Chris Jones, Research Engineer, IIHR Hydroscience and Engineering

Drivers of Water Quality in the Corn-Soy-Ethanol-CAFO Production System

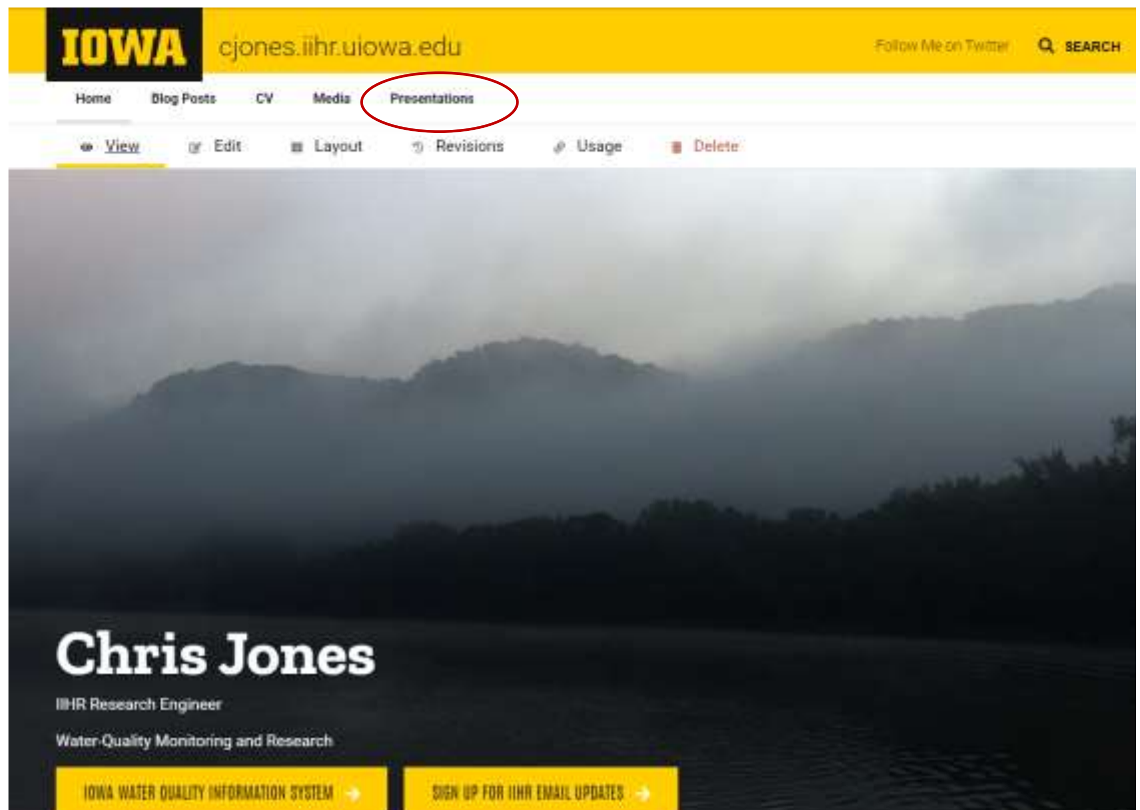
March 7, 2023

Oaknoll

Slides Available at:

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

- Grew up in Ankeny, IA
- Went to Simpson College in Indianola, IA
- PhD work at Montana State University (1989)
- Managed commercial analytical testing laboratory in MN, 1988-1999
- Consulting work for water and wastewater utilities, MN, 1999-2003
- Des Moines Water Works, supervisor of water quality, 2003-2011
- Iowa Soybean Association, environmental scientist, 2011-2015
- UI, 2015-present

