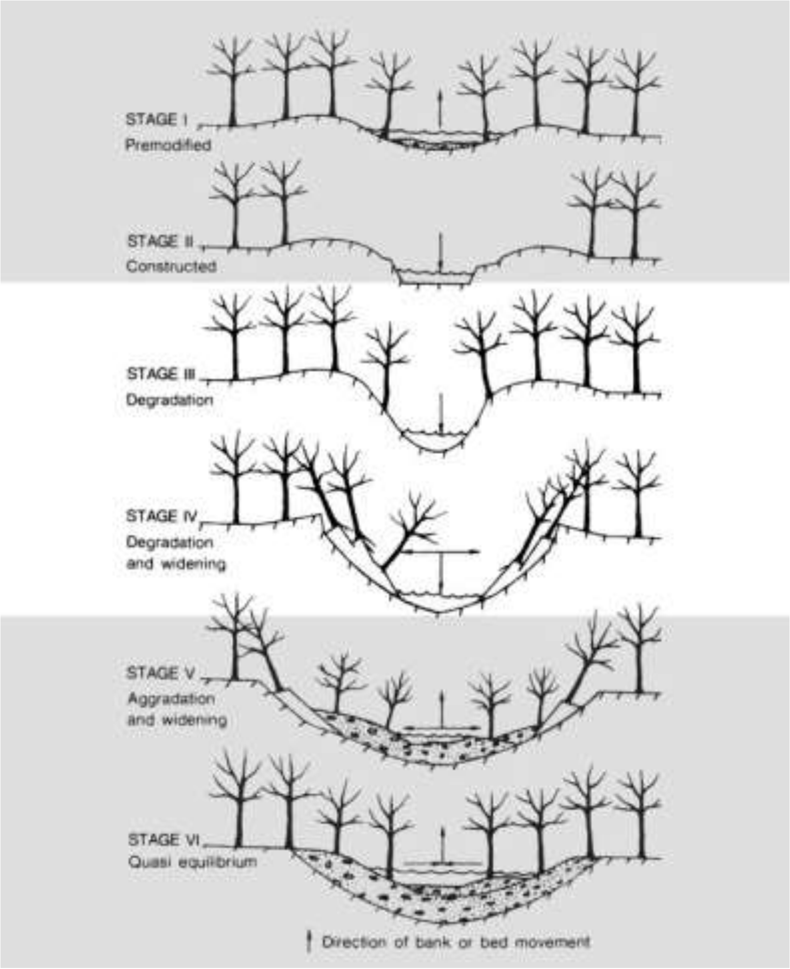
Hand digging tile, Boone Co. IA. ca 1914
Source: 'An Iowa album: a photographic history, 1860-1920' by M. J. Bennet, University of Iowa Press, Iowa City, Iowa