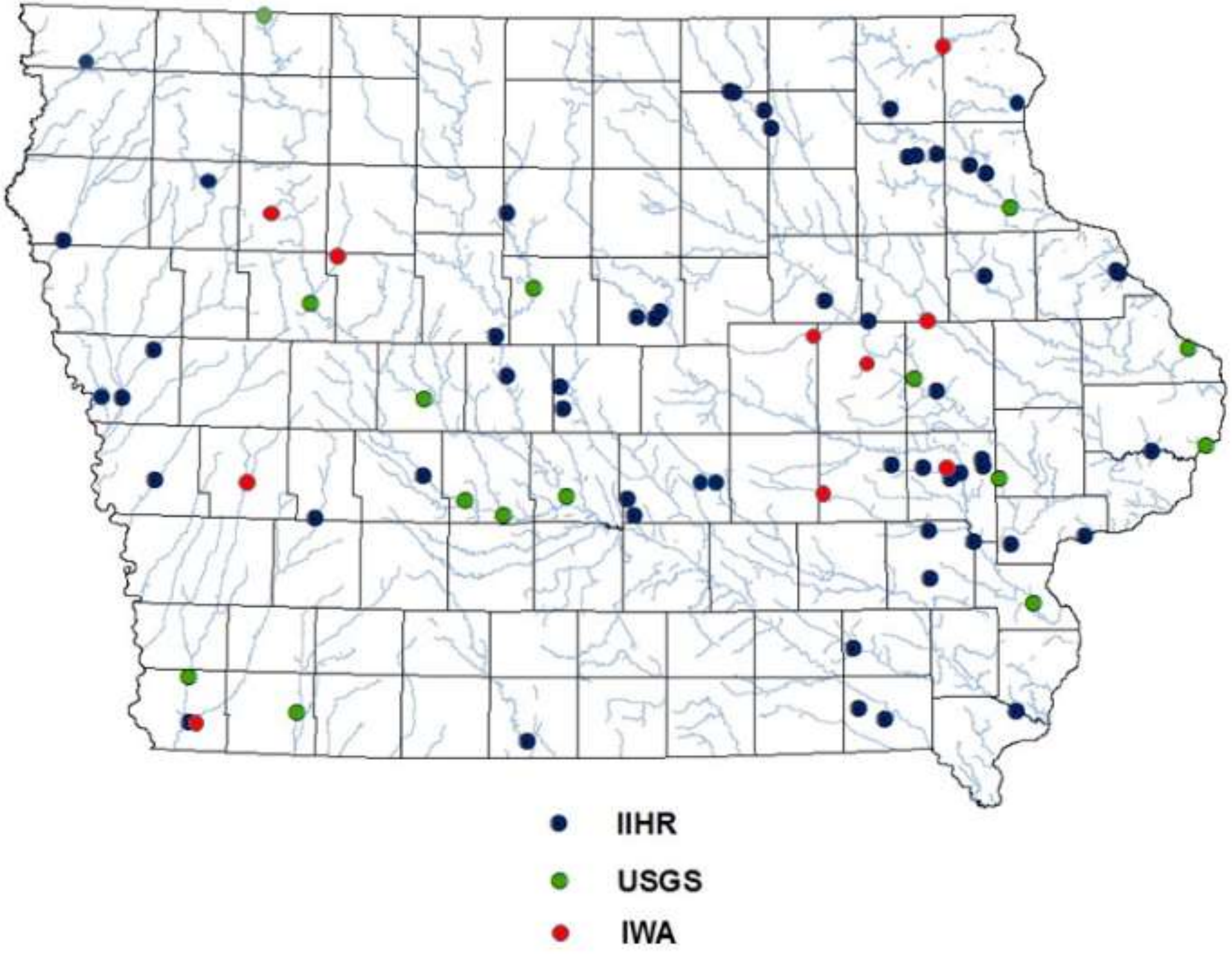


IIHR Water Quality Sensor Network

Sites

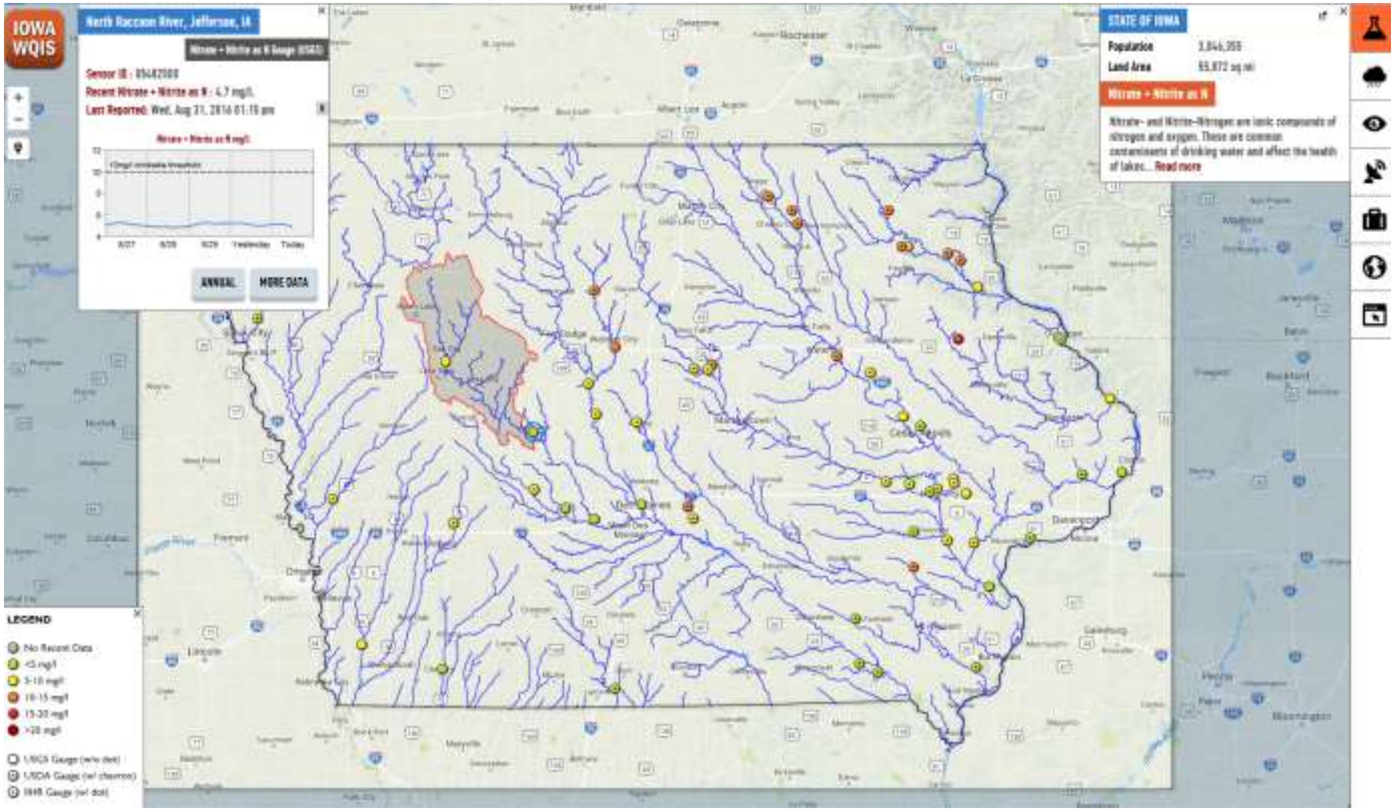
70+ sites
Nitrate-N

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



Site infrastructure

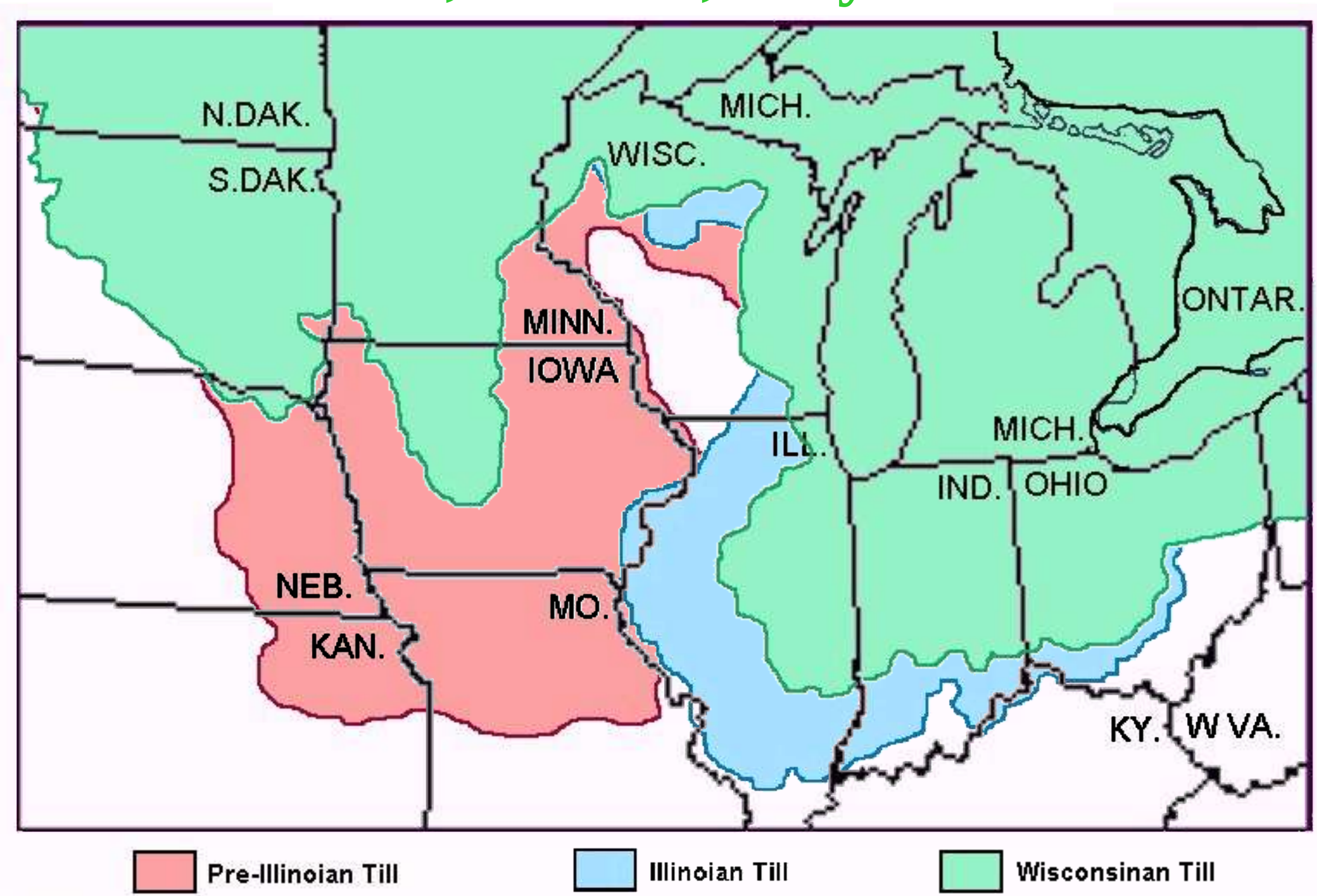
Iowa Water Quality Information System

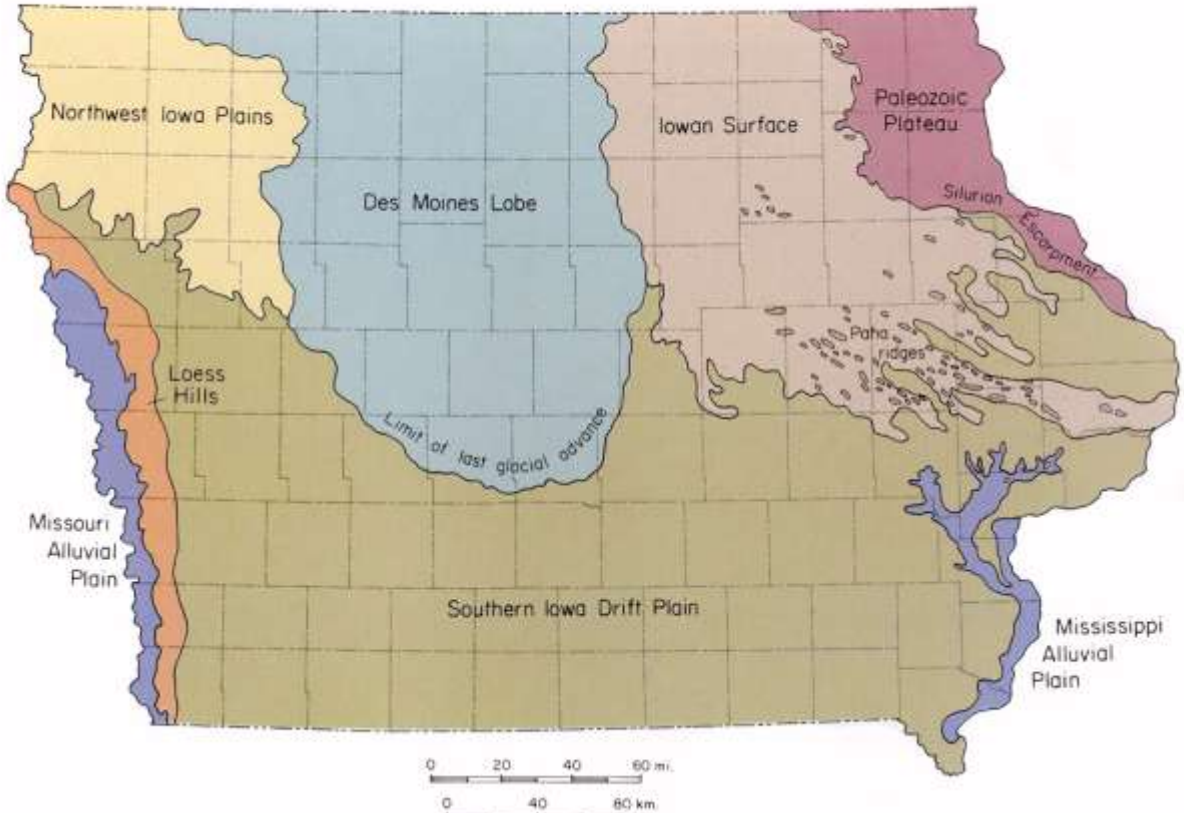


iwqis.iowawis.org/

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

30,000 – 10,500 years





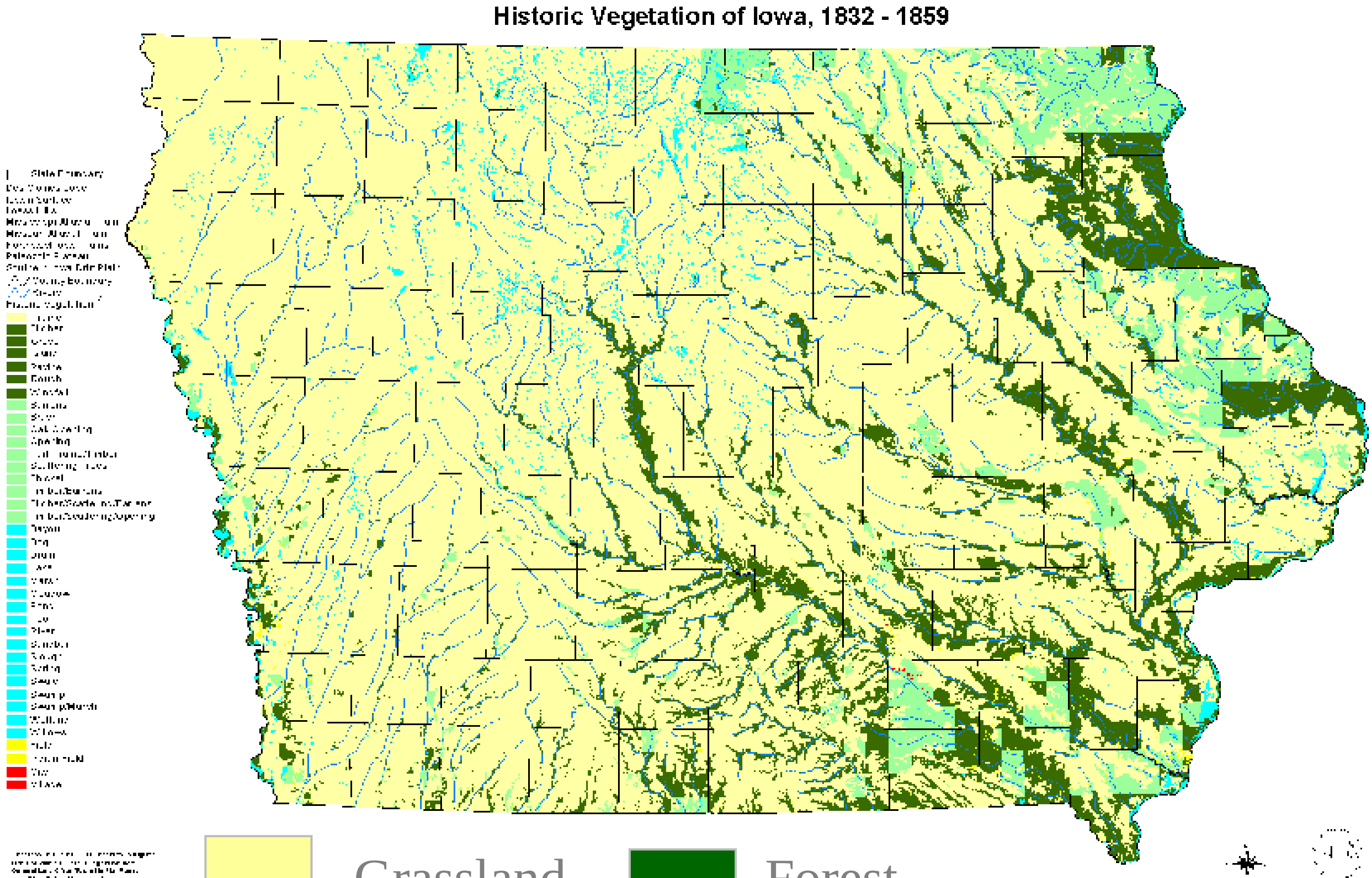
Landform Regions of Iowa


Wetland: 20% of Iowa, 7.6 million acres, <1% remains


Oak Savannah: ~5%, < 1% remains


Prairie: 70%, 0.1% Remains

Land Cover in Iowa around 1850

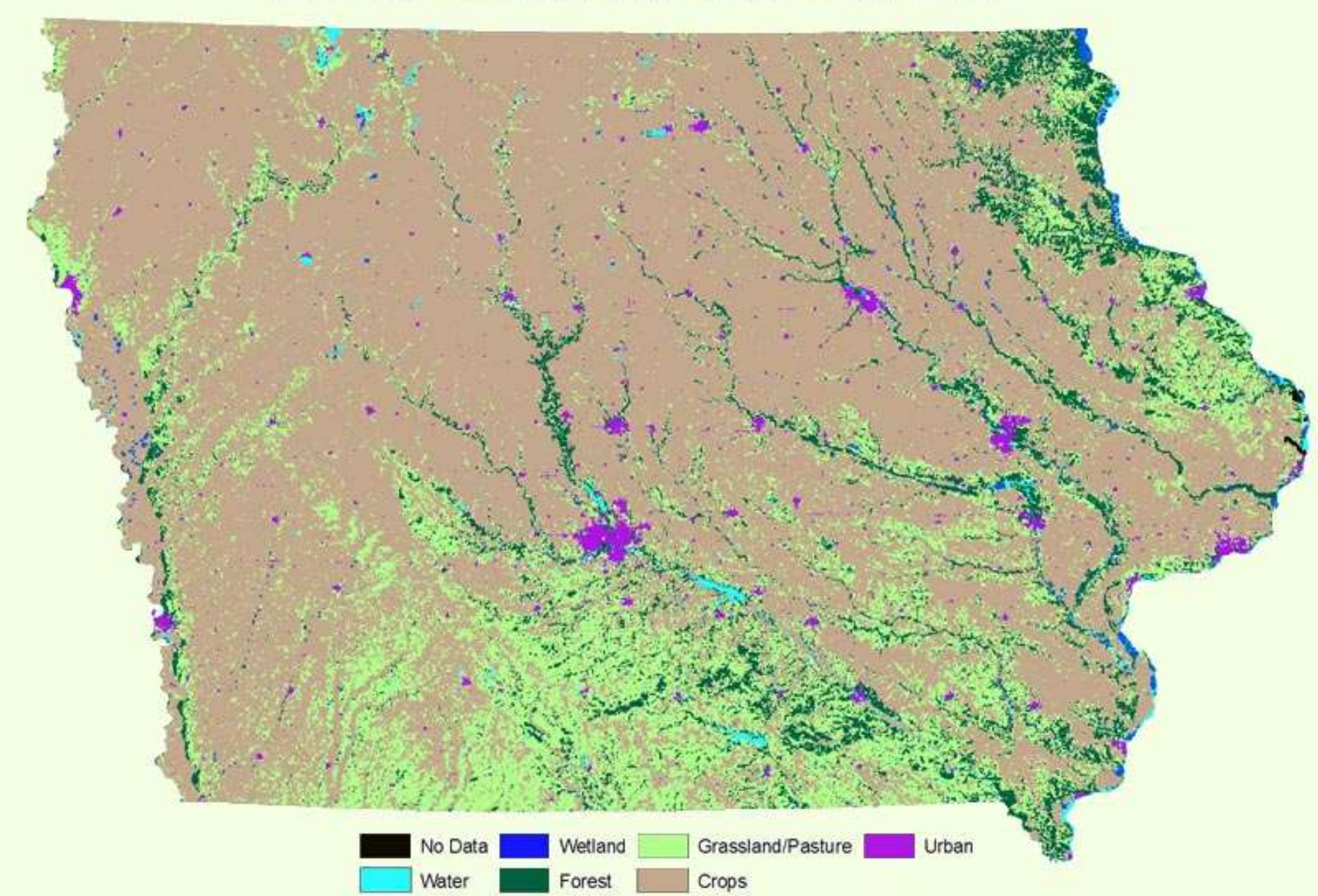


Grassland

Forest

IOWA

Iowa Land Cover

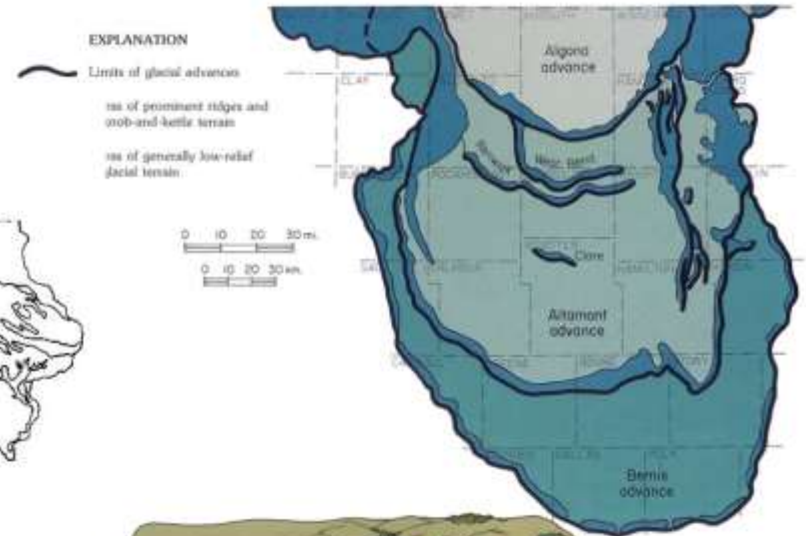


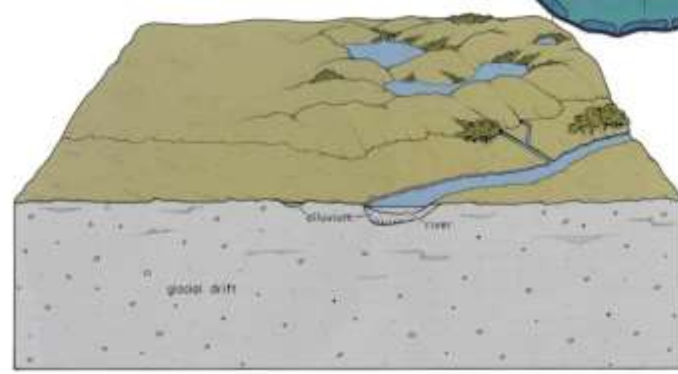
Data source: Adapted from DNR Iowa Geological Survey's "Land Cover of the State of Iowa in the Year 2002" available online at http://www.igsb.uiowa.edu/nrgislibx/

Landforms

Photo credit: Katharine McCarville, Upper Iowa University

- Newly deposited glacial till
- Little or no loess
- Knob and kettle features at glacier edges
- Level
- Poorly drained (few streams)
- Glacial lakes and wetlands





Images: IA Geological Survey

https://www.geocaching.com/geocache/GC7FY8J_glacial-evidence-algona-advance?guid=de7c76f4-a3f7-4e47-af0d-aa28c57243a4

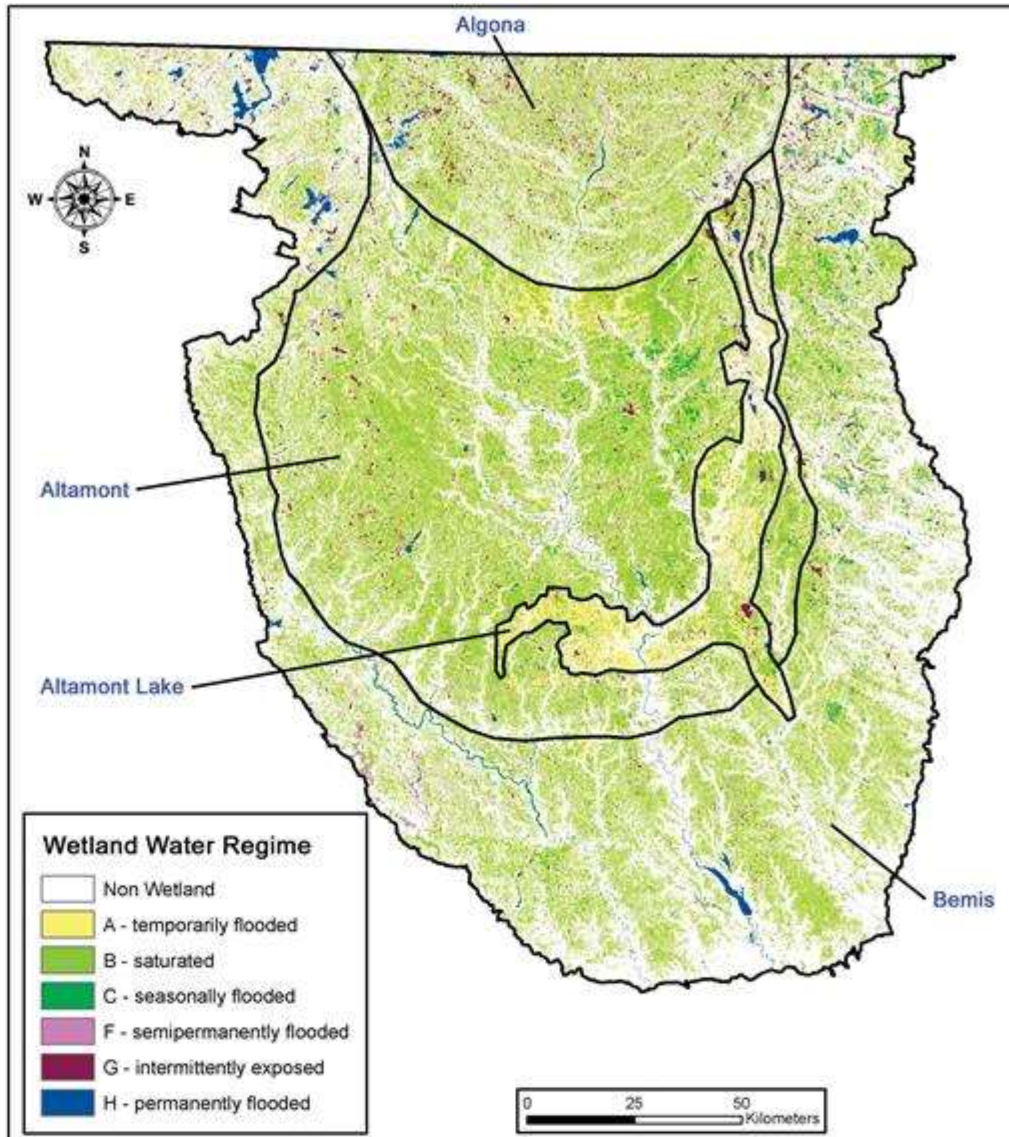
Source: Iowa Geological Survey

1 December 2009

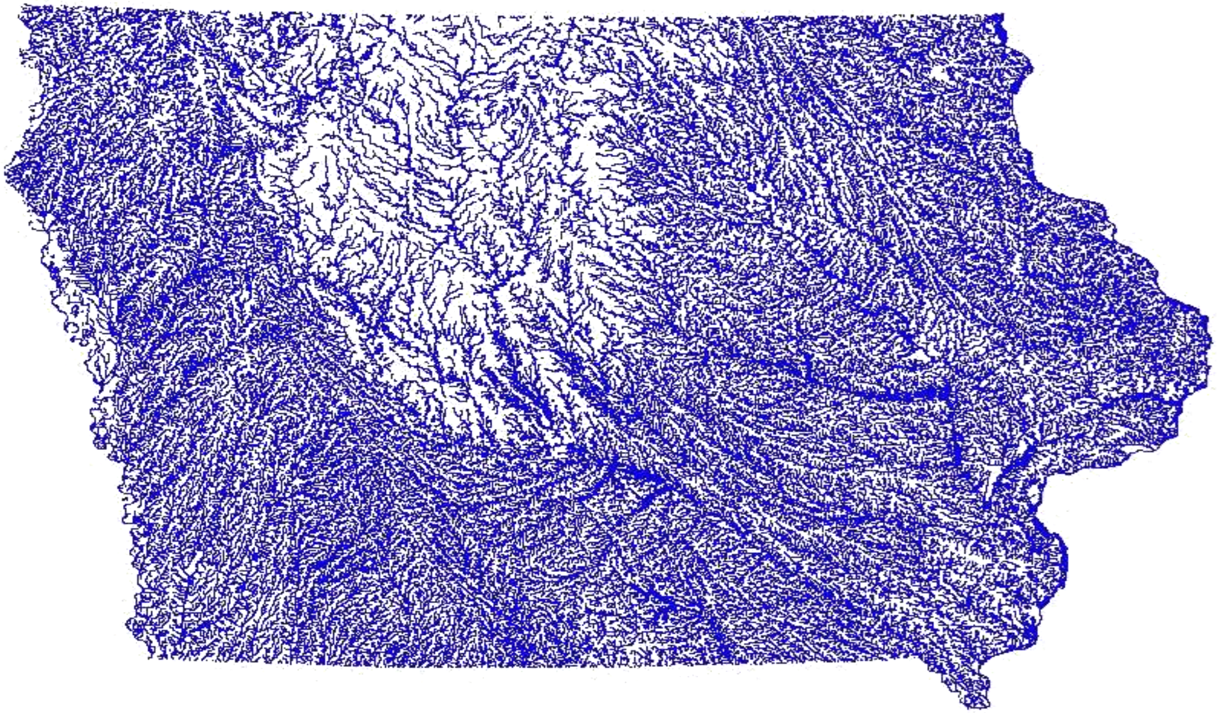
Spatial Distribution of Historical Wetland Classes on the Des Moines Lobe, Iowa