Tiling field now

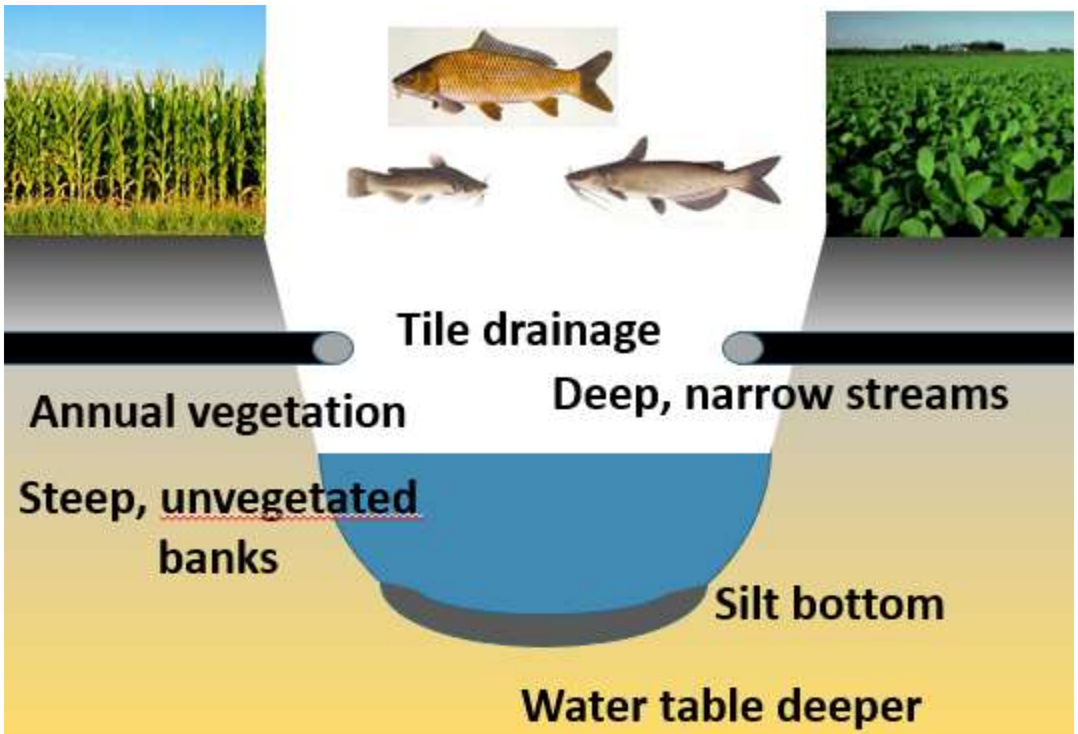
Source of the Iowa River

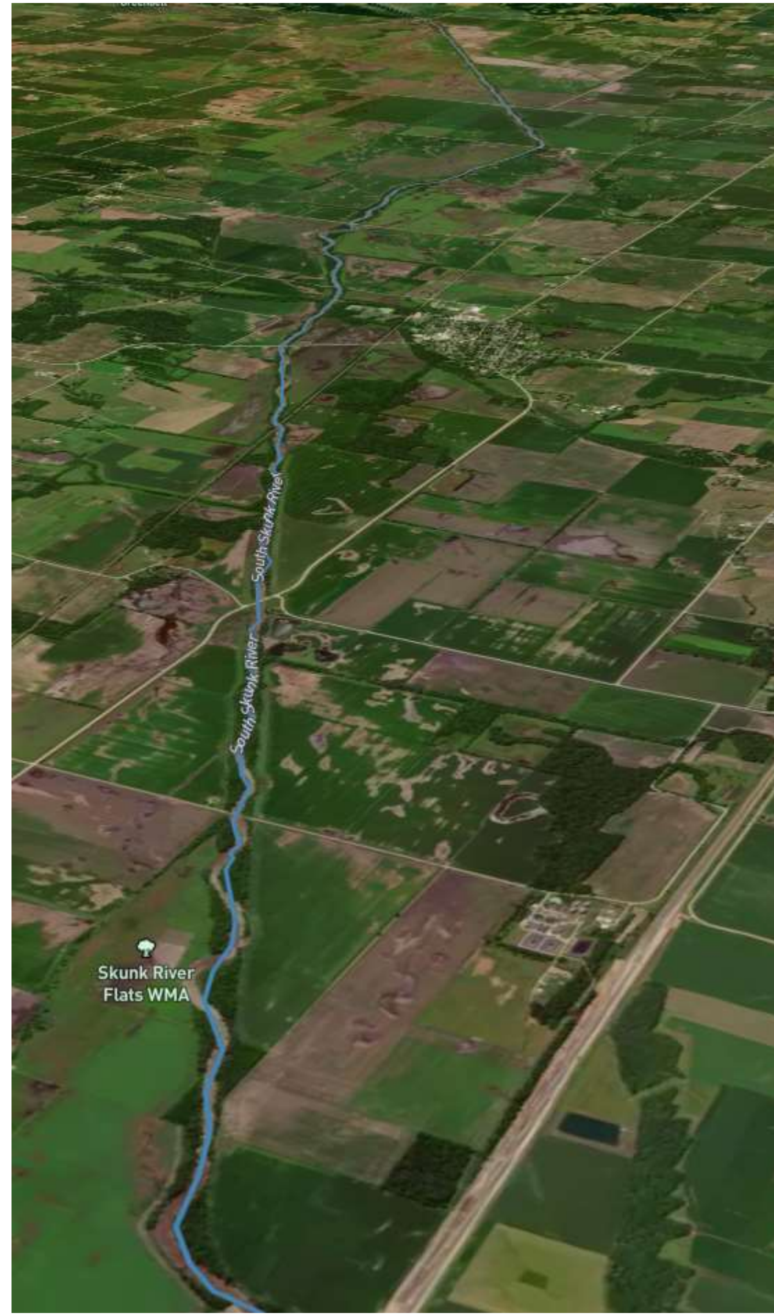
Stream Straightening, 1930-1975





Modified Streams





Transformation of Iowa Farms

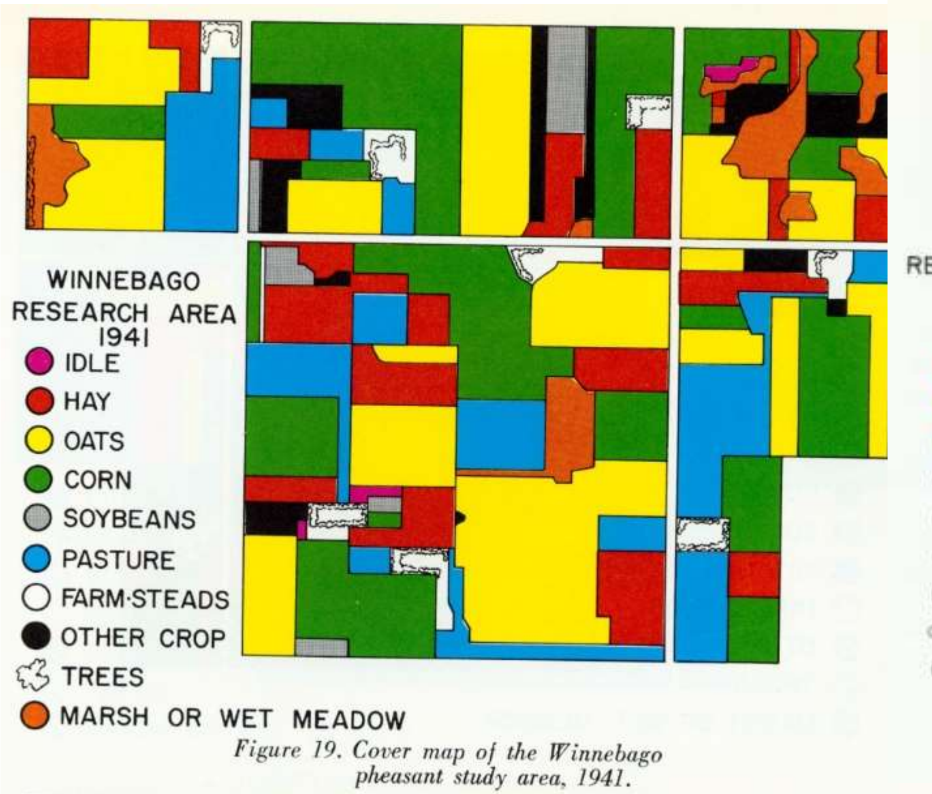


Figure 19. Cover map of the Winnebago pheasant study area, 1941.

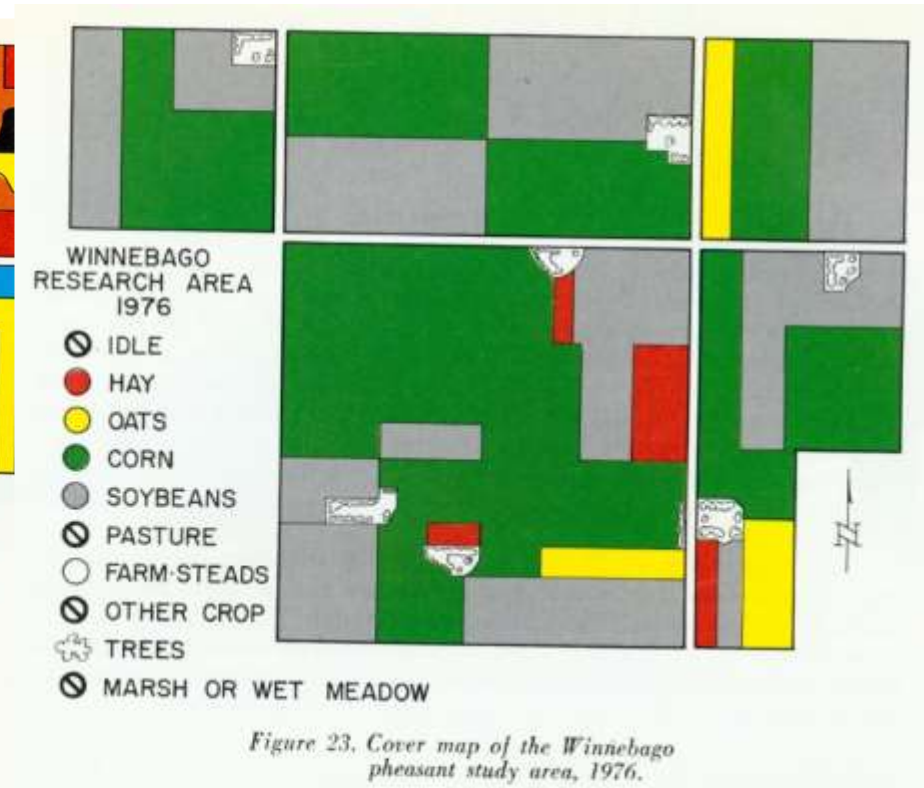


Figure 23. Cover map of the Winnebago pheasant study area, 1976.

1941

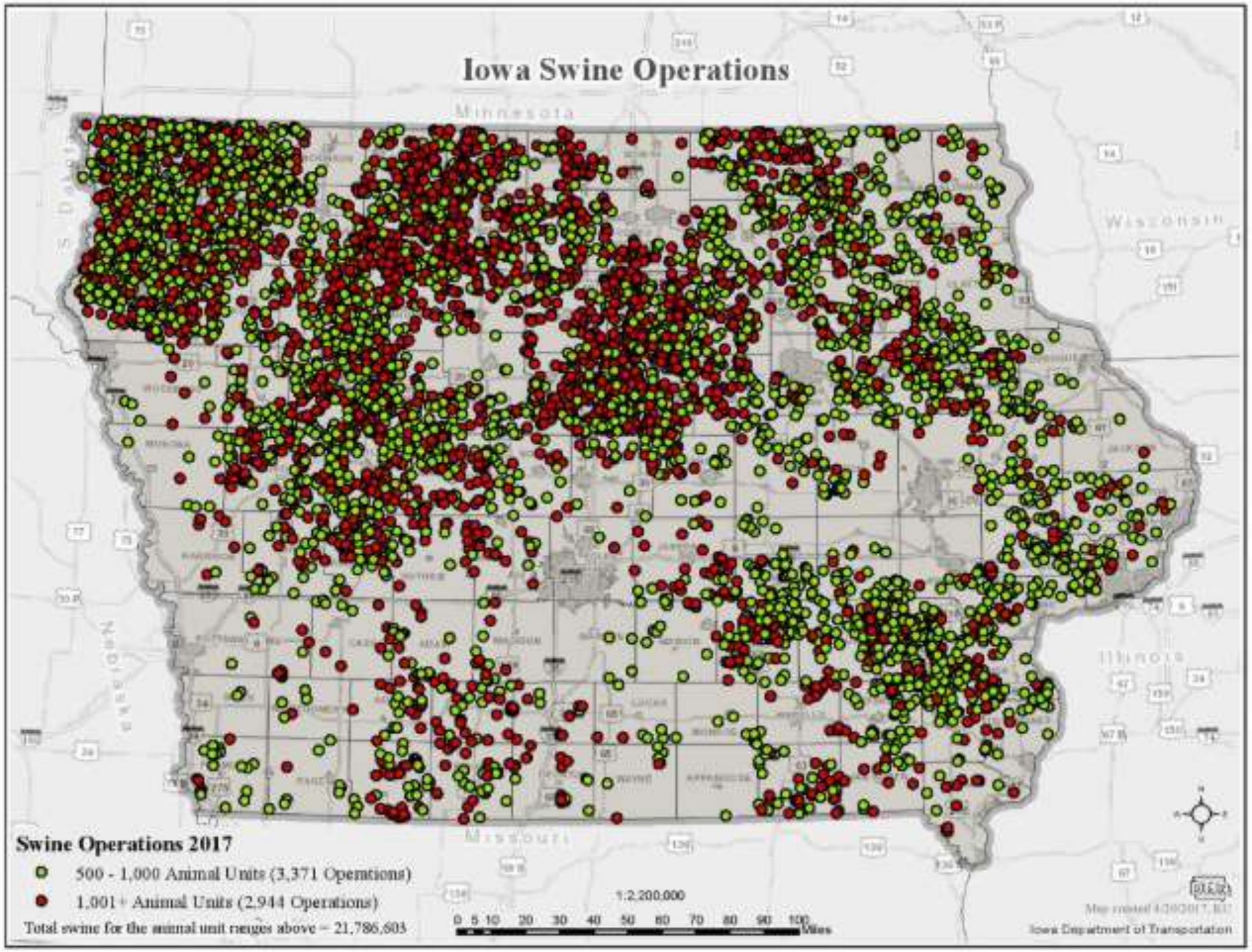
1976




Transformation required Simplification

- Many crops to two crops
- Plant-based energy to fossil fuel energy
  - Animals to tractors and other machinery, 80% had a tractor by 1950
- Organic Fertilizers to Inorganic Fertilizers (Post WWII)
- Many farmers (230,000 in 1951) to Fewer farmers (85,000 today)
- Livestock on almost all farms to livestock on only a few
  - 1980: 65,000 farmers raising 13 million hogs
  - Now: 5,000 farmers raising 25 million hogs
- GMO Crops
  - Roundup Ready Soybeans and Corn (87% of soy RR by 2005)
  - Bt Corn (82% of US Corn Crop)

8000 CAFOs



Iowa Swine Operations
Minnesota
Wisconsin
Illinois
Missouri
Swine Operations 2017
500 - 1,000 Animal Units (3,371 Operations)
1,001+ Animal Units (2,944 Operations)
Total swine for the animal unit ranges above = 21,786,603
1:2,200,000
0 5 10 20 30 40 50 60 70 80 90 100 Miles
Iowa Department of Transportation

Problem of Scale

- 70% of land in corn-soy rotation
- 11,000 square miles used for ethanol production
- 25 million hogs
- 4 million beef cattle
- 80 million laying chickens
- 5 million turkeys
- 4 million broiler chickens
- 220,000 dairy cows

Water Quality Consequences

Nutrients

Nitrogen: Applied as anhydrous ammonia, urea, UAN, manure, MAP and NAP.