Bradley A. Miller, William G. Crumpton, Arnold G. van der Valk

Author Affiliations +



Stream Density low on Des Moines Lobe



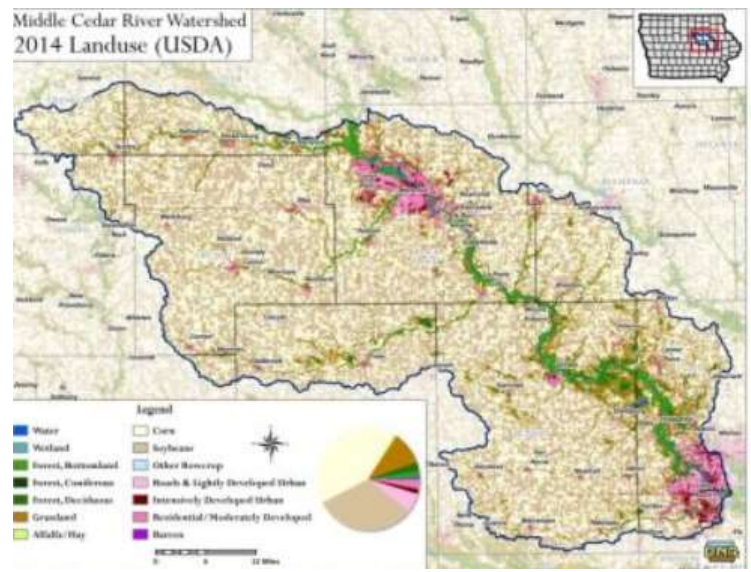
Excavating a large ditch using steam power, circa 1910.

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

Internal Drainage

2 million miles of tile in Iowa

Landform	% of Iowa's Area	$/year spent on new tile
Iowan Surface	16.9	$24,500,000
Des Moines Lobe	21.4	$5,845,000
Northwest Iowa Plains	8.3	$2,272,545
Paleozoic Plateau	4.6	$3,580,862
Southern Iowa Drift Plain	41.3	$33,837,580
Total	92.5	$70,064,878

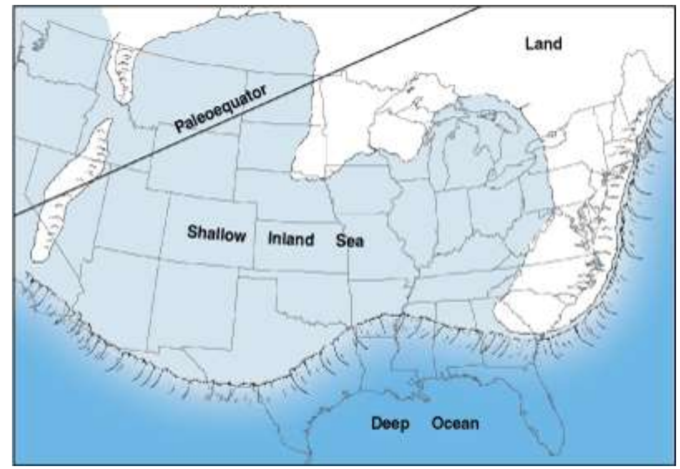


1200 miles new tile/year!

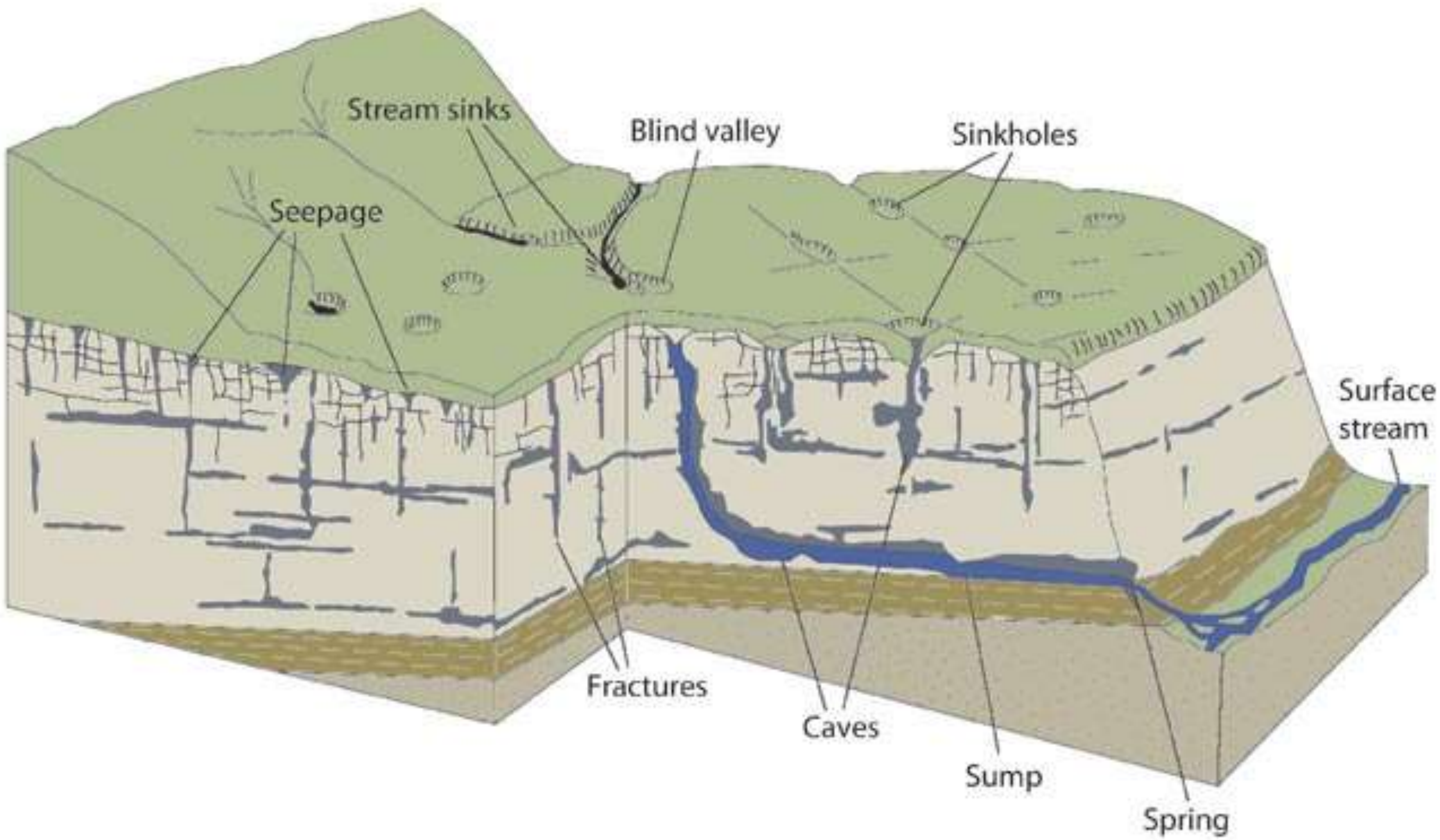
Paleozoic Plateau

Images: IA Geological Survey

Driftless (Paleozoic Plateau)

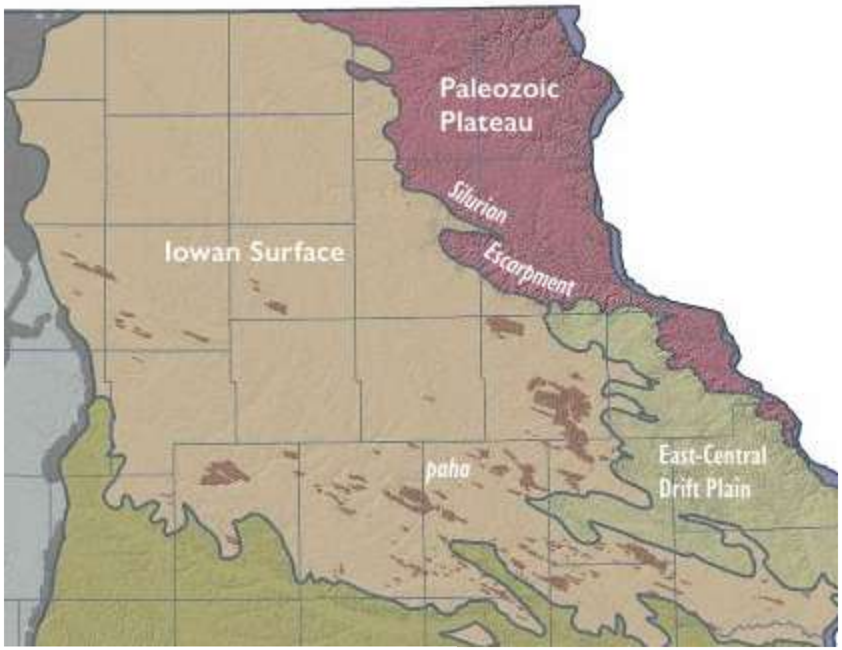


Karst

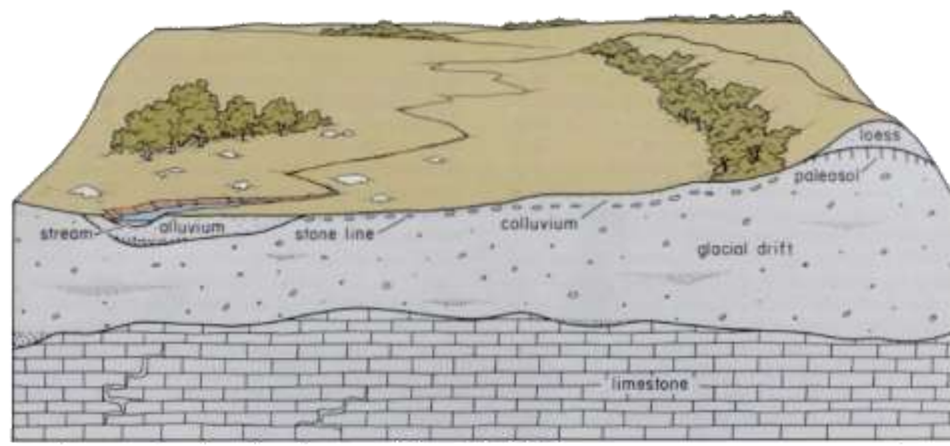


Images: IA Geological Survey

Iowan Surface



- **Thin loess over glacial drift**
- **Bedrock near the surface**
- **Approximately level but rolling**
- **Glacial erratics**



Images: IA Geological Survey

Glacial Erratics

Northwest Iowa Plains

Very similar to Iowa Surface

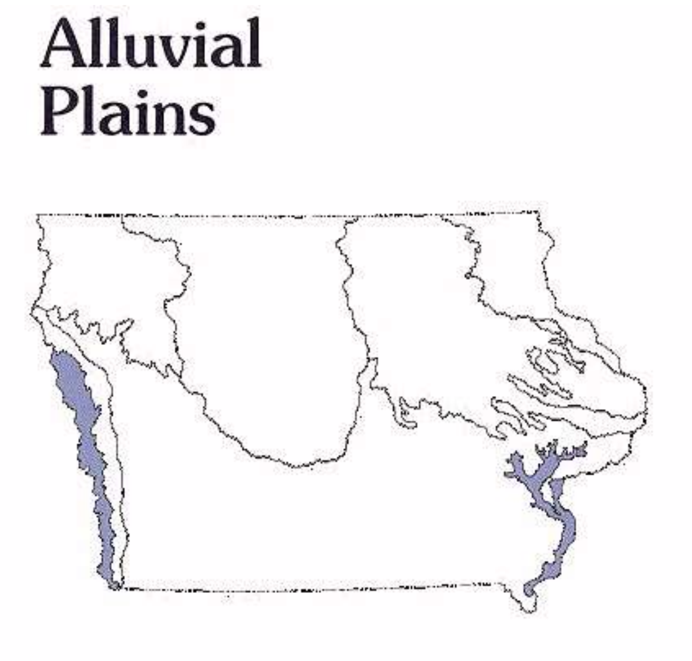
- Erosion features shaped by severe cold and wind of Wisconsin glacier

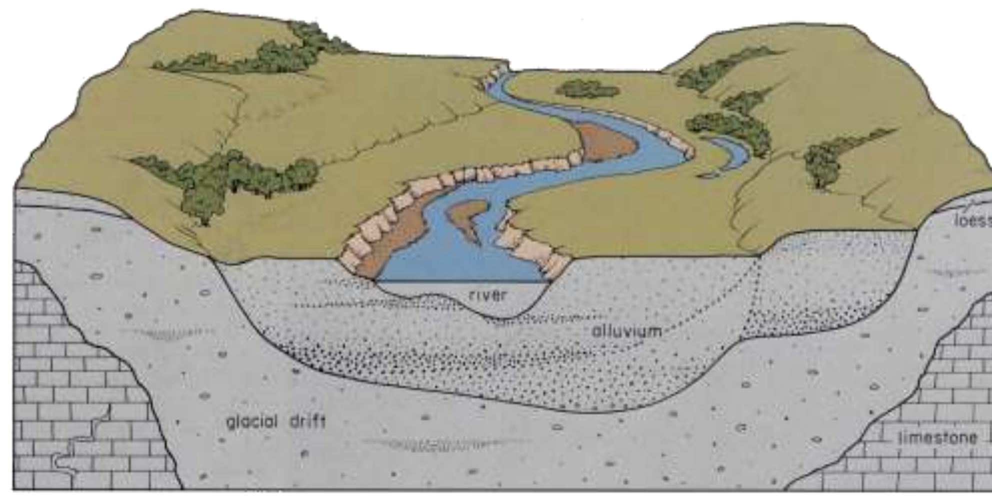
Differences

- Thick loess
- Very few trees here

Images: IA Geological Survey

Sioux Quartzite

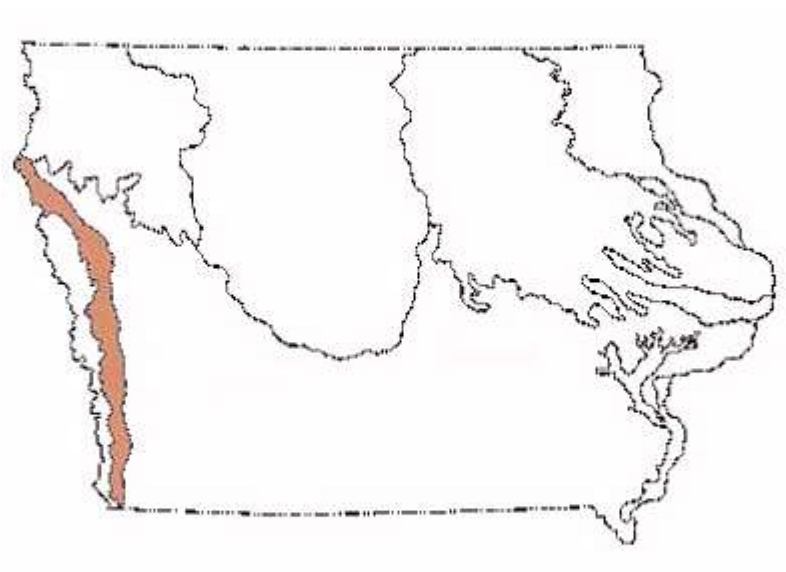


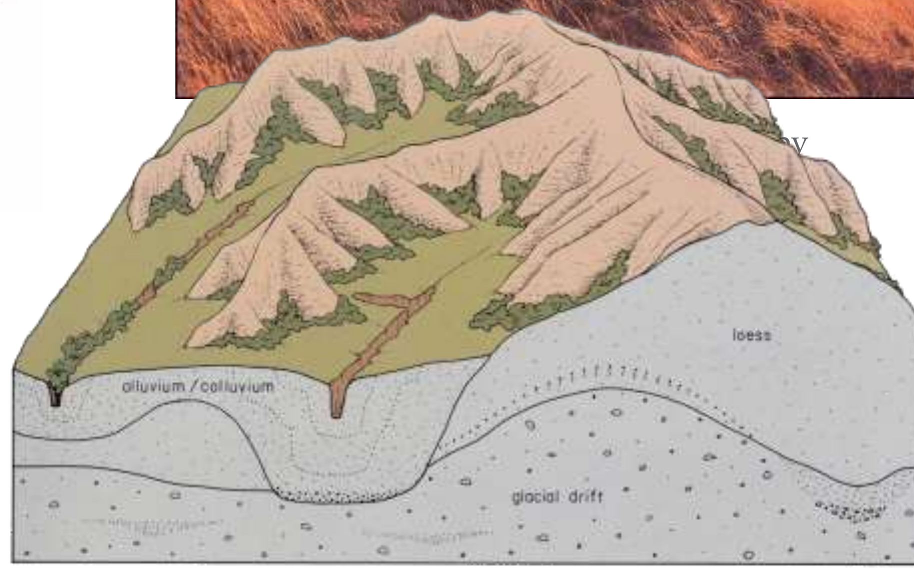


-Thick alluvial deposits
-level terrain along valleys
includes stream channels, floodplains, oxbow lakes, terraces, alluvial fans, sand dunes

Source: Iowa Geological Survey

Loess Hills

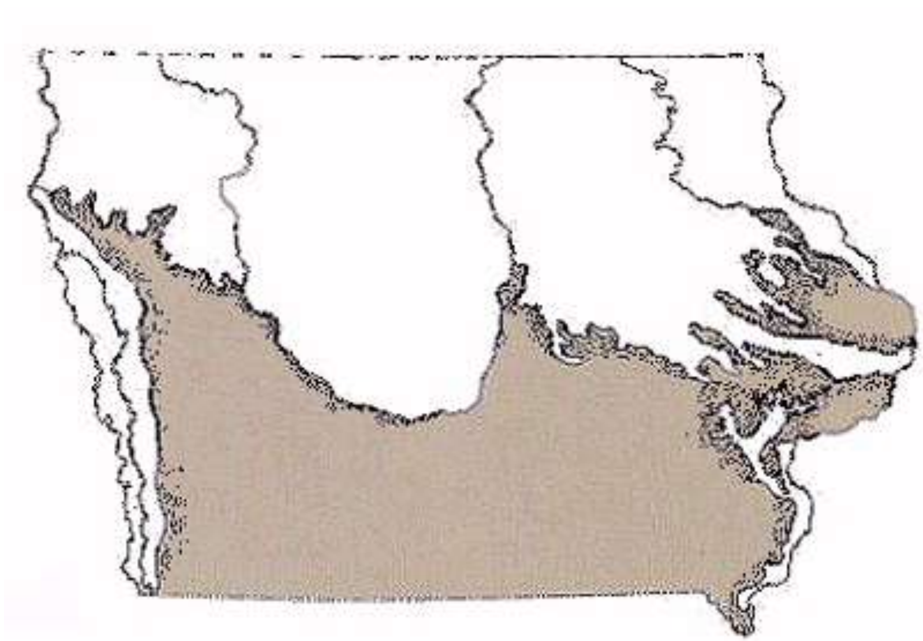


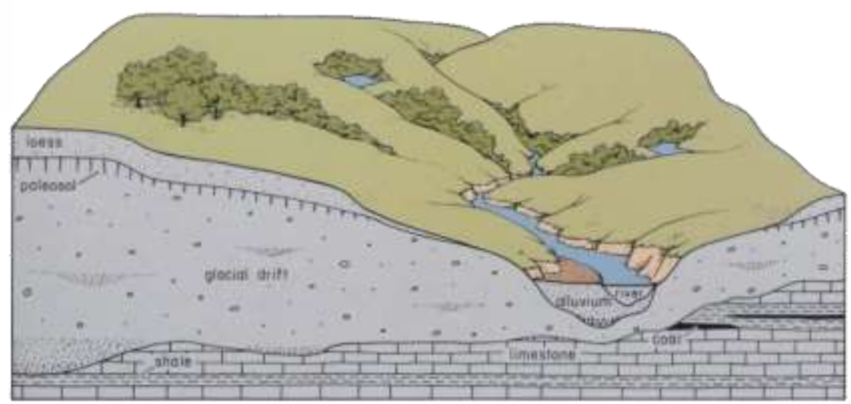


Terrain Characteristics
*** thick loess cover**
*** sharply ridged terrain**
*** high drainage density**
*** rapid surface runoff**
*** gully development**

Source: Iowa Geological Survey

Southern Iowa Driftplain

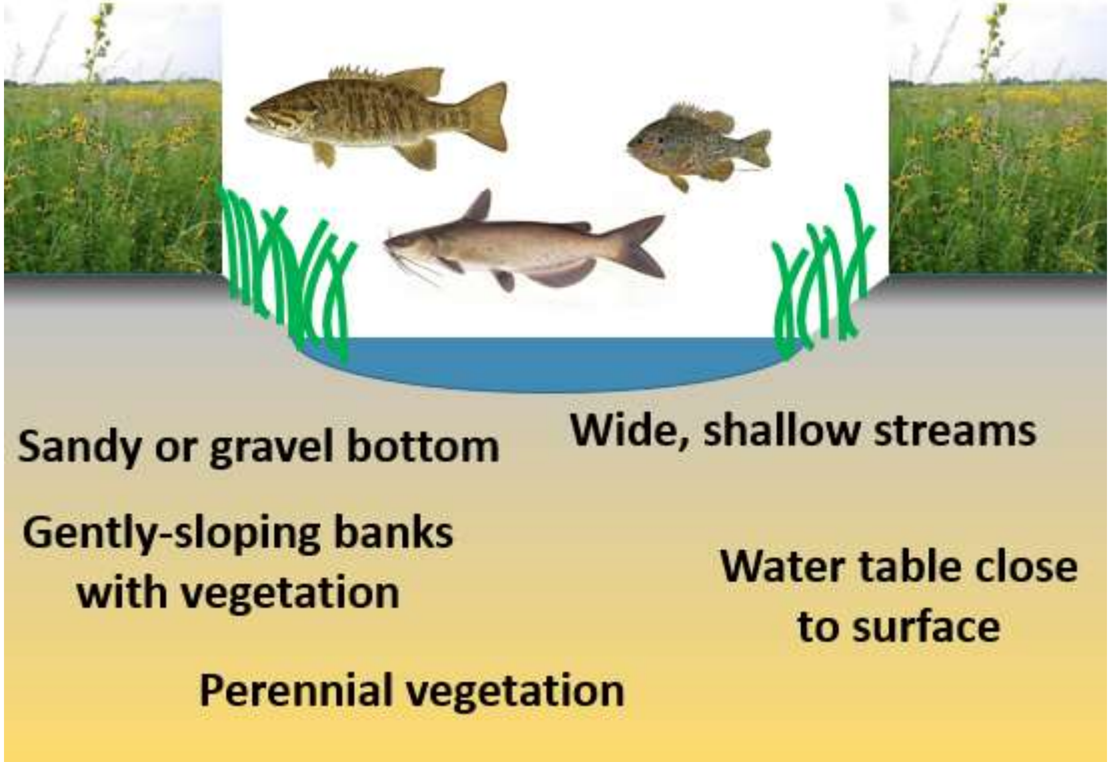




Terrain Characteristics
*** Loess of varying thicknesses**
*** stepped erosion surfaces**
*** bedrock exposed in deeper valleys**

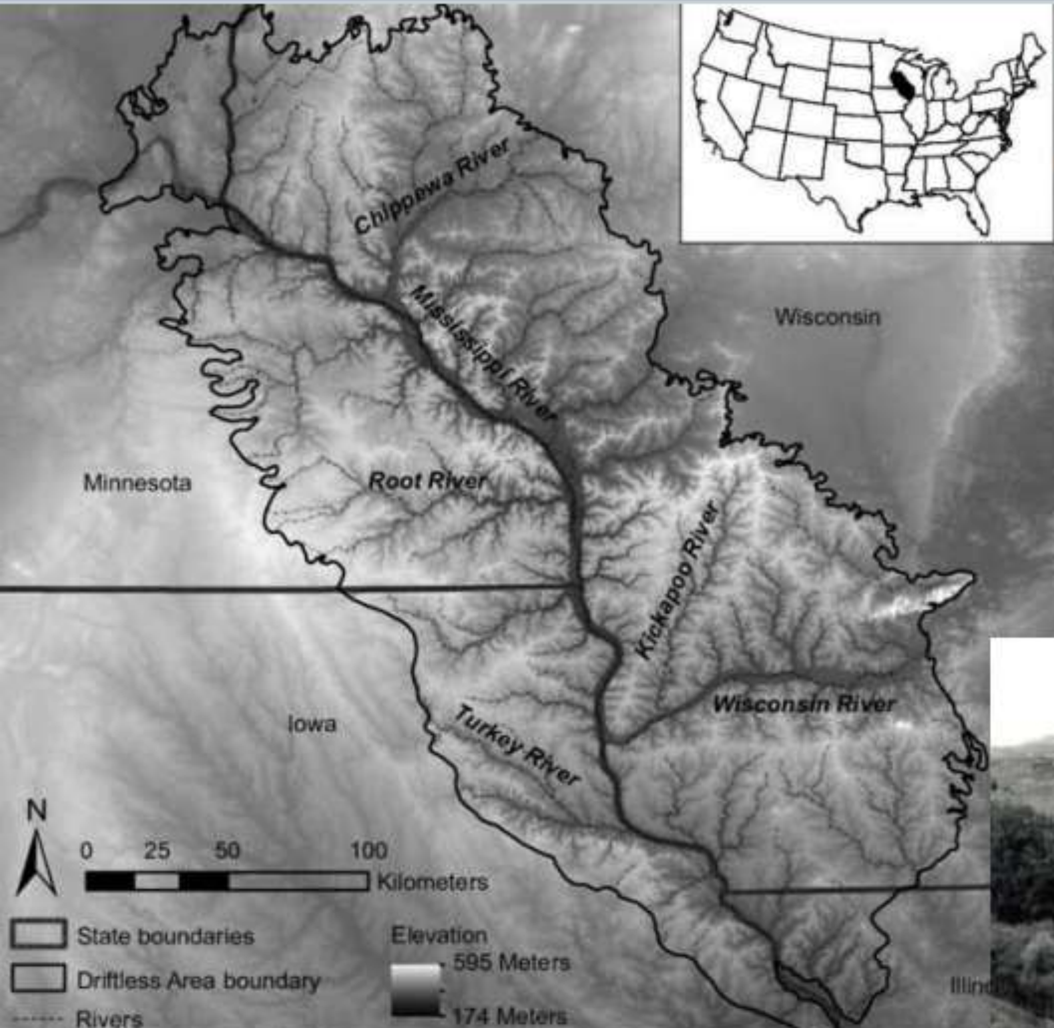
Source: Iowa Geological Survey

Pre-European Settlement Streams



Breaking the prairie

Photo courtesy of Deere and Company



Credit: Shea, M.E., Schulte, L.A. and Palik, B.J., 2014. Reconstructing vegetation past: pre-Euro-American vegetation for the midwest driftless area, USA. *Ecological Restoration*, *32*(4), pp.417-433.

Credit: USDA

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

How the landscape used to hold water

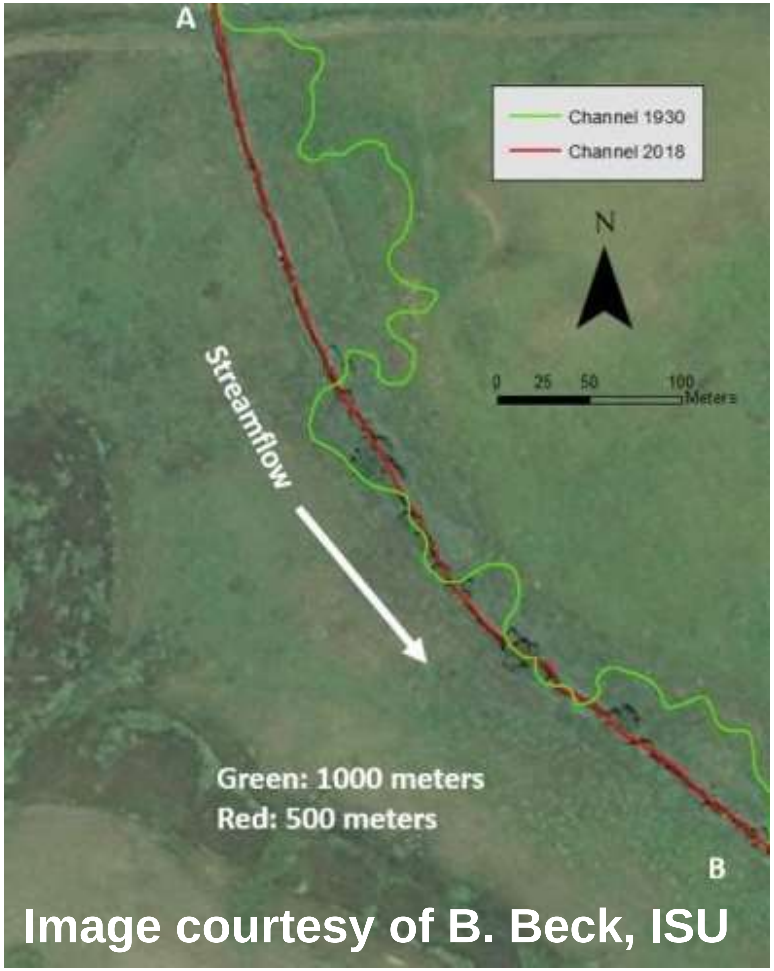
Attachment 1. Photo of ponded water in drained wetlands of Iowa's Prairie Pothole Region after a heavy rain temporarily backed up the drain tile in early May, 2005. Photo courtesy of Guy Zenner, Iowa DNR Waterfowl Biologist.

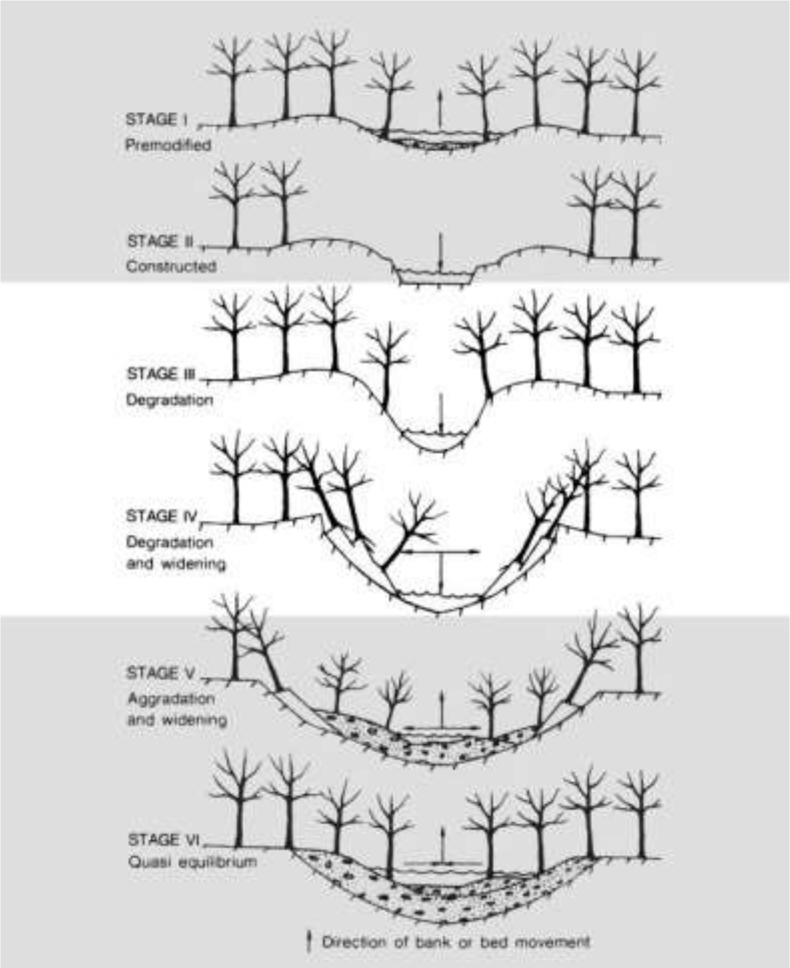
In the early 1800s, Iowa contained about 10 to 15 million ha of wetlands. About 99% of that acreage is gone.