Converted to nitrate in the soil profile, mediated by bacteria

Roughly 40% applied in fall, 60% in spring

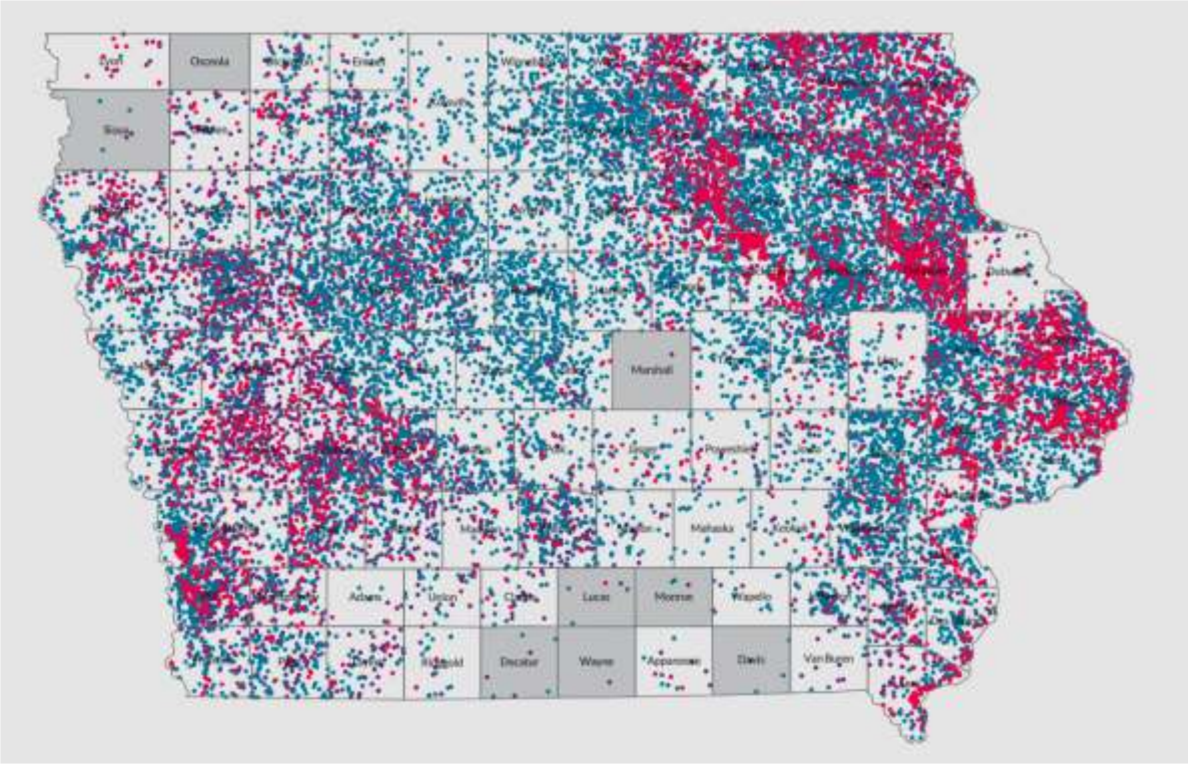
Especially important in marine ecosystems

VERY WATER SOLUBLE

Loss through tile systems and leaching to groundwater

Nitrate: NO_3^-
Regulated drinking water contaminant since 1974
Limit: 10 ppm (as N)

Drinking Water



7000 private wells have tested above the safe drinking water level of 10 mg/L since 2000

1/3 of Iowa's Public Water Supplies are vulnerable to nitrate contamination

60 PWSs are removing nitrate

25% of Iowa drink water that has been treated for nitrate reduction

Drinking Water

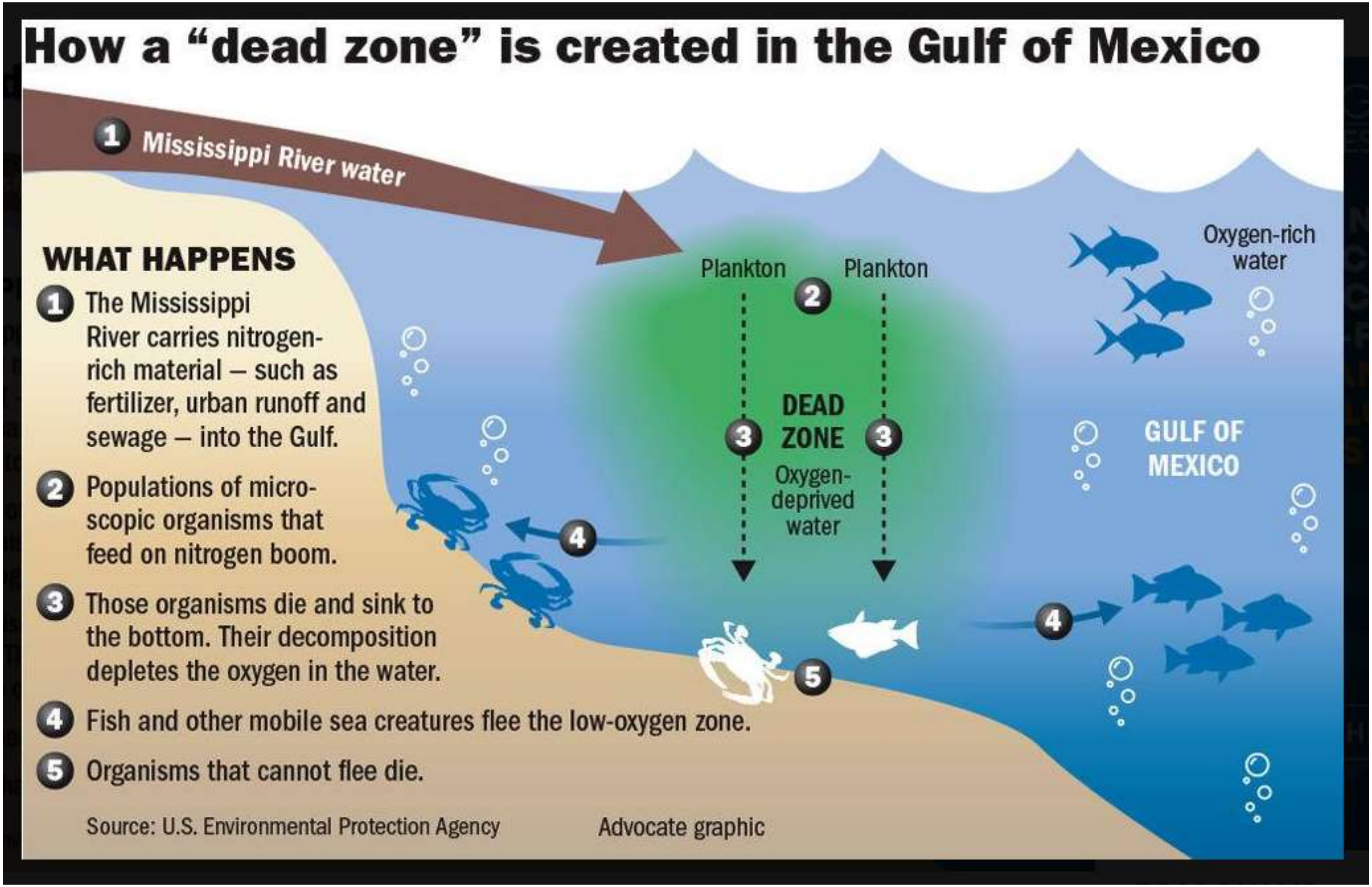
Toledo, OH

Des Moines, IA

Surface Water

Lake Erie Algae Blooms

Gulf of Mexico Hypoxia


How a "dead zone" is created in the Gulf of Mexico
1 Mississippi River water
WHAT HAPPENS
1 The Mississippi River carries nitrogen-rich material – such as fertilizer, urban runoff and sewage – into the Gulf.
2 Populations of micro-scopic organisms that feed on nitrogen boom.
3 Those organisms die and sink to the bottom. Their decomposition depletes the oxygen in the water.
4 Fish and other mobile sea creatures flee the low-oxygen zone.
5 Organisms that cannot flee die.
Source: U.S. Environmental Protection Agency
Advocate graphic
Plankton
2
Plankton
DEAD ZONE
3
3
Oxygen-deprived water
4
4
5
Oxygen-rich water
GULF OF MEXICO

United States Environmental Protection Agency

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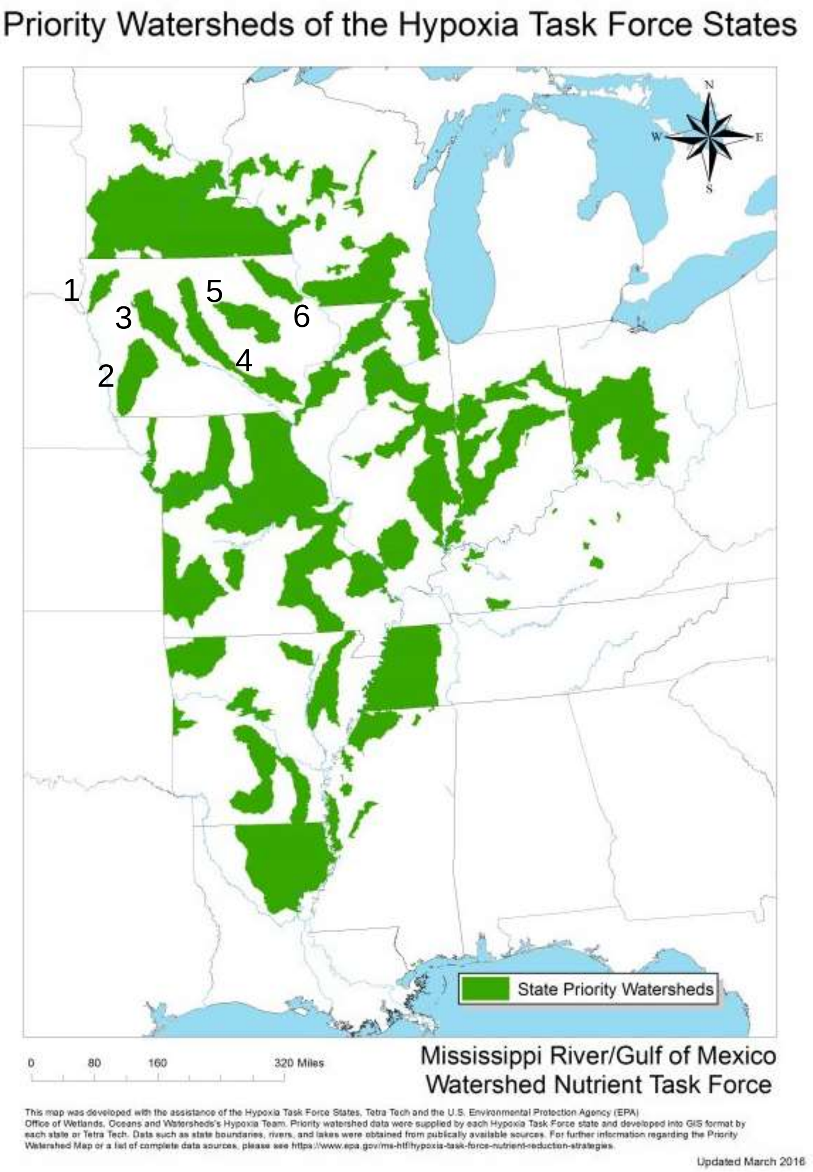
CONTACT US

Mississippi River/Gulf of Mexico Hypoxia Task Force

Iowa Priority Watersheds

1) Floyd
2) Nishnabotna
3) North Raccoon
4) Skunk
5) Middle Cedar
6) Turkey



IOWA STATE UNIVERSITY

Iowa Nutrient Reduction Strategy

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- Iowa Nutrient Research Center

Iowa Nutrient Reduction Strategy

The Iowa Nutrient Reduction Strategy is a science and technology-based framework to assess and reduce nutrients to Iowa waters and the Gulf of Mexico. It is designed to direct efforts to reduce nutrients in surface water from both point and nonpoint sources in a scientific, reasonable and cost effective manner.

The Mississippi River/Gulf of Mexico Watershed Nutrient Task Force was established in 1997 to coordinate activities to reduce the size, severity and duration of hypoxia in the Gulf. Hypoxia is a large area of low oxygen that can't sustain marine life. Nutrients that lead to algae growth are the main culprit.

In its 2008 Action Plan, the task force called upon each of the 12 states along the Mississippi River to develop its own nutrient reduction strategy.

Working together, the Iowa Department of Agriculture and Land Stewardship, the Iowa Department of Natural Resources, and the Iowa State University College of Agriculture and Life Sciences developed this proposed strategy.

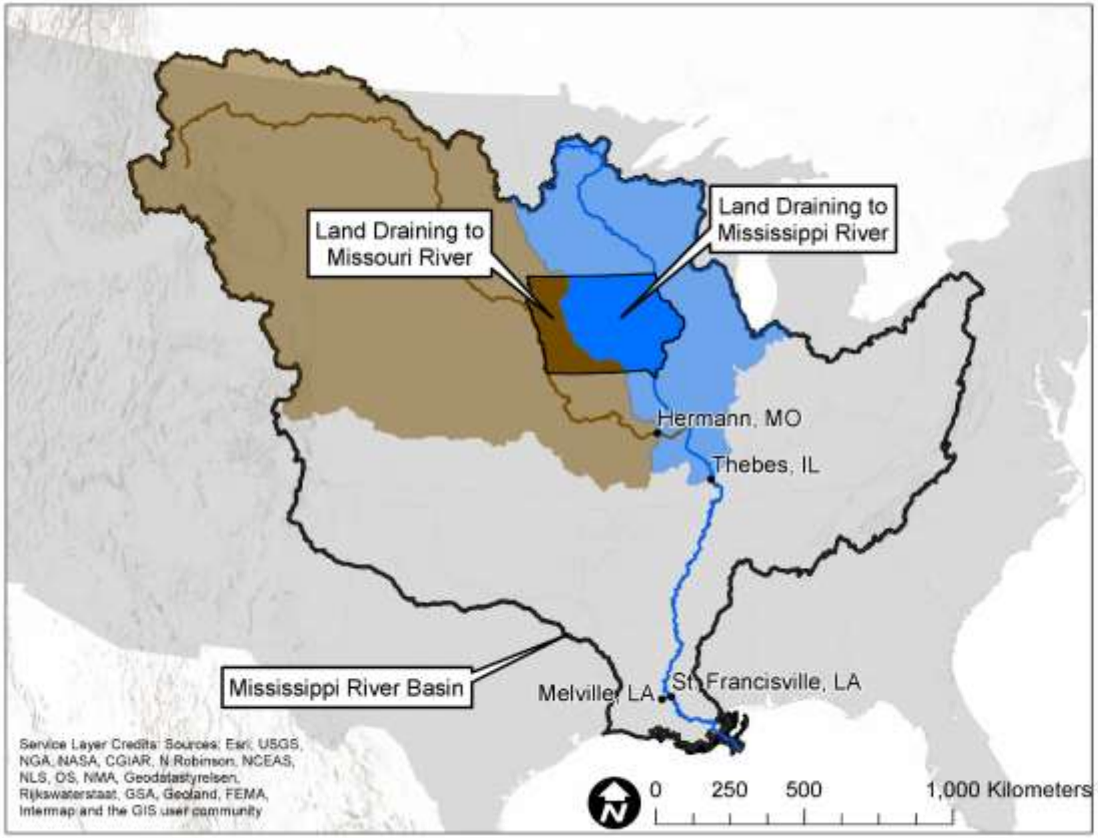
The Iowa Nutrient Reduction Strategy was developed by:

IOWA DEPARTMENT OF AGRICULTURE & LAND STEWARDSHIP

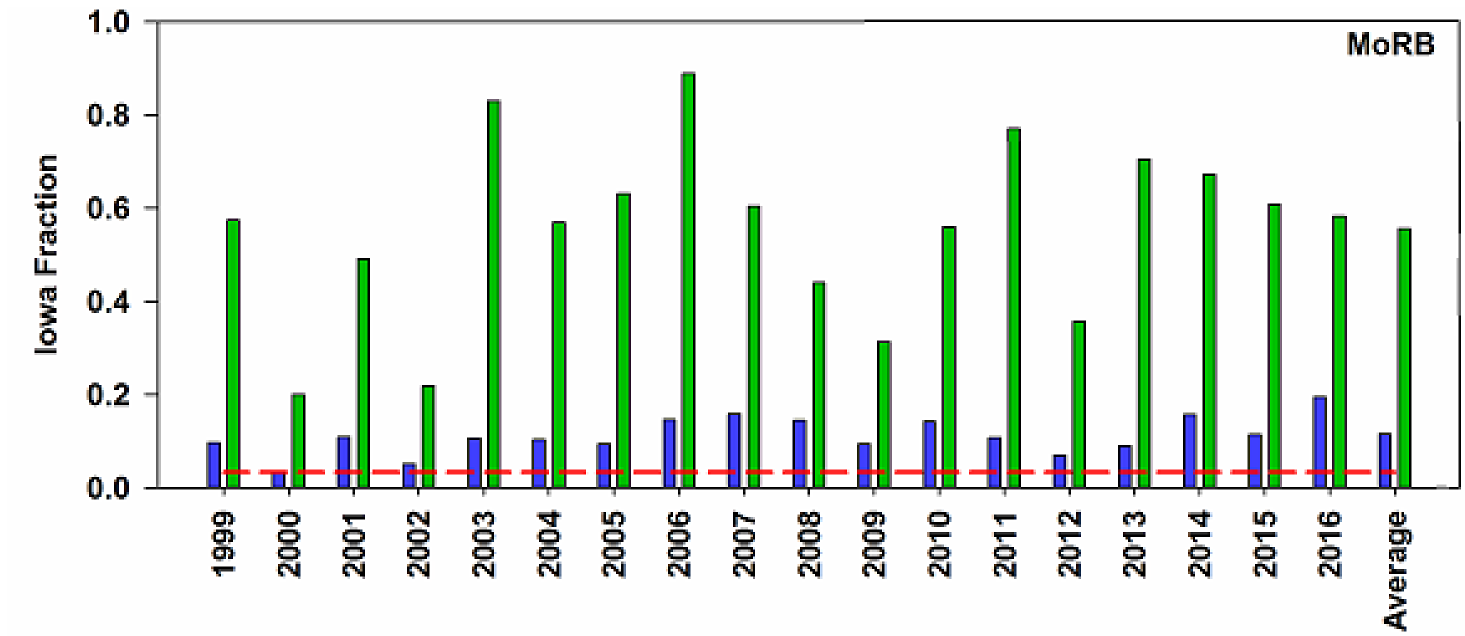
DNR IOWA DEPARTMENT OF NATURAL RESOURCES