Tiling field now

Source of the Iowa River

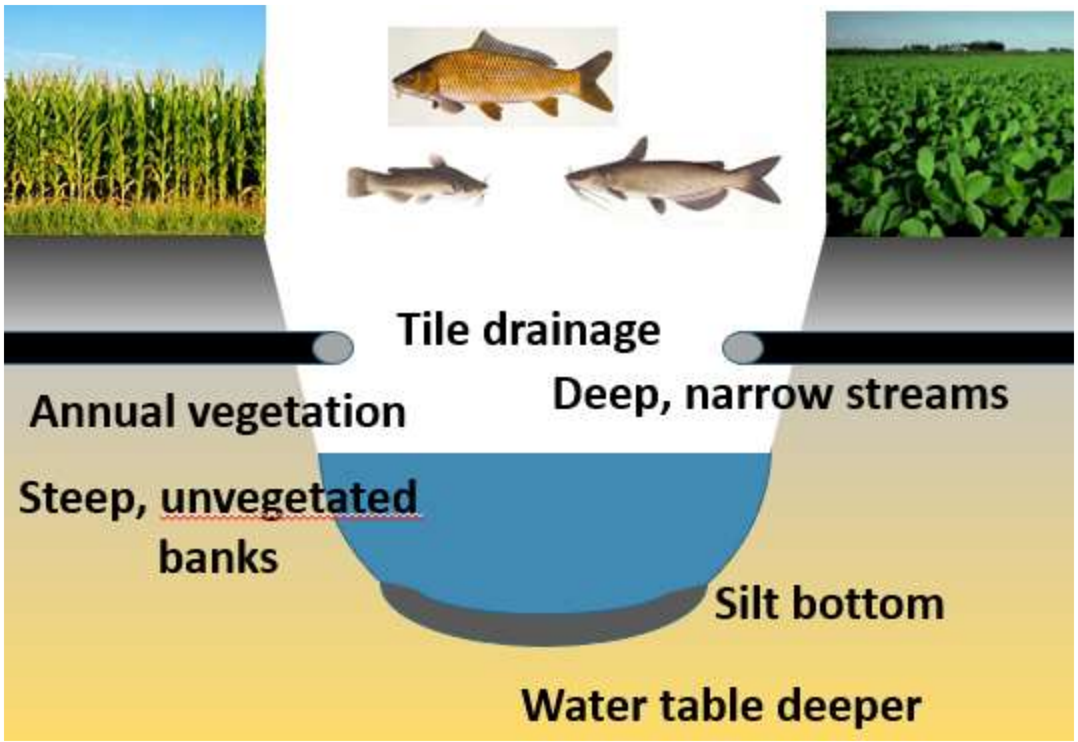
Stream Straightening, 1930-1975





Images courtesy of B. Beck, ISU

Modified Streams



Transformation of Iowa Farms

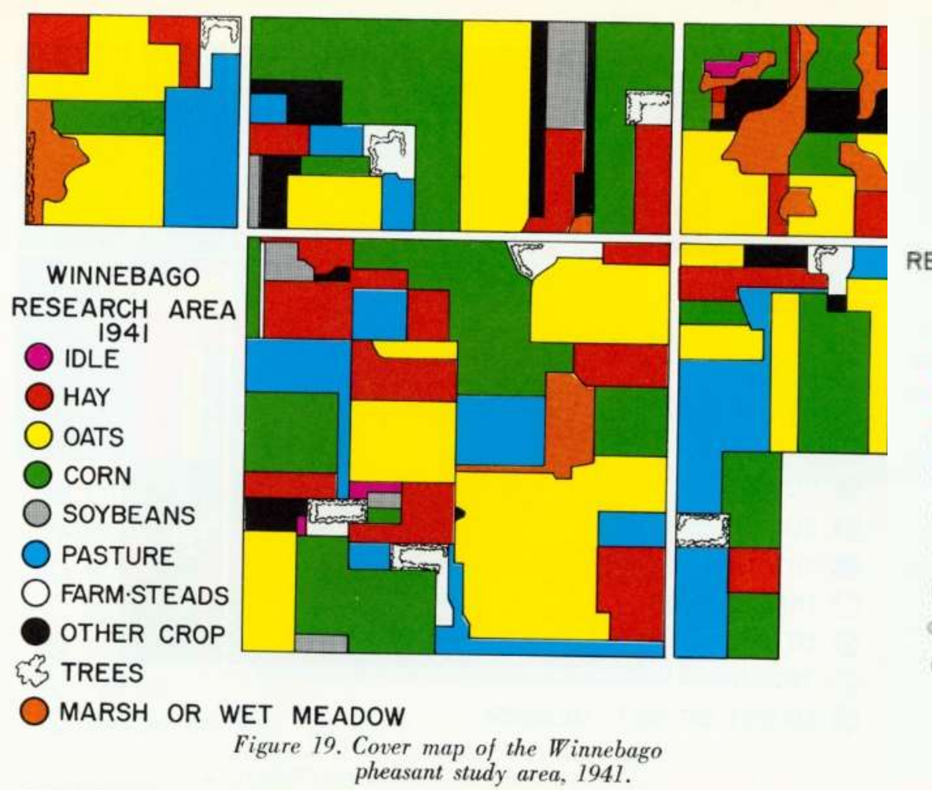


Figure 19. Cover map of the Winnebago pheasant study area, 1941.

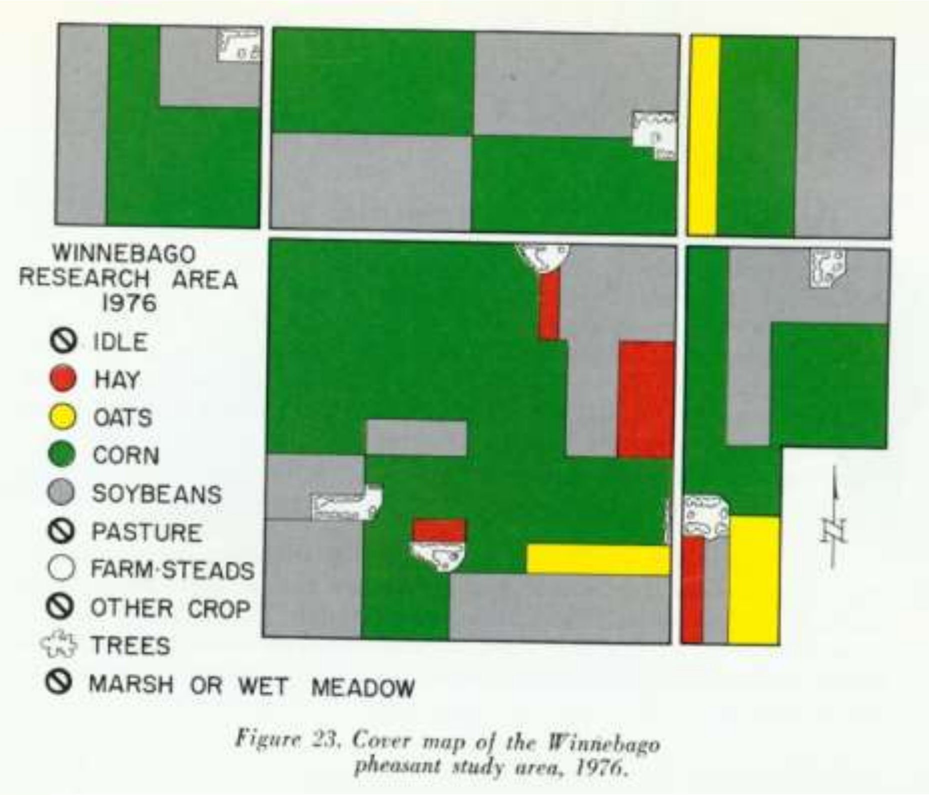


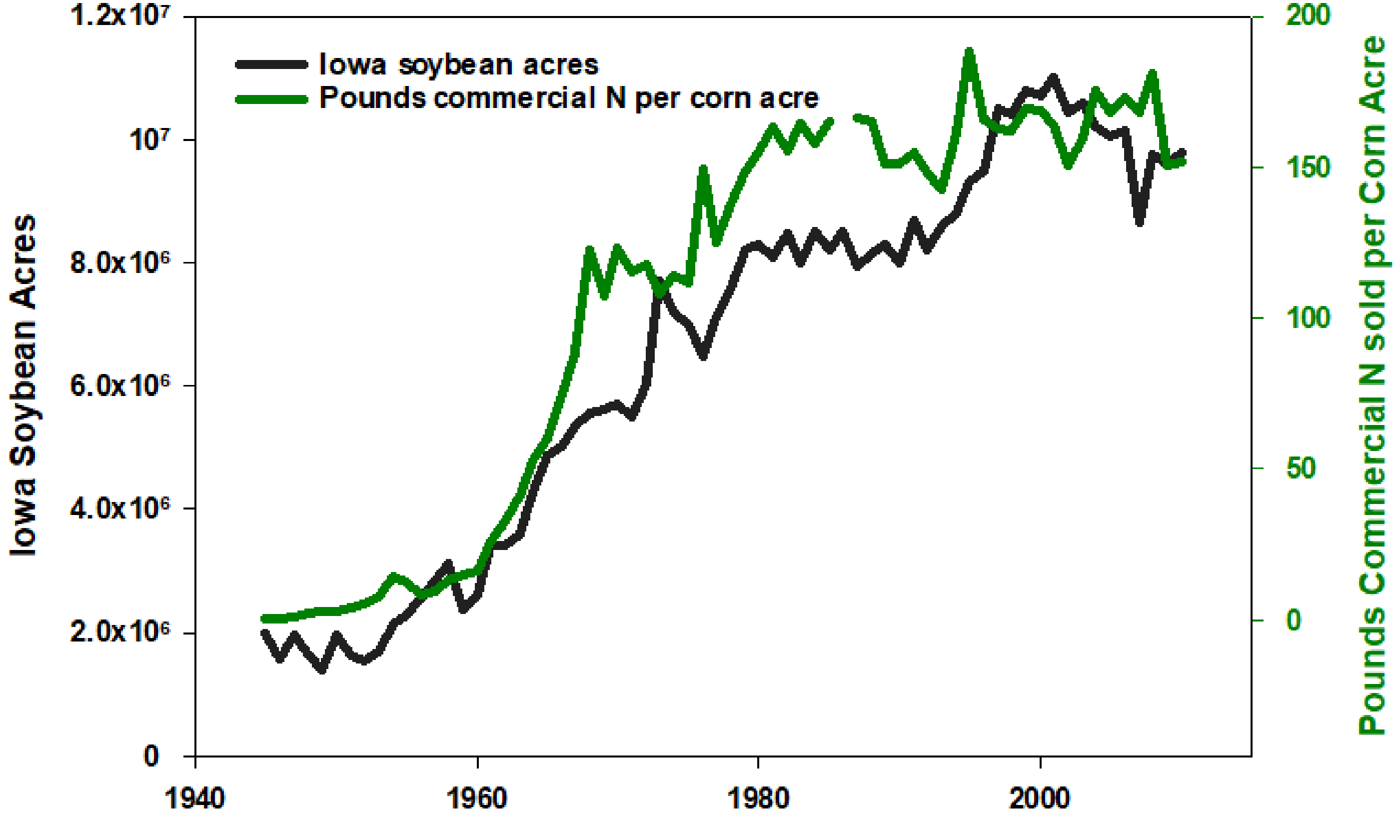
Figure 23. Cover map of the Winnebago pheasant study area, 1976.

1941

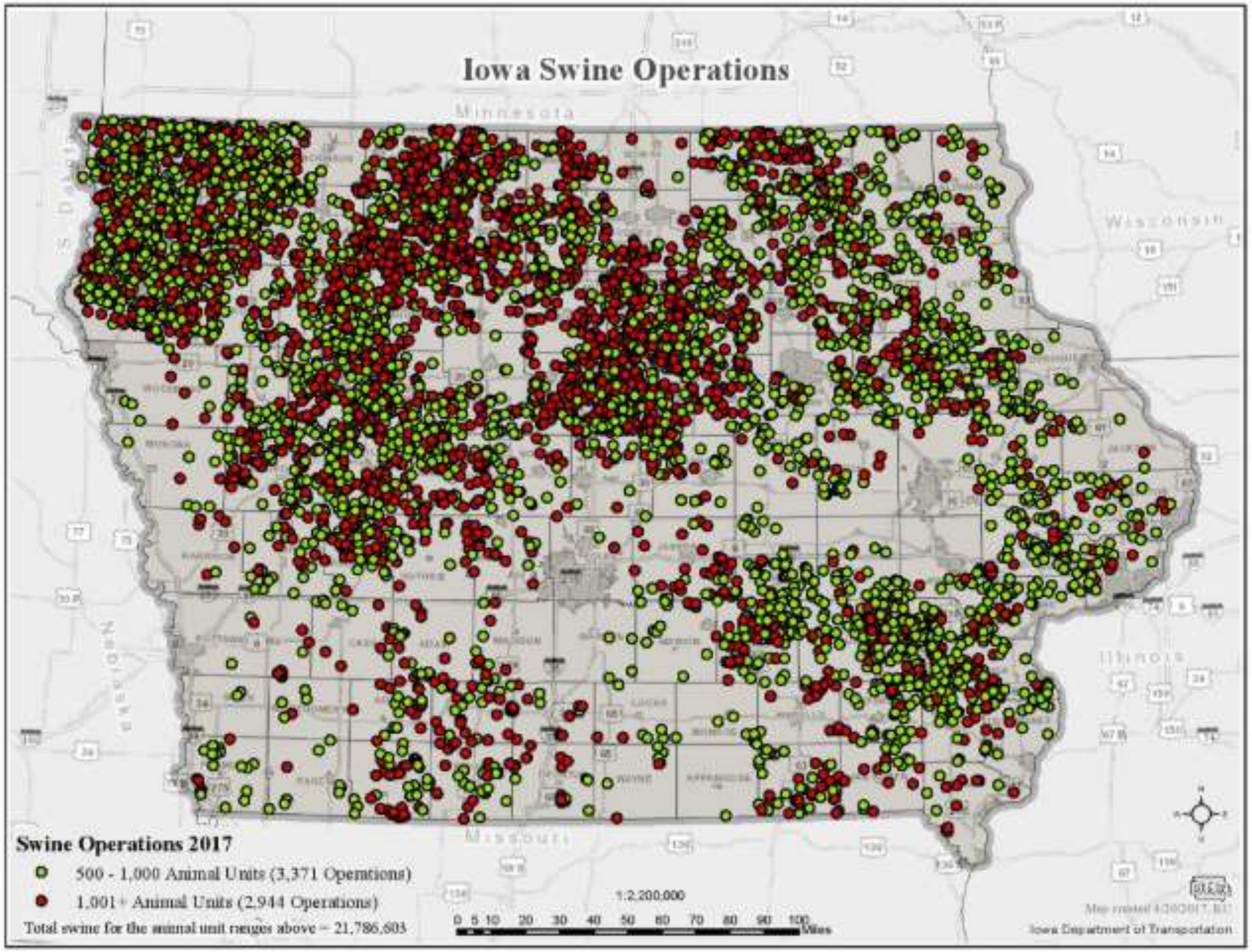
1976




Role of Soybeans



8000 CAFOs

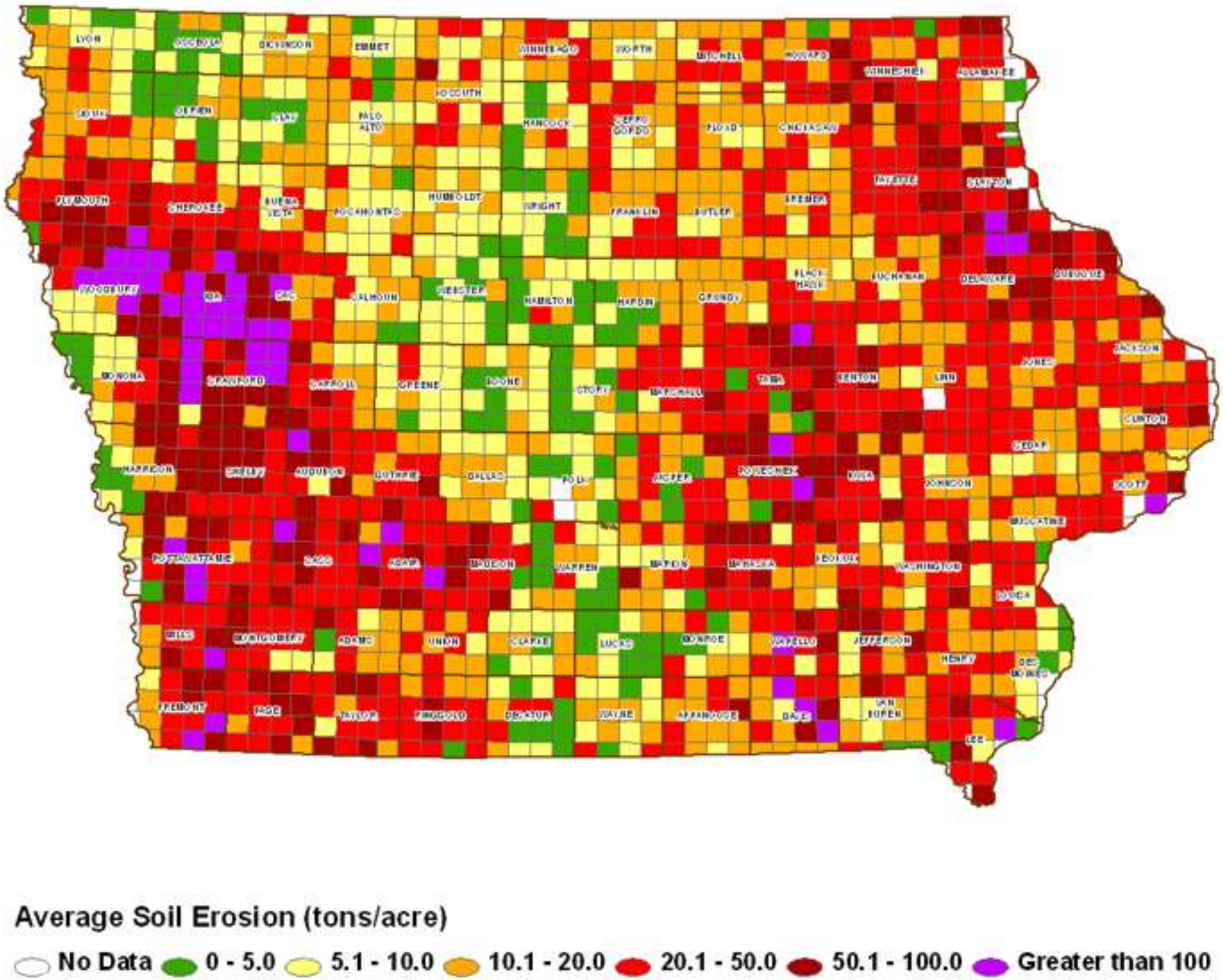

Iowa Swine Operations
Minnesota
Wisconsin
Illinois
Missouri
Nebraska
Swine Operations 2017
500 - 1,000 Animal Units (3,371 Operations)
1,001+ Animal Units (2,944 Operations)
Total swine for the animal unit ranges above = 21,786,603
1:2,200,000
0 5 10 20 30 40 50 60 70 80 90 100 Miles
Iowa Department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