IOWA STATE UNIVERSITY

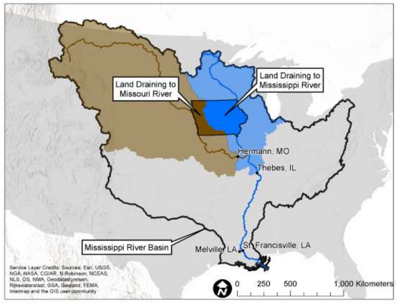
Iowa Contributions



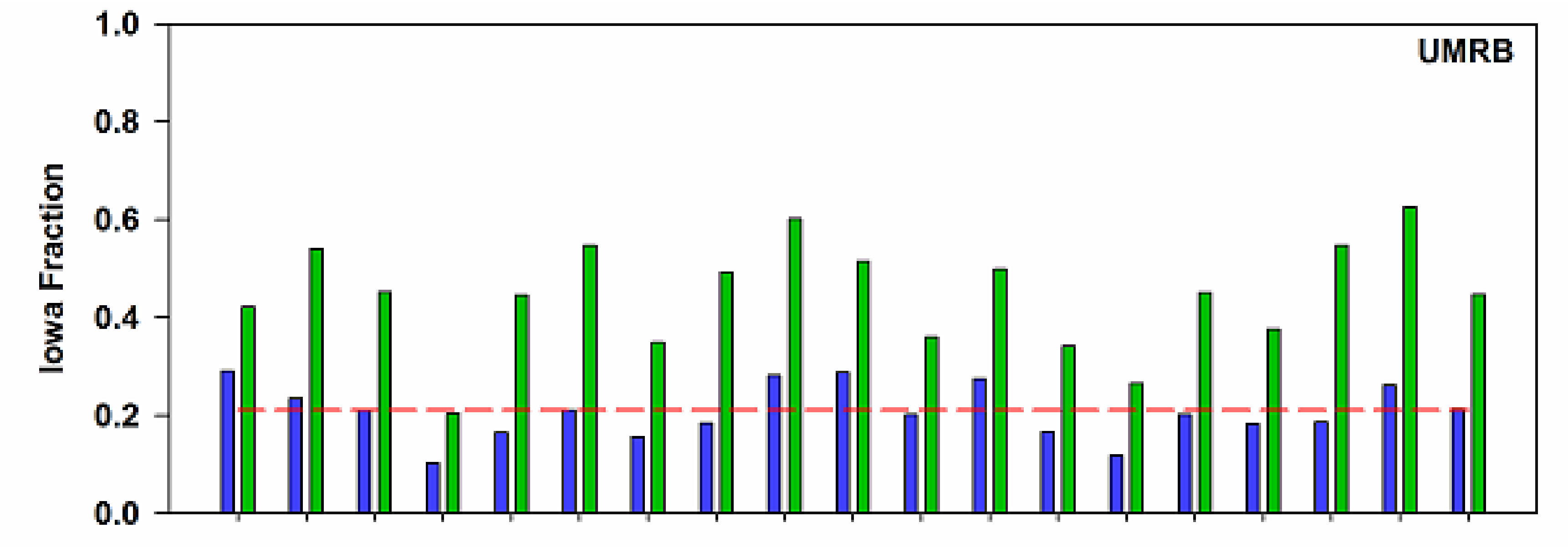
Missouri Basin: Nitrogen



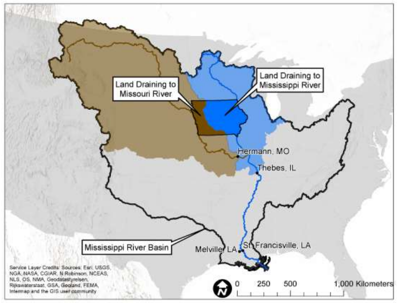
3.3% of the land
12% of the water
55% of the nitrate



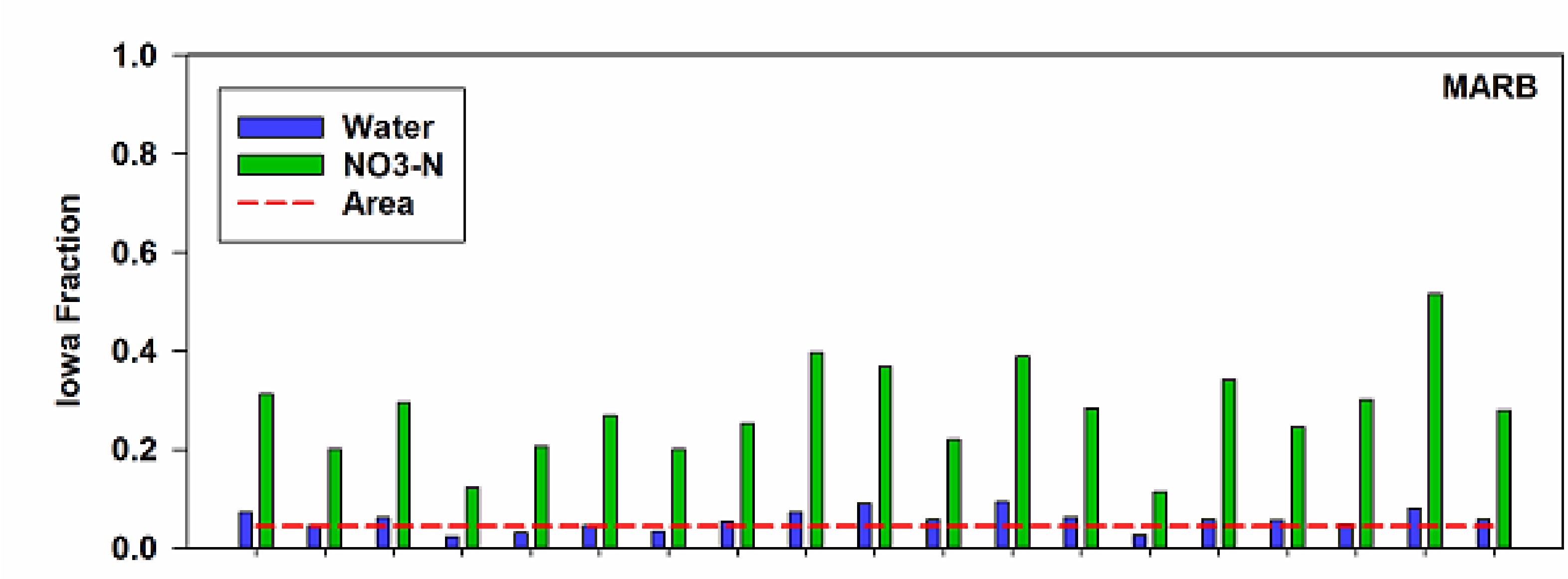
Upper Mississippi: Nitrogen



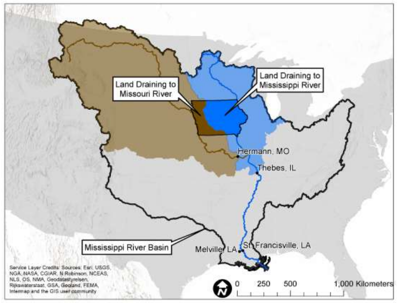
21% of the land
21% of the water
45% of the nitrate



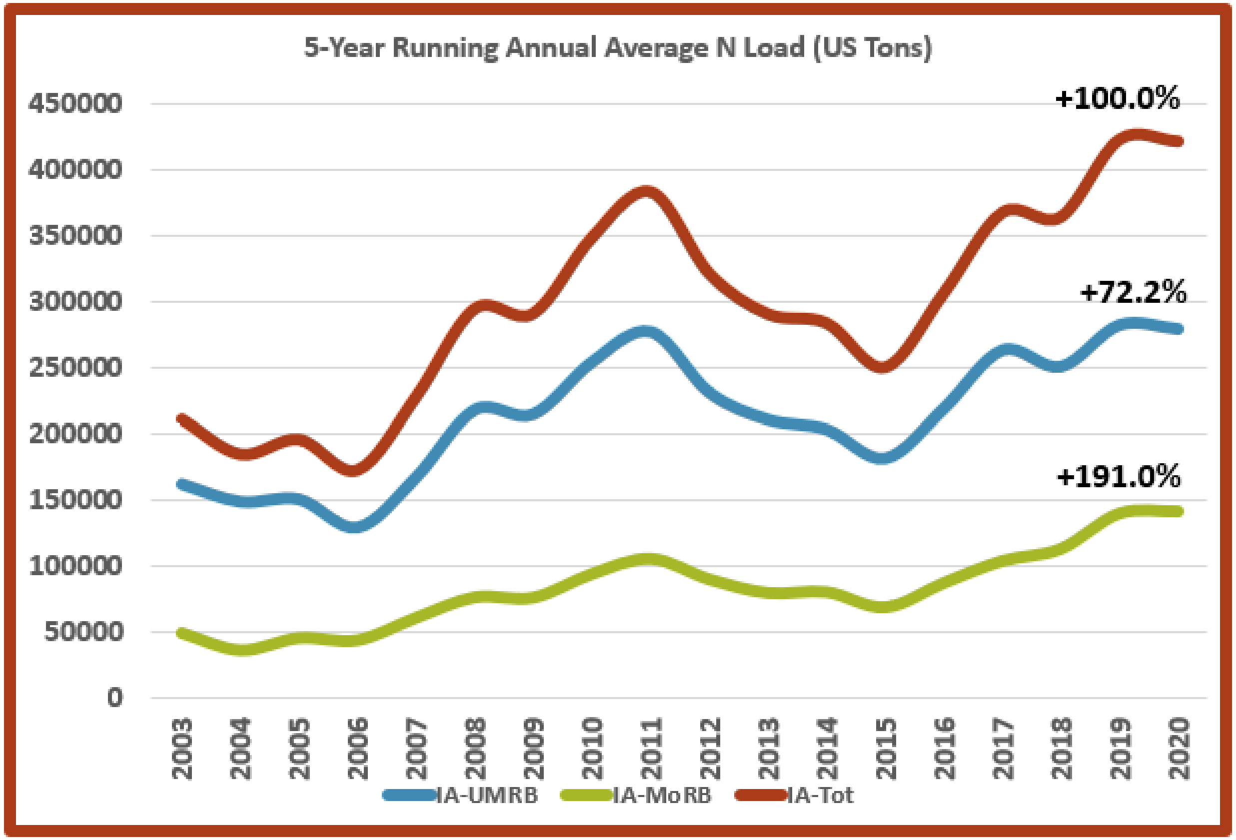
Mississippi-Atchafalaya: Nitrogen

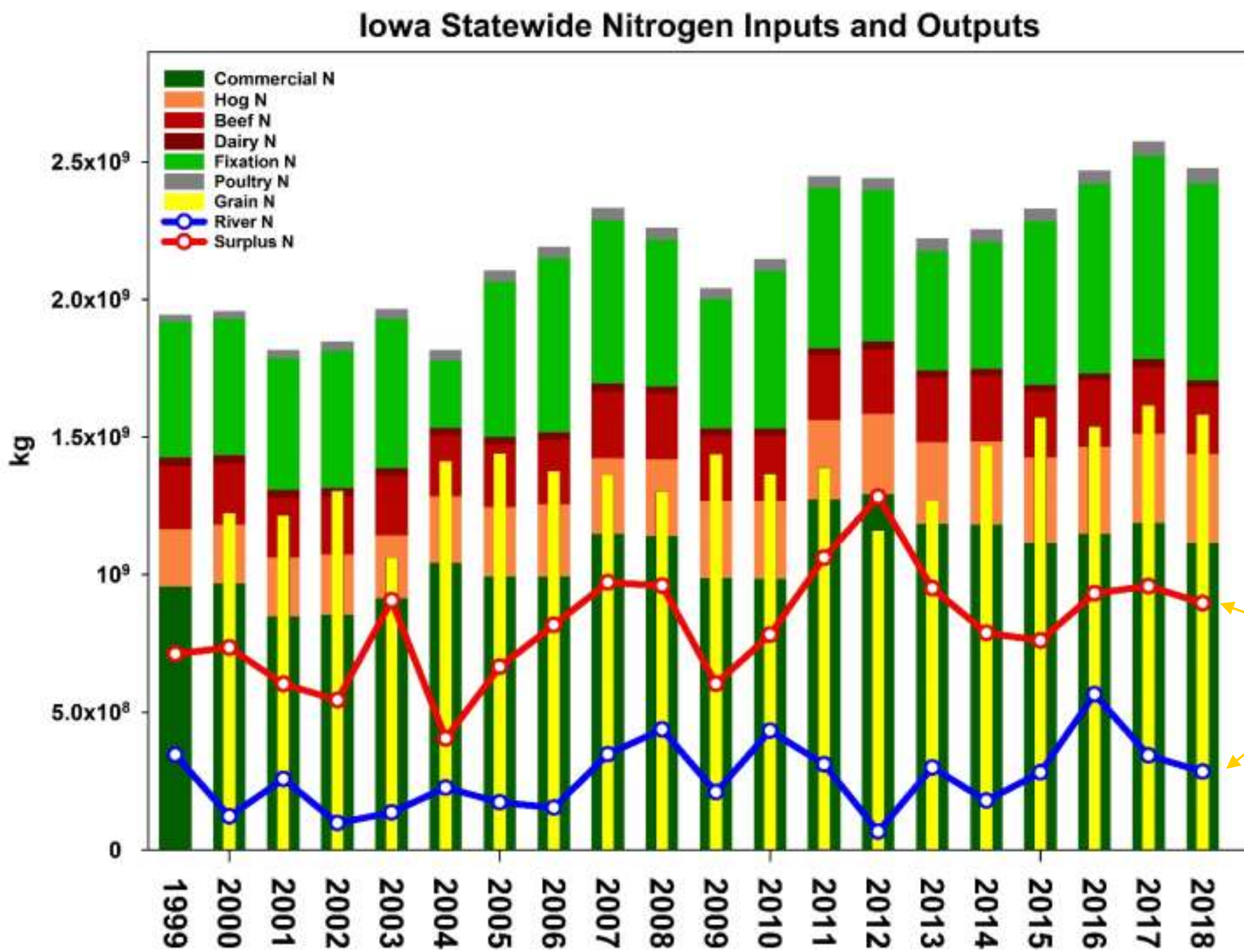


4.5% of the land
5.9% of the water
29% of the nitrate



How Much Nitrogen Leaves Iowa?





About 32% of "surplus" makes it to streams

Nitrogen Change since 19999

N Category	% change
River	83
Chicken	76
Turkey	59
Hogs	59
Surplus	51
Fixation	41
total inputs	36
Commercial	34
Grain N	27
Beef	10
Dairy	-11

PLOS ONE

RESEARCH ARTICLE

Iowa stream nitrate and the Gulf of Mexico

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1 IIHR-Hydroscience and Engineering, University of Iowa, Iowa City, Iowa, United States of America, **2** Iowa Geological Survey, Iowa City, Iowa, United States of America

☯ These authors contributed equally to this work.
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Phosphorus

Applied as MAP, DAP, Super Triple Phosphate and manure.

Not a regulated drinking water contaminant

Attaches tenaciously to soil particles

Loss through erosion primarily

Especially important in freshwater ecosystems.

Phosphorus

Iowa contributes 15% of Phosphorus Load to Gulf of Mexico (4.5% of Area)

“P concentrations in Iowa streams are likely 2–3 times higher than Illinois streams on average”

“P loads 43% higher in 2017 than in 2004”

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Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/jhydrol

Research papers

Total phosphorus export from Iowa agricultural watersheds: Quantifying the scope and scale of a regional condition

Keith E. Schilling[a,*], Matthew T. Streeter[a], Anthony Seeman[b], Christopher S. Jones[c], Calvin F. Wolter[d]

[a] Iowa Geological Survey, University of Iowa, Iowa City, IA, United States
[b] Iowa Soybean Association, Ankeny, IA, United States
[c] IIHR Hydroscience and Engineering, University of Iowa, Iowa City, IA, United States
[d] Iowa Department of Natural Resources, Des Moines, IA, United States

Solutions

Nitrate: Floyd County Example

68 kg N per day

Cost $500,000

Drains to Cedar River

Cedar River N Load at Conesville (2020): 152,000 kg/day

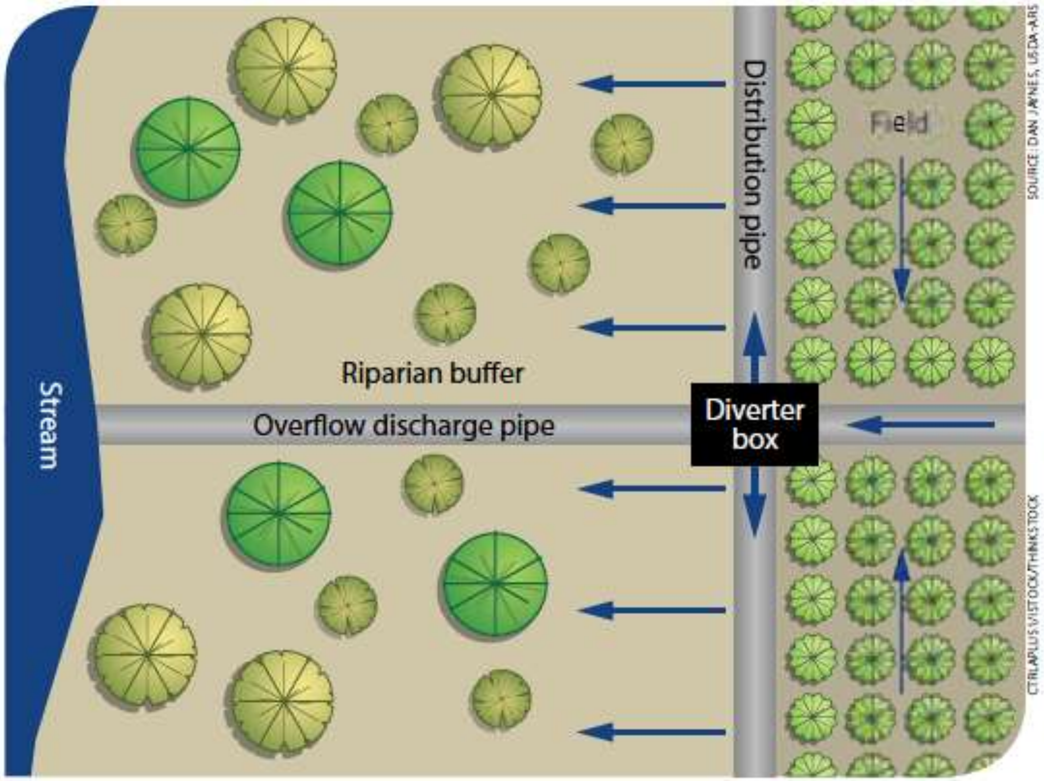
Cover Crops

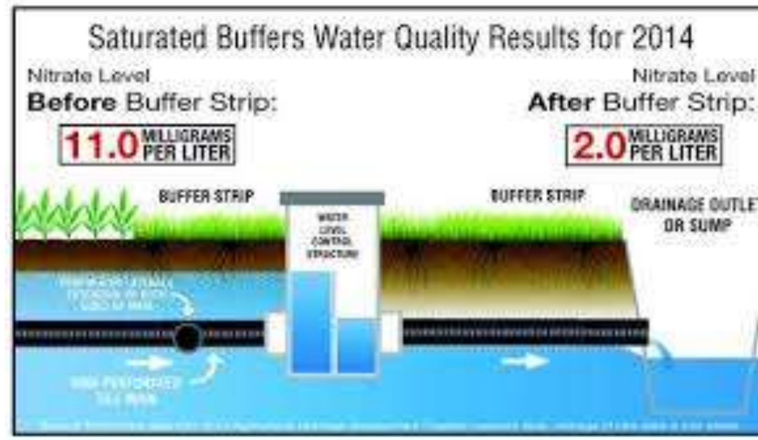
Economics of Nitrogen Loss

- 2016 production costs (labor, land, seed, machinery, chemicals, insurance, fertilizer) for corn following soybean, assuming a yield of 180 bushels per acre: $719/acre
- Value of N lost to streams ($17.74) was 2.5% of production cost during a wet year (2016)
- Cover Crops cost $30/acre, which increases production costs 4.2% for corn, 5.6% for soybean
- Cover Crops sequester 31% of lost nitrogen ($5.50).
- All Iowa C/SB acres in cover crops: $563M/year, $175/Iowan.
- Yield benefit would have to be 8 bushels of corn, 3 bushels of soybean