Soil loss is still very high



Source:
EWG

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

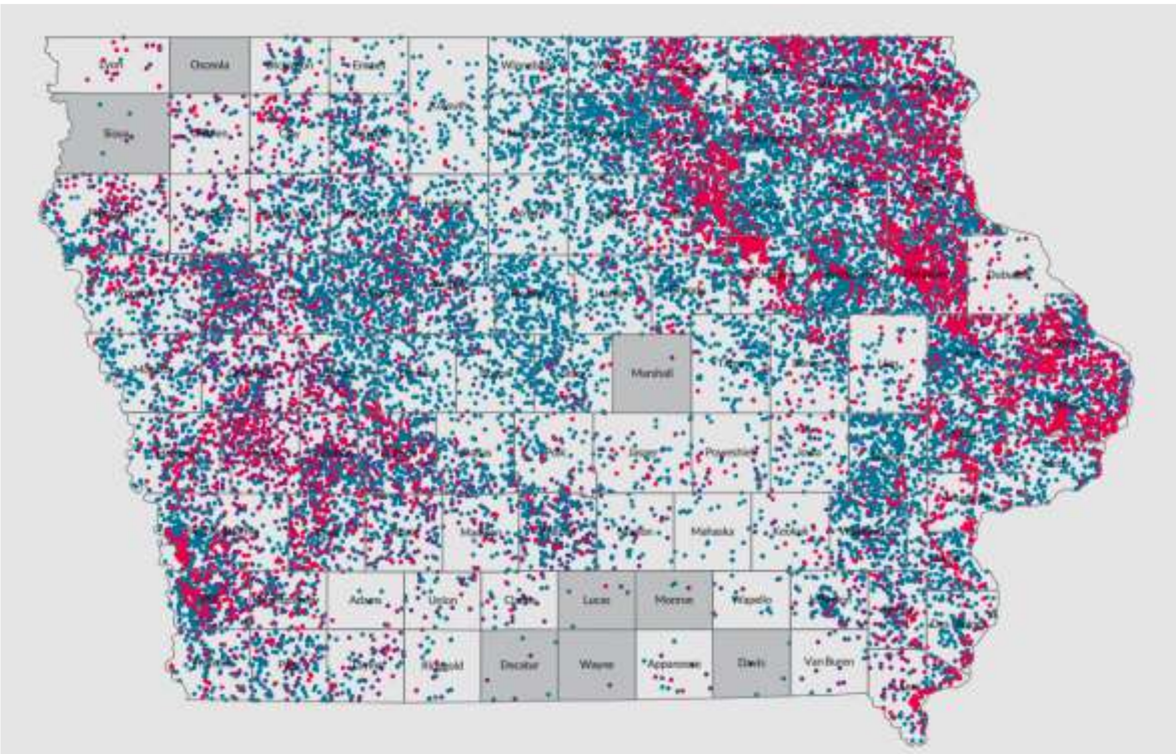
Especially important in marine ecosystems

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

United States Environmental Protection Agency

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CONTACT US

Mississippi River/Gulf of Mexico Hypoxia Task Force

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

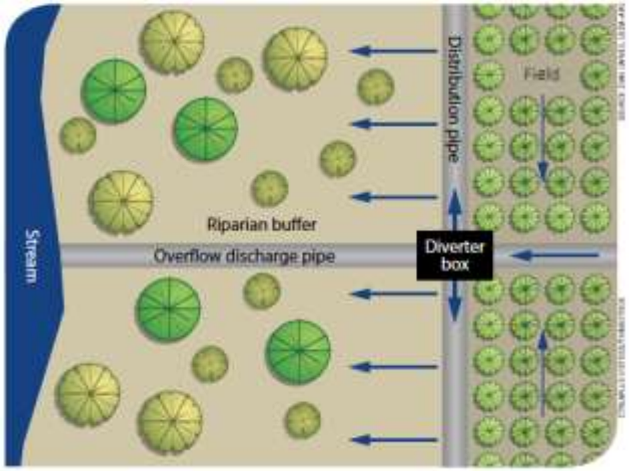
IOWA DEPARTMENT OF NATURAL RESOURCES

IOWA STATE UNIVERSITY

Practices

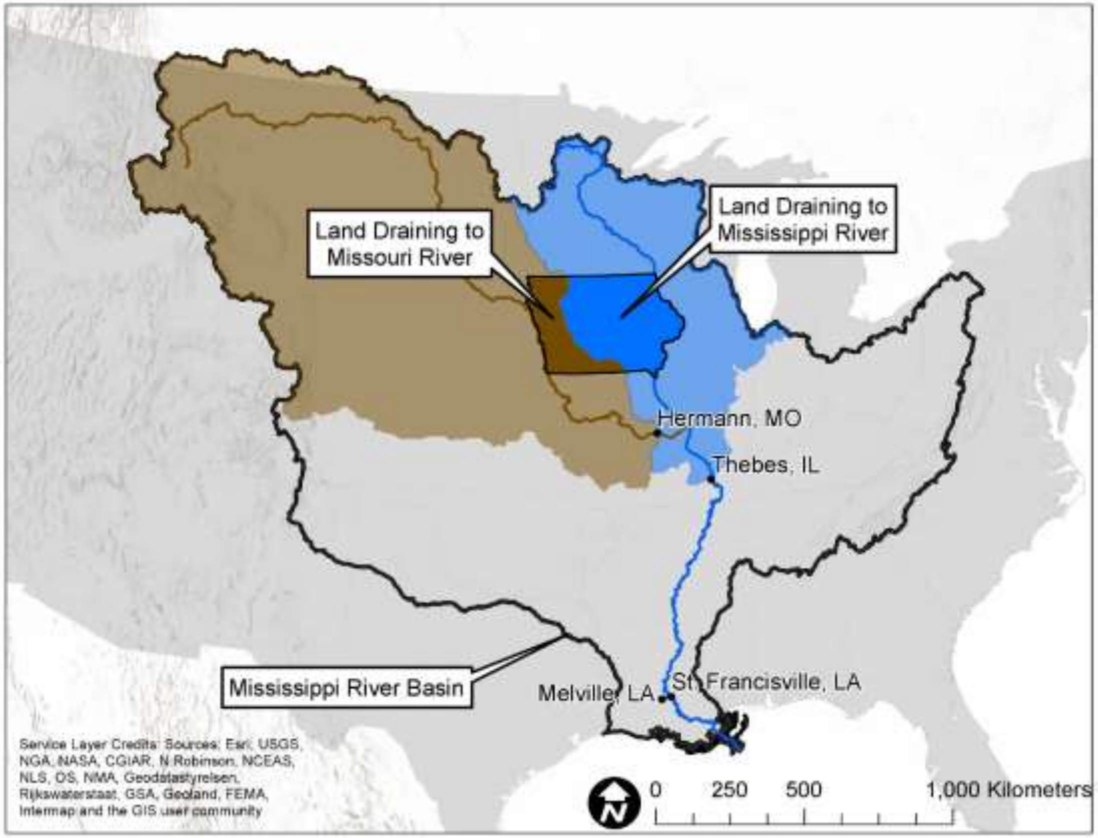
Cover crops

Wetland construction

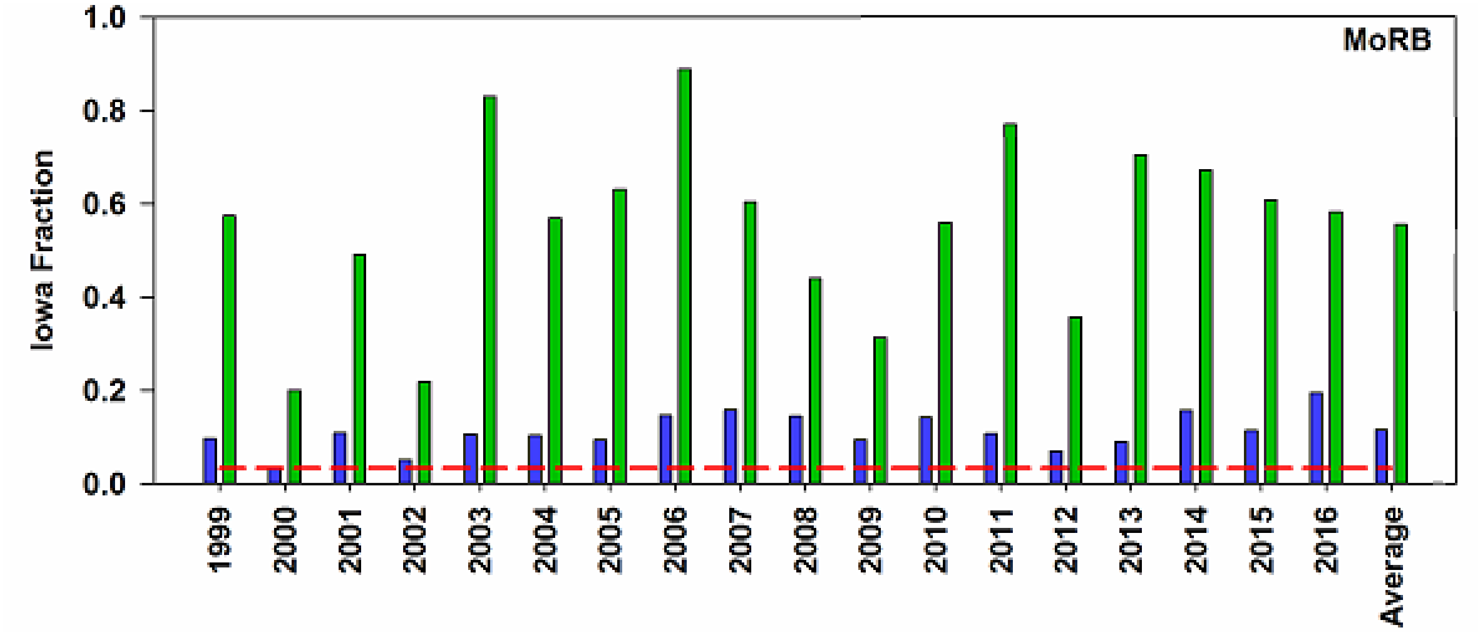


Saturated Buffer

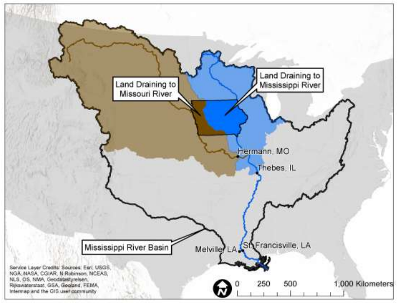
Iowa Contributions



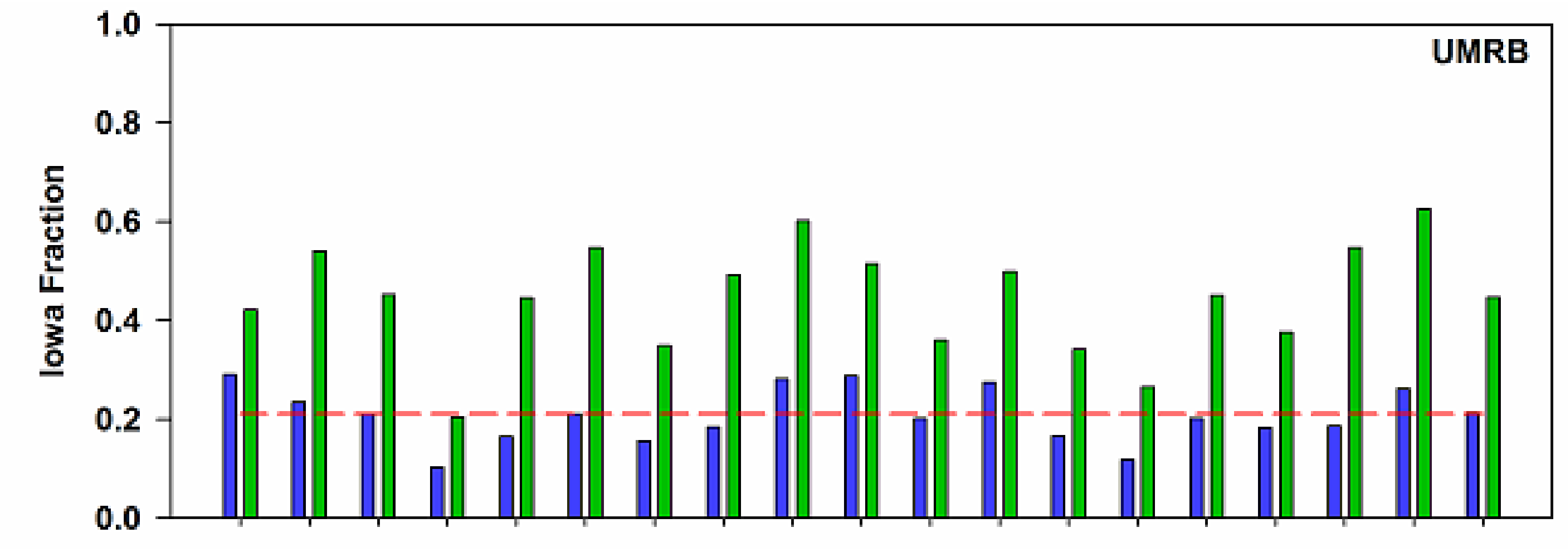
Missouri Basin: Nitrogen



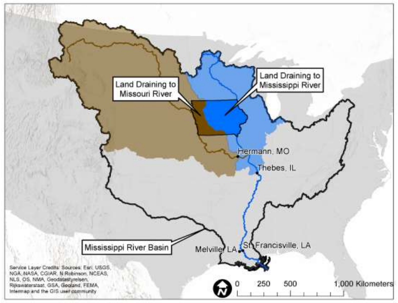
3.3% of the land
12% of the water
55% of the nitrate