Two Stage Ditch

Saturated Buffers: $4000 to treat 80 Acres ($50/acre)

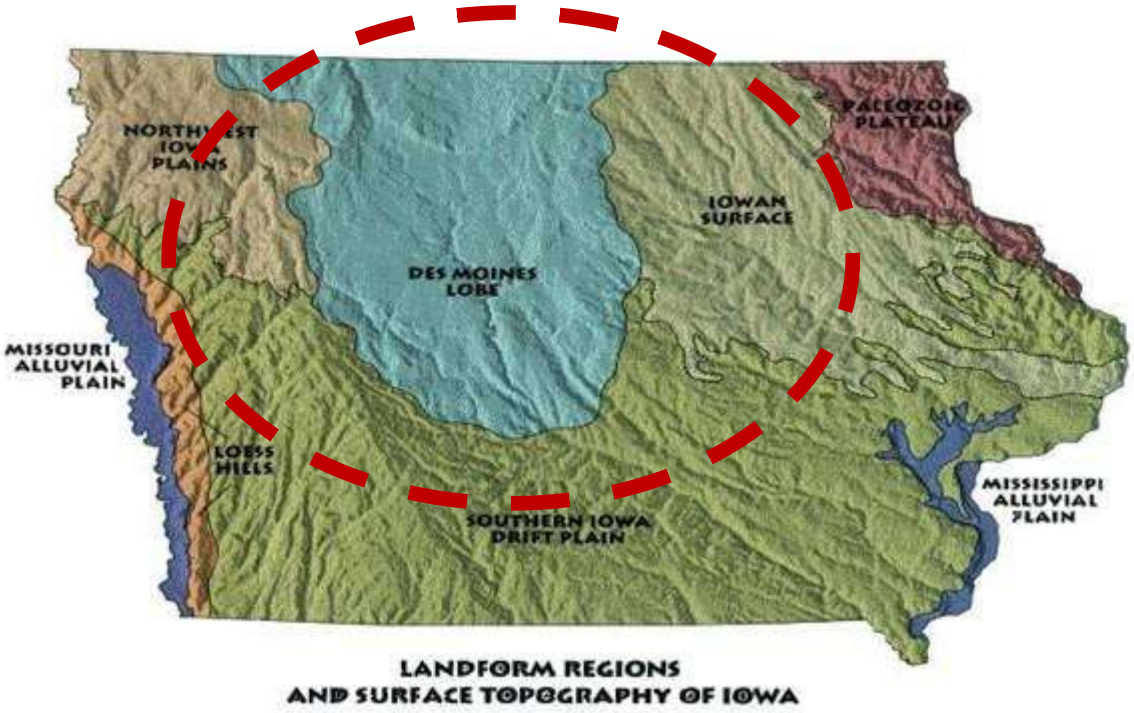




50% reduction

IIHR Hydroscience & Engineering
The University of Iowa
College of Engineering

7.7 million acres



$400M to treat with saturated buffers

Economics of N loss

Cost of Nitrogen: today about $1.20/lb

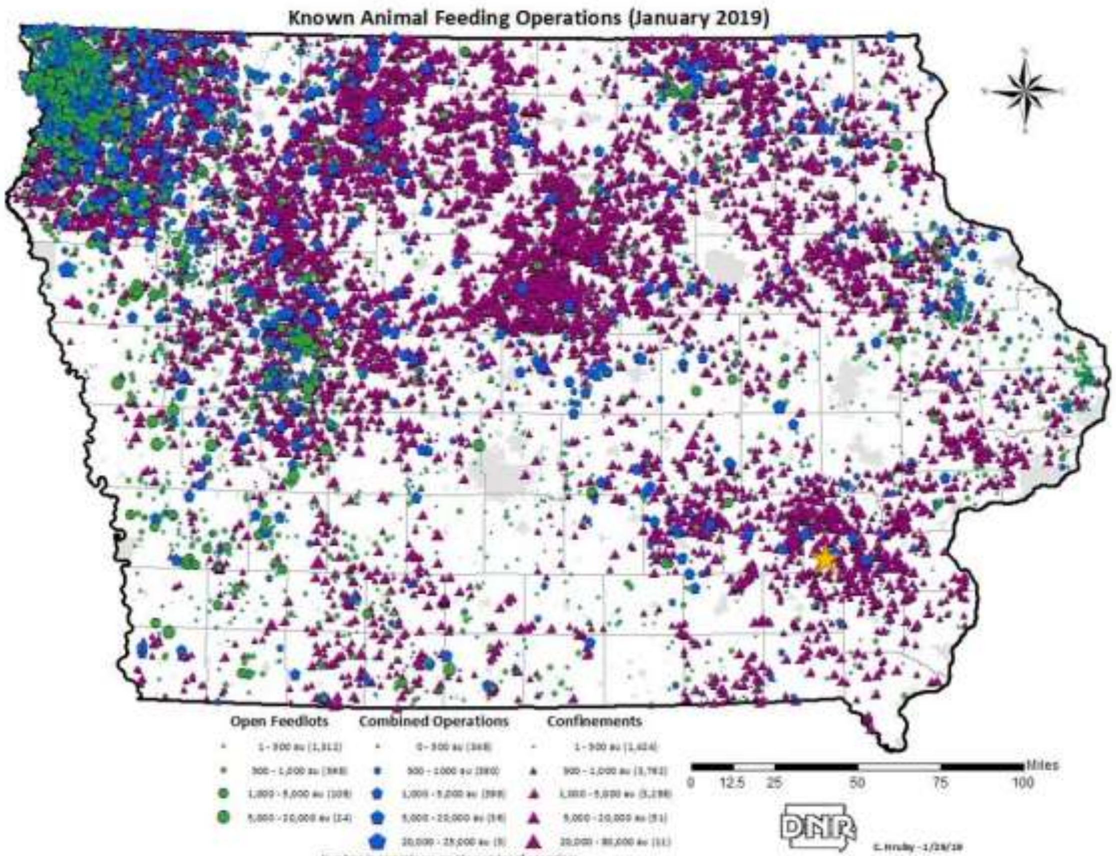
Cost to remove nitrogen using BMPs: $2-$10/pound

Average statewide load: 600 million lbs

45% reduction = 270 million lbs/year

$540M to $2.7B/year

How Do You Overcome Structural Drivers to Bad Water Quality?



More Diverse Farming Systems

Marsden Long Term Rotation Study-ISU

Matt Liebman

Corn/Soybean/Oat/Alfalfa/Alfalfa vs Corn/Soybean
N fertilizer use 91% lower
Herbicide use 97% lower
Weed biomass similar
Soybean sudden death syndrome much lower

Soil health is better
Tile nitrate 57% lower
Soil erosion 50% lower
Fossil Fuel use 60% lower
Net returns similar (revenue lower but input costs also lower)

Regulations?