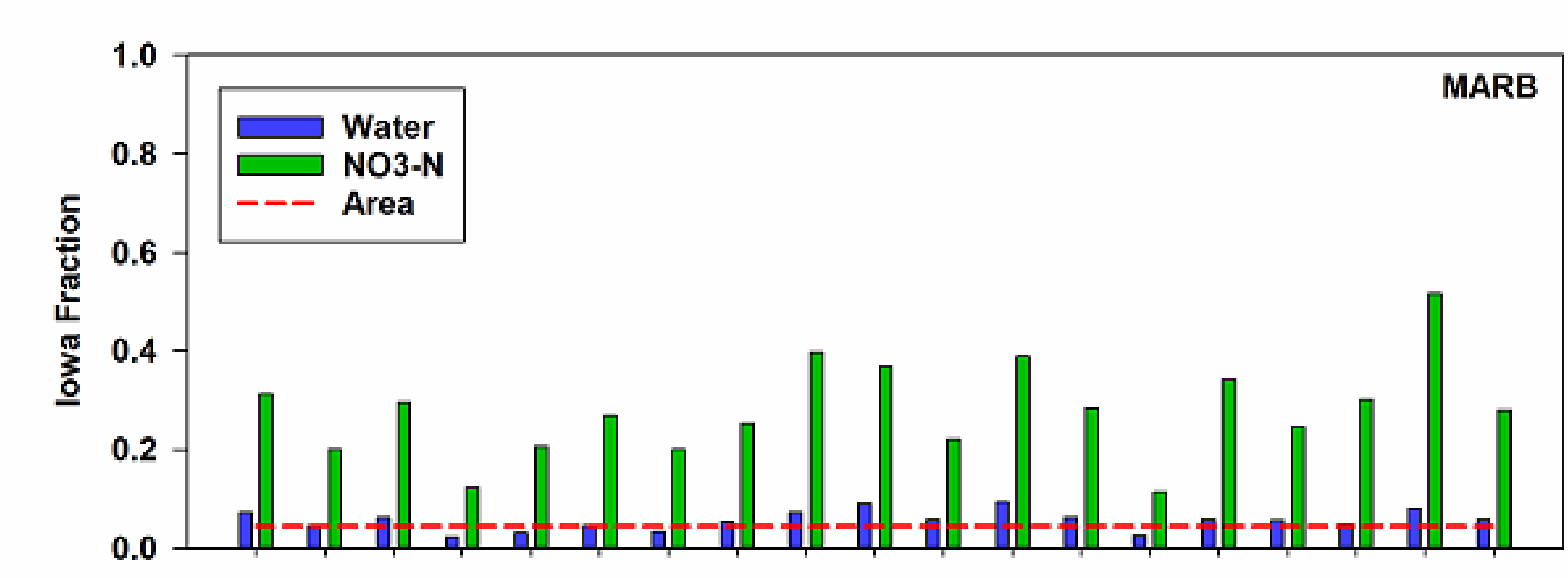
Upper Mississippi: Nitrogen

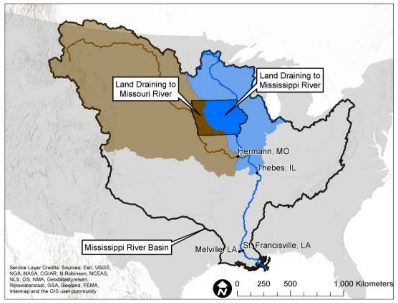


21% of the land
21% of the water
45% of the nitrate



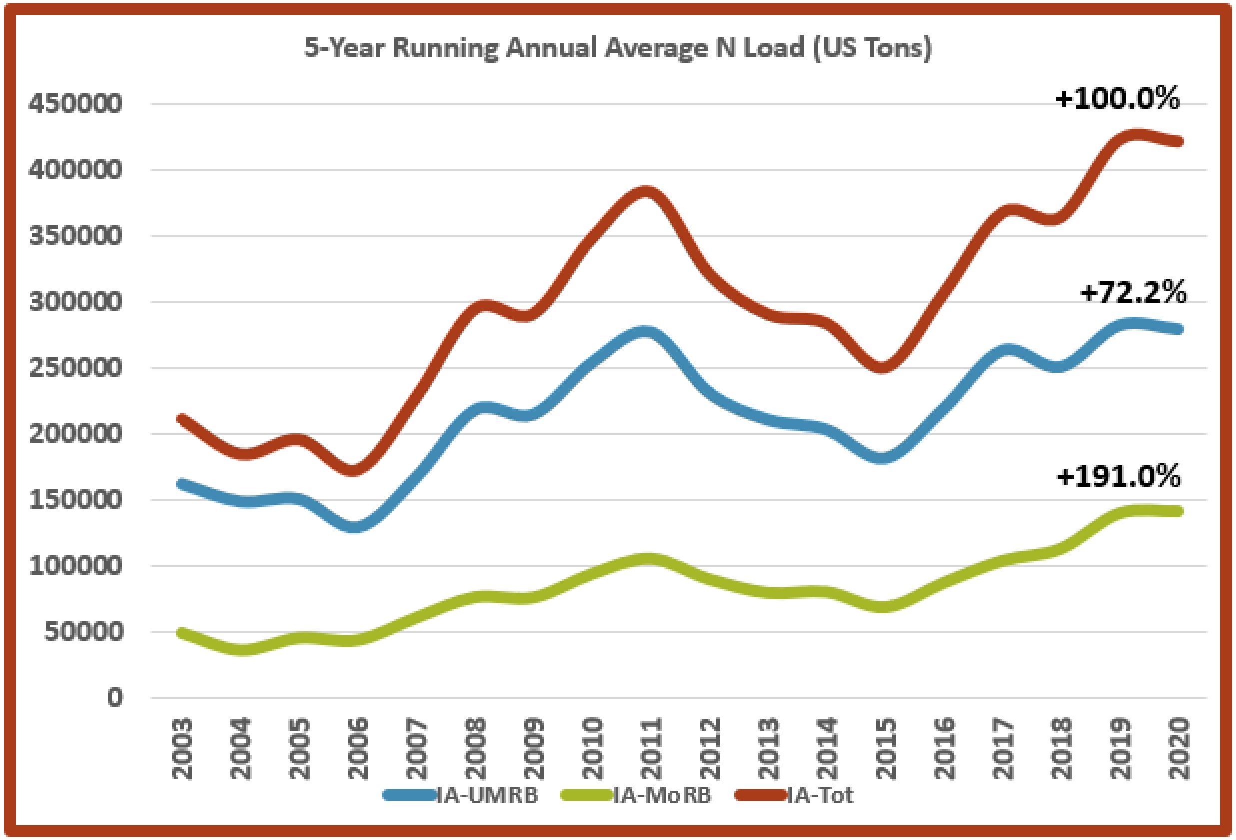
Mississippi-Atchafalaya: Nitrogen





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

How Much Nitrogen Leaves Iowa?



PLOS | ONE

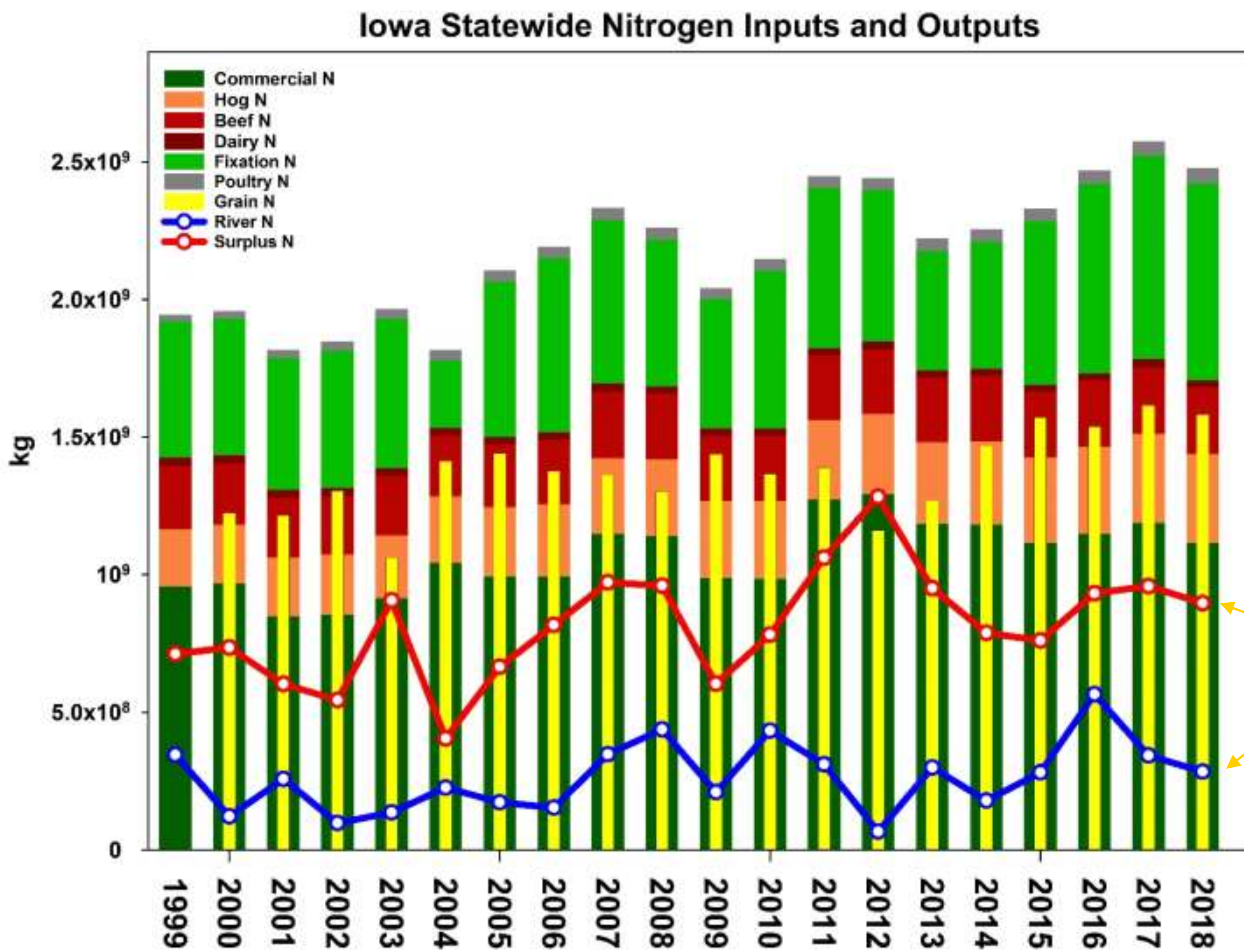
RESEARCH ARTICLE

Iowa stream nitrate and the Gulf of Mexico

Christopher S. Jones[1☯*], **Jacob K. Nielsen**[1☯], **Keith E. Schilling**[2☯], **Larry J. Weber**[1☯]

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.
* Christopher-s-jones@uiowa.edu



About 32% of "surplus" makes it to streams

Nitrogen Change since 1999

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

Phosphorus

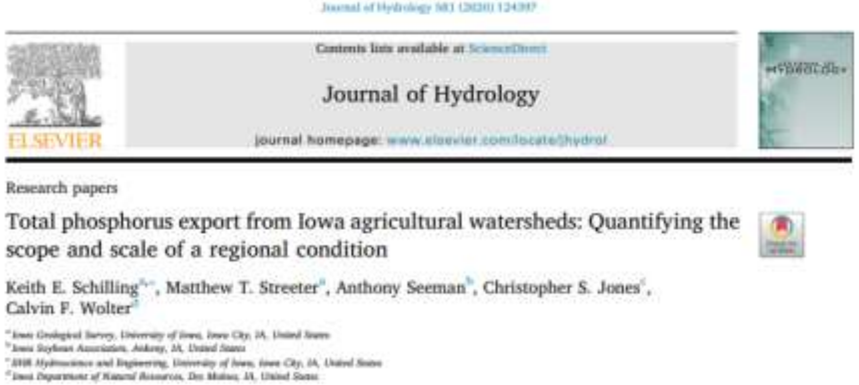
Applied as MAP, DAP, Super Triple Phosphate and manure.
Not a regulated drinking water contaminant
Attaches tenaciously to soil particles
Loss through erosion primarily
Especially important in freshwater ecosystems.

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”


Contents lists available at ScienceDirect

Journal of Hydrology

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, Matthew T. Streeter, Anthony Seeman, Christopher S. Jones, Calvin F. Wolter

Economics of N loss

Cost of Nitrogen: today about $0.86/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

New Tile

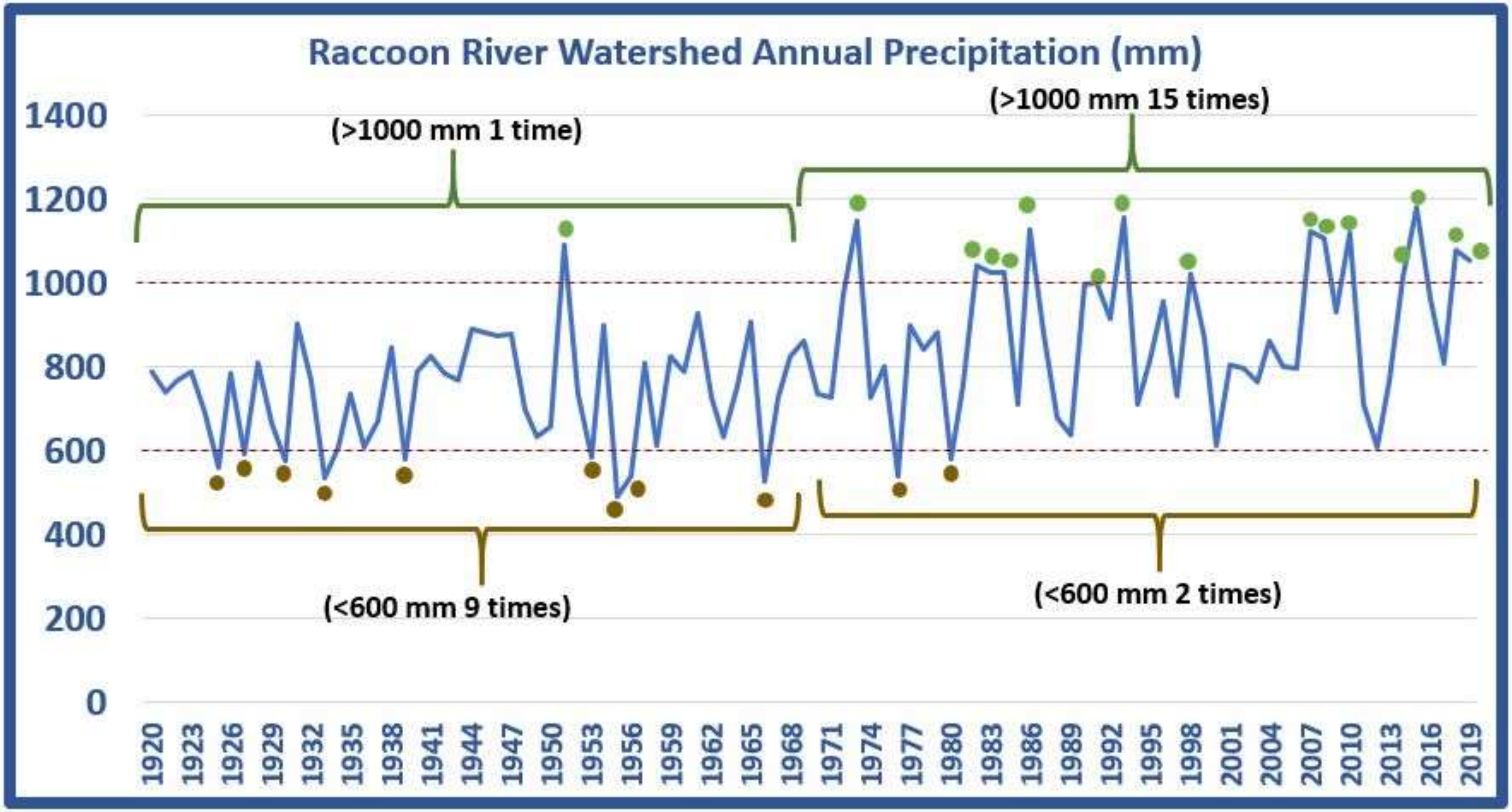
Watershed	2002	2007	2016
Middle Cedar	$1,900,000	$5,100,000	$5,600,000
Upper Wapsi	$1,800,000	$2,200,000	$6,600,000
English River	$187,000	$492,000	$1,124,000
North Raccoon	$536,000	$936,000	$1,175,000
Upper Iowa	$106,000	$231,000	$931,000
Clear Creek	$9,350	$4,300	$50,500

Table 1: Estimated amount spent on new drainage tile in six Iowa watersheds.

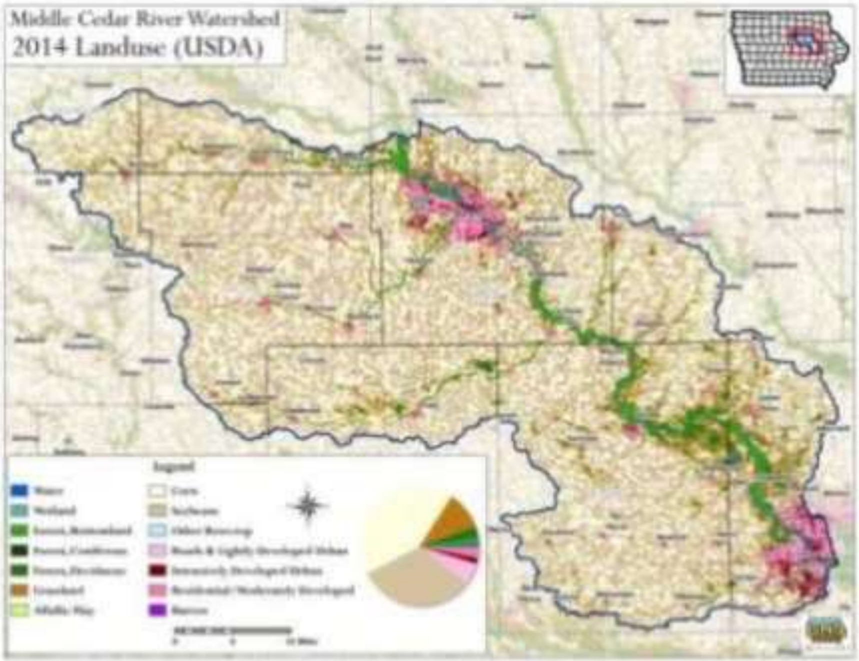
Landform	% of Iowa's Area	$/year spent on new tile
Iowan Surface	16.9	$24,500,000
Des Moines Lobe	21.4	$5,845,000
Northwest Iowa Plains	8.3	$2,272,545
Paleozoic Plateau	4.6	$3,580,862
Southern Iowa Drift Plain	41.3	$33,837,580
Total	92.5	$70,064,878

Table 2: Estimated amounts spent in 2016 on new drainage tile in five of Iowa's landforms.