1. Ban cropping in the 2-year Flood Plain

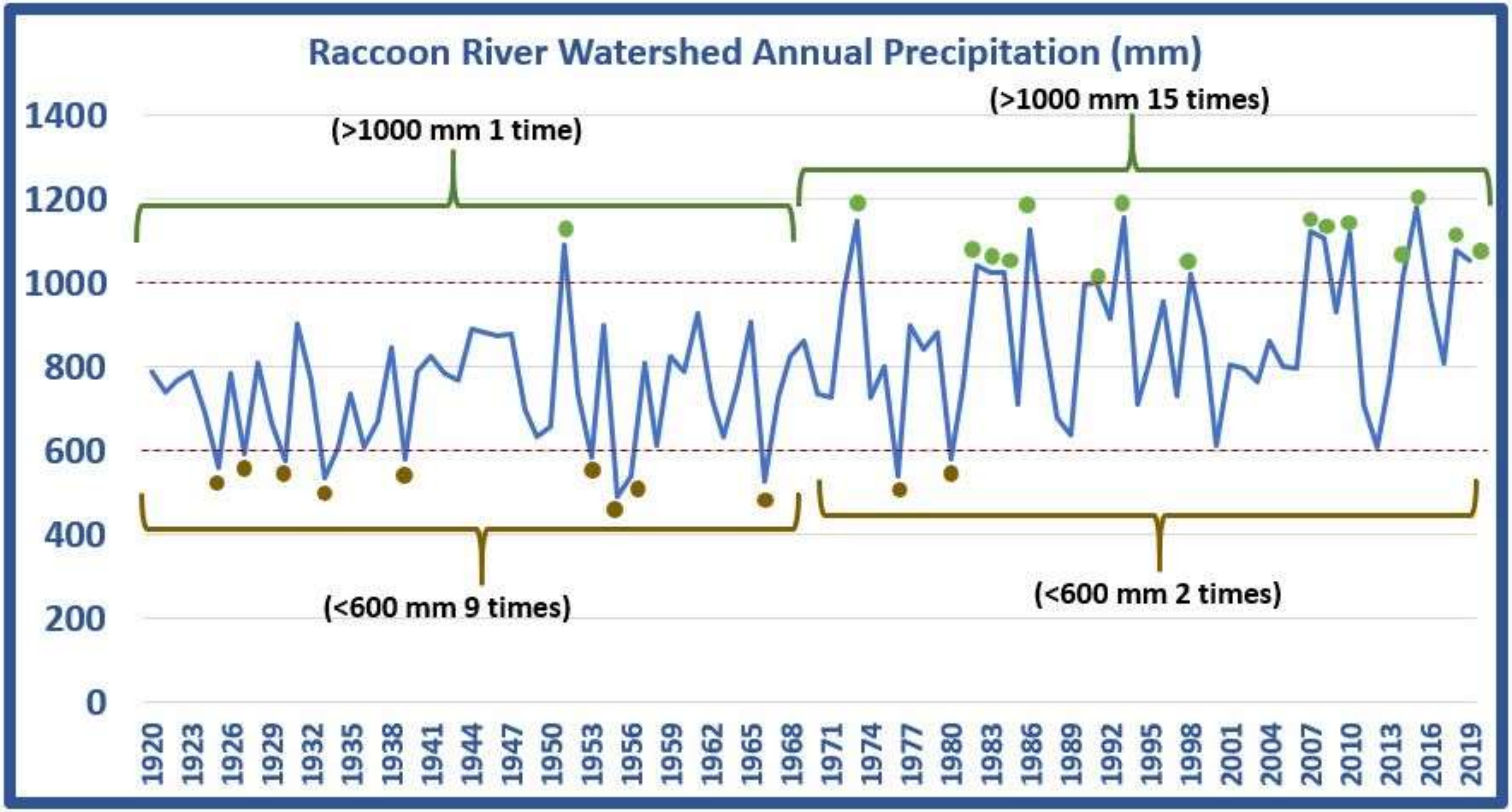
2. Ban fall tillage

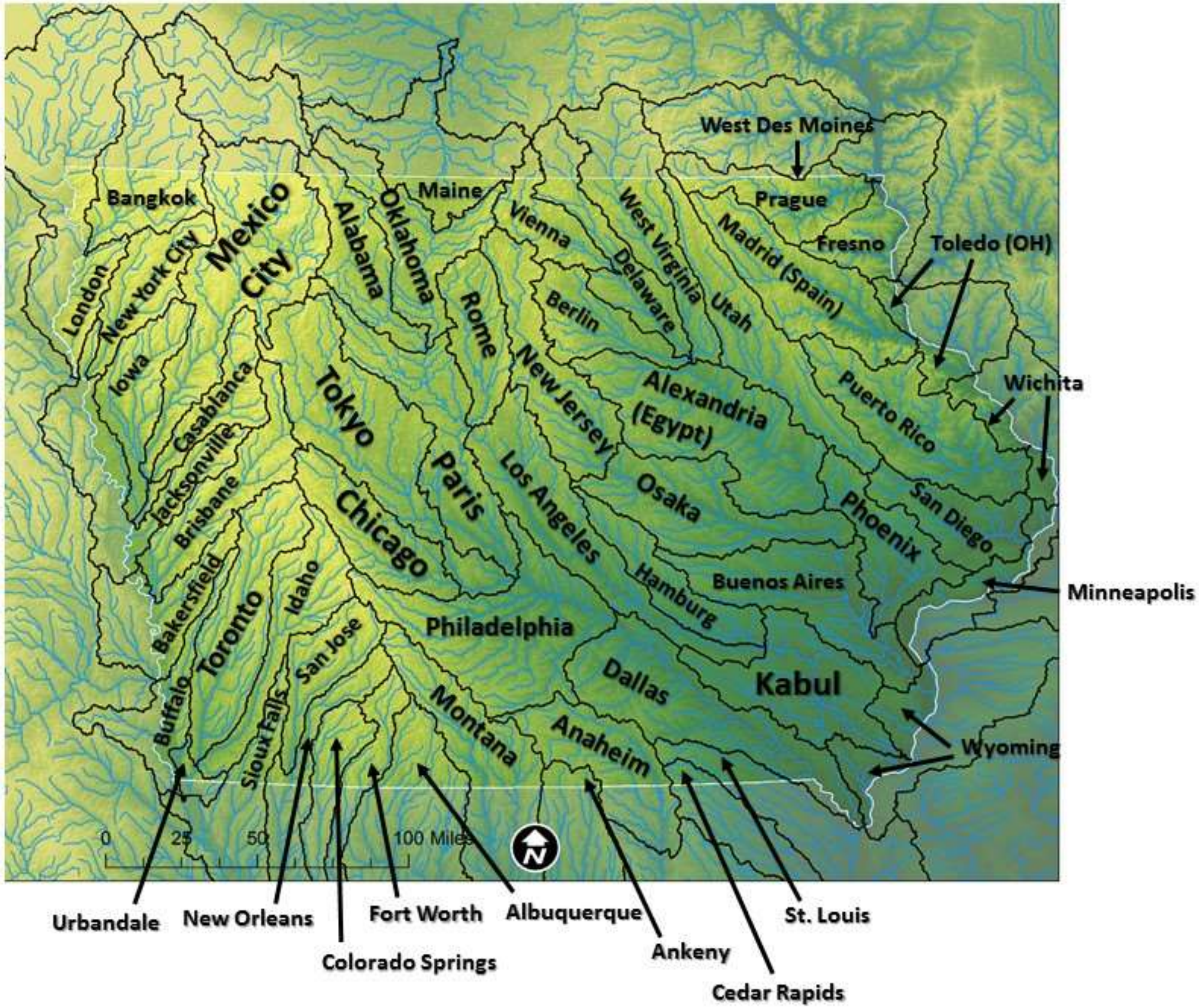
3. Ban manure on snow and frozen ground

4. Make farmers adhere to ISU fertilization guidelines

5. Reformulate CAFO Regulations

Climate Change

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Kabul
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Anaheim
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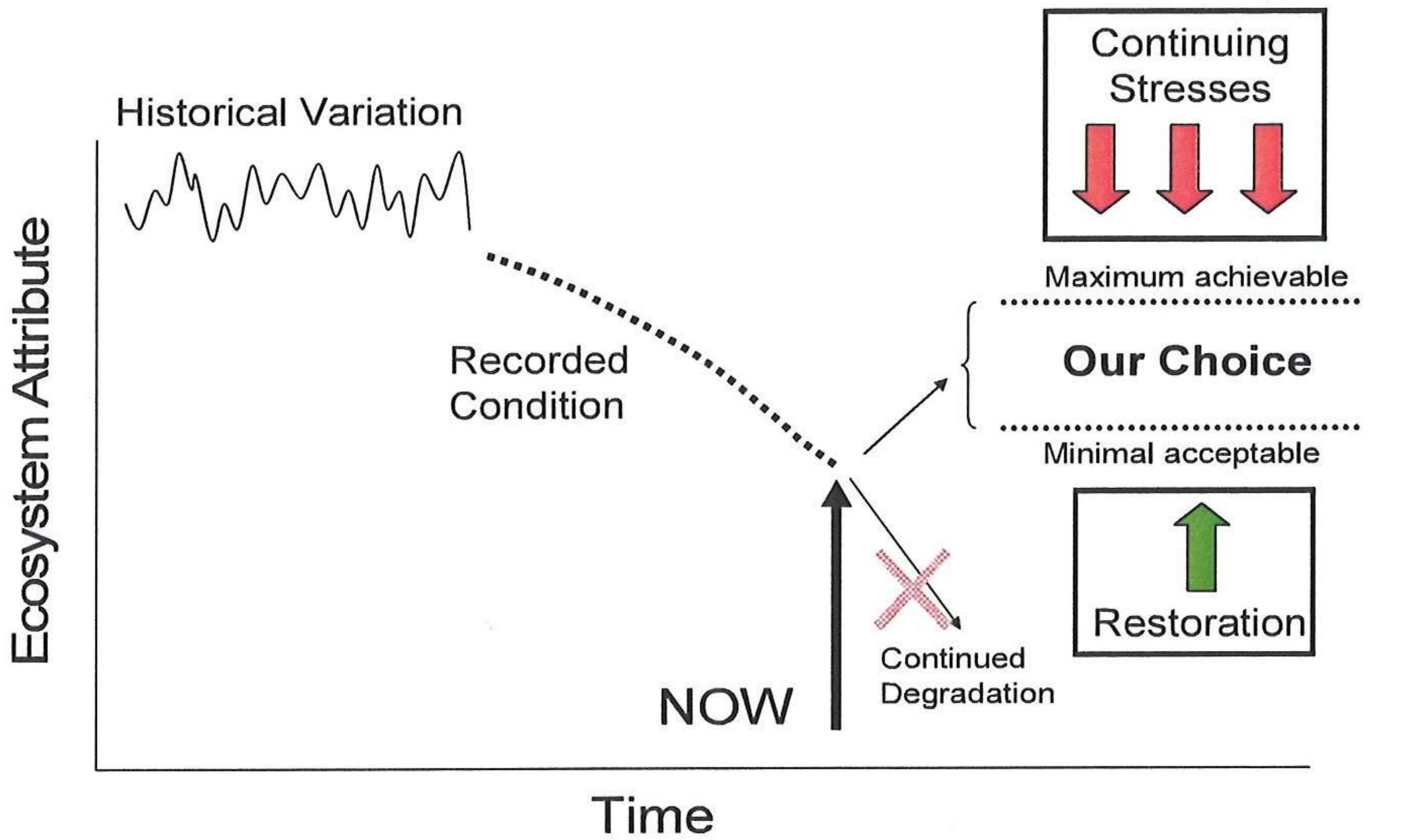
25
50
100 Miles
Urbandale
New Orleans
Colorado Springs
Fort Worth
Albuquerque
Ankeny
Cedar Rapids
St. Louis

IOWA

What do we want our production system to look like?

Commerce

Nutrition?


Historical Variation
Ecosystem Attribute
Recorded
Condition
Continuing
Stresses
Maximum achievable
Our Choice
Minimal acceptable
Restoration
NOW
Continued
Degradation
Time

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