Climate Change



More N loss: Middle Cedar Example



Iowa's Middle Cedar Watershed (credit: Middle Cedar Watershed Management Authority and Iowa DNR)

1200 miles new tile per year

1 acre of pattern tile = 1452' (0.275 mi)

1200 miles = 4364 acres

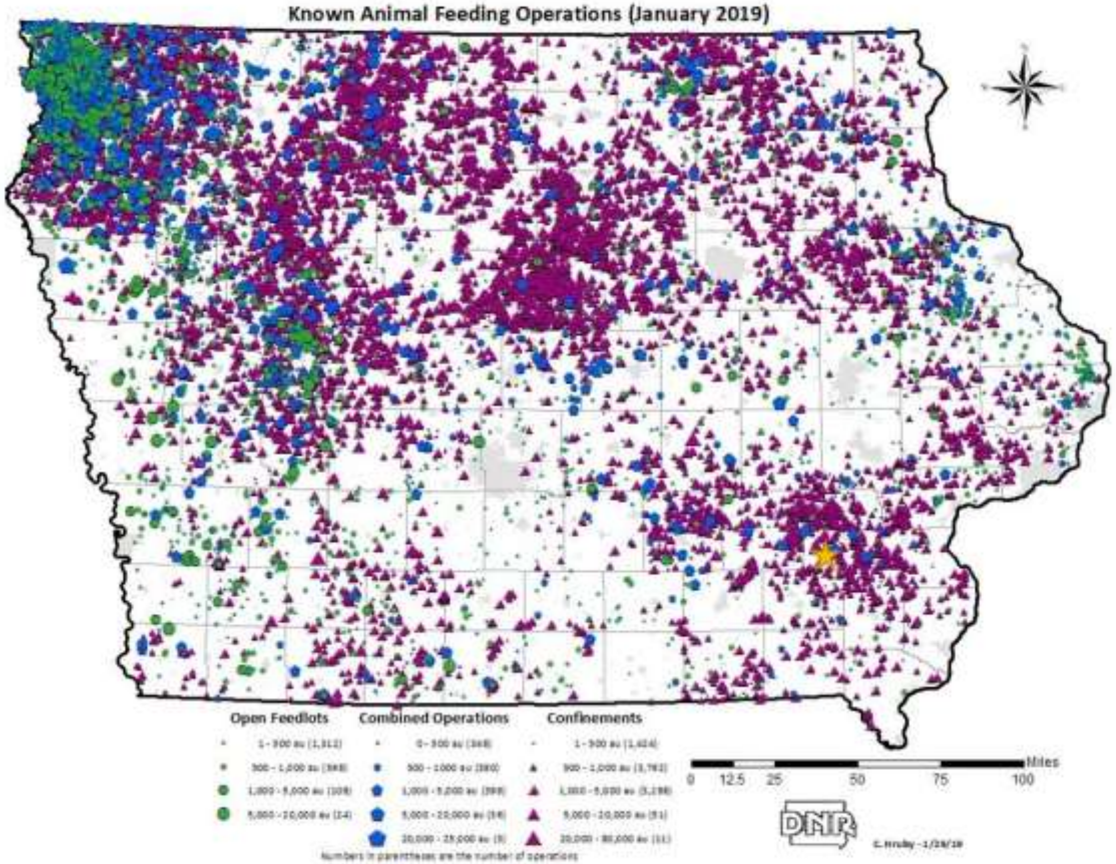
2018 N loss = 31.5 lbs/ac

New tile multiply N loss by 1.5 (15.9 lbs)

Increase watershed N load by 69,000 lbs

- 136 woodchip bioreactors (we currently have about 50 statewide), or,
- 3 constructed wetlands (currently we have about 100 statewide), or
- Around 7000 new acres of cover crops (currently we have million ac statewide).

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)

What has happened to Iowa Ag since 1970?

Loss of Crop Diversity

Concentration of Livestock

Decouple Livestock and Crop Production

Huge increase in Hogs and Chickens

Loss of Cattle—especially on pasture

Fewer Farmers farming more land

Regulations?

1. Ban cropping in the 2-year Flood Plain

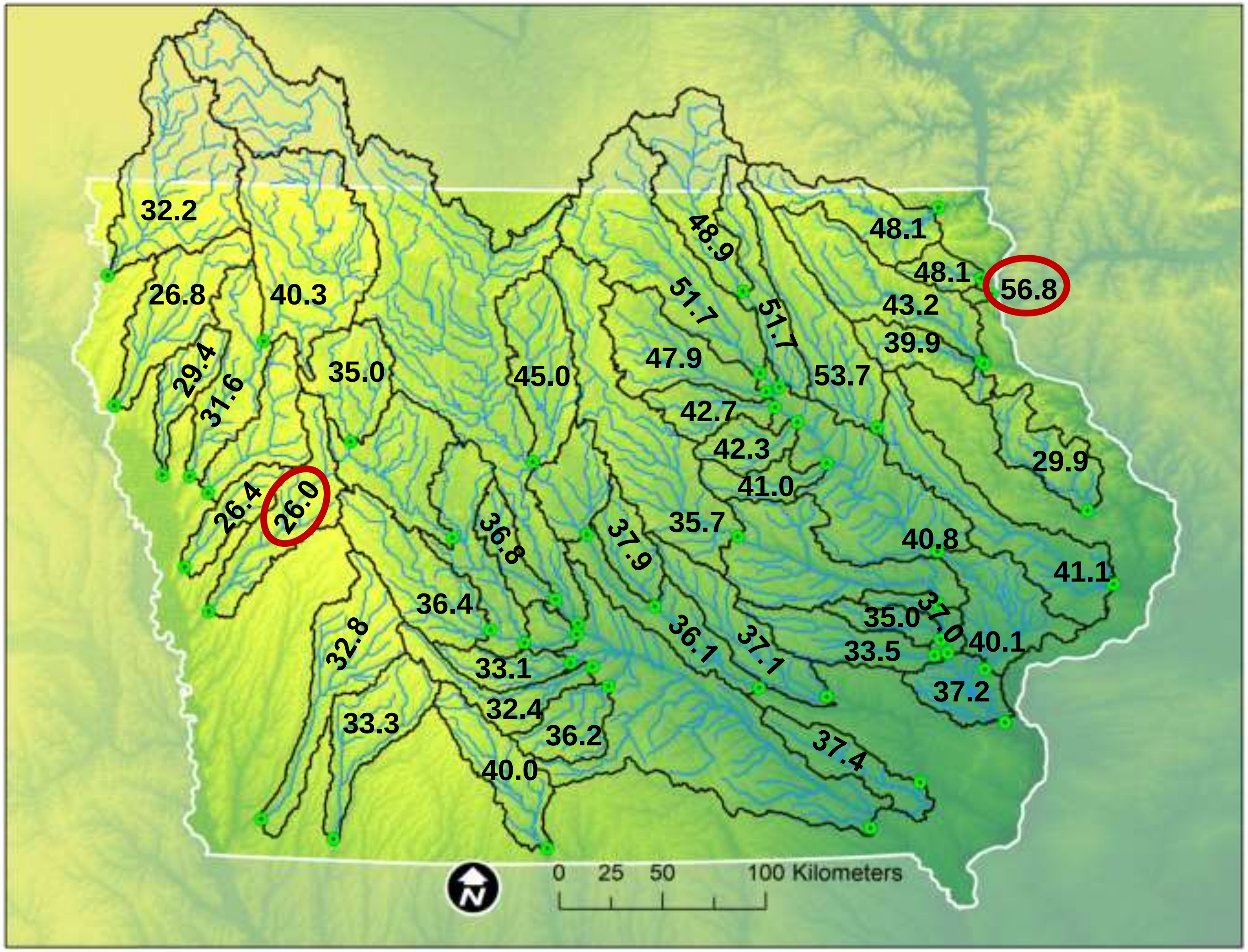
2. Ban fall tillage

3. Ban manure on snow and frozen ground

4. Make farmers adhere to ISU fertilization guidelines

5. Reformulate CAFO Regulations

2000-2020



>96=Excellent
81-95=Good
66-80=Fair
46-65=Marginal
10-45=Poor
<10=Very Poor

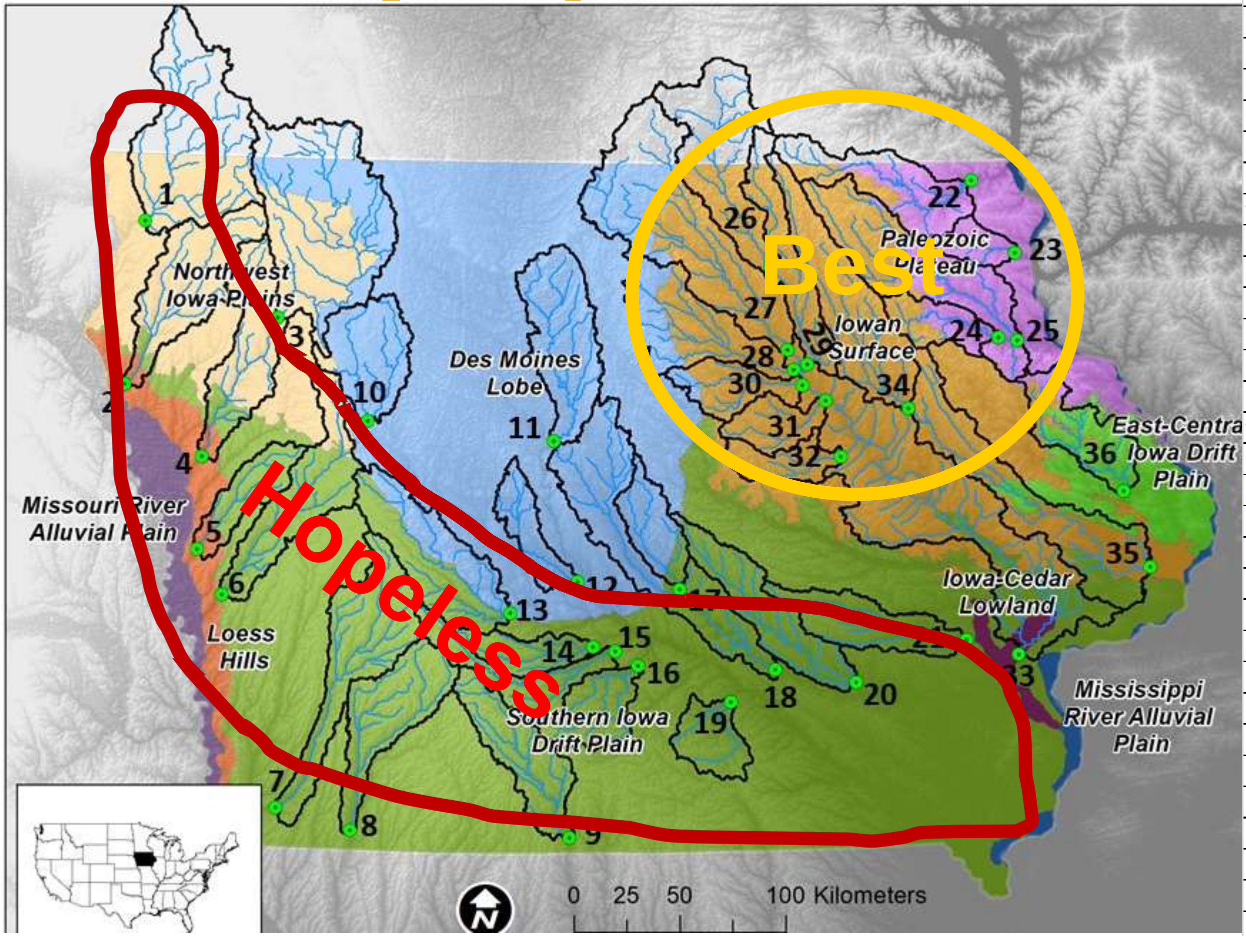
Stream Water Quality Since 1999

3/44 improving (>5%)

16/44 <5% change

25/44 declining (>5%)

Water Quality Index

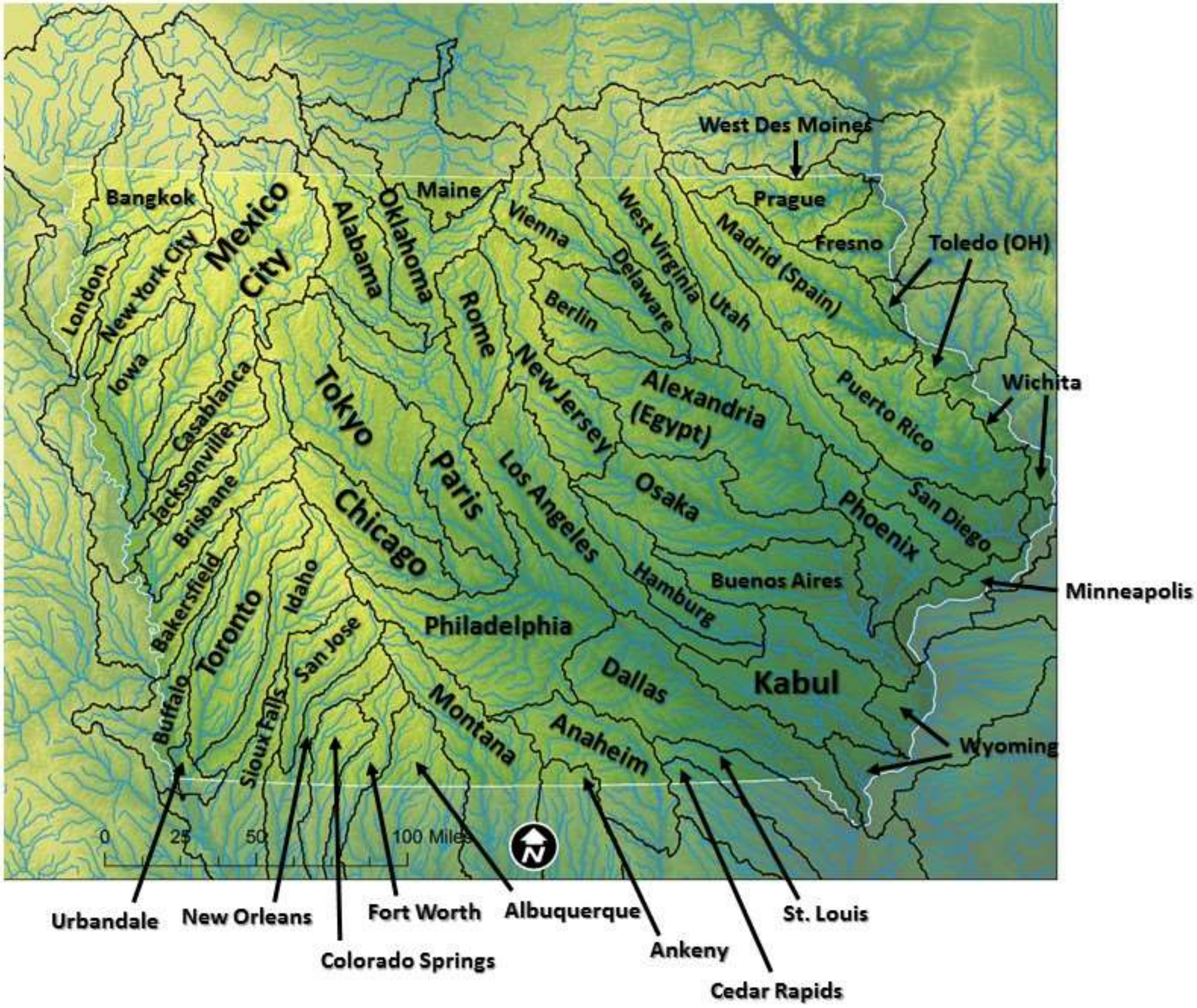


Site	Rank	Map #	00-20
Wapsipinicon River at Independence	1	34	53.7
Cedar River at Janesville	2	29	51.7
Shellrock River at Shellrock	3	27	51.7
Cedar River at Charles City	4	26	48.9
Upper Iowa River at Dorchester	5	22	48.1
Yellow River at Ion	6	23	48.1
W. Fork of the Cedar River at Finchford	7	28	47.9
Boone River at Stratford	8	11	45.0
Turkey River at Garber	9	25	43.2
Beaver Creek at Cedar Falls	10	30	42.7
Blackhawk Creek at Waterloo	11	31	42.3
Wapsipinicon River at DeWitt	12	35	41.1
Wolf Creek at LaPorte City	13	32	41.0
Little Sioux River at Larrabee	14	3	40.3
Cedar River at Conesville	15	33	40.1
Thompson River at Davis City	16	9	40.0
Volga River at Elkport	17	24	39.9
Indian Creek at Colfax	18	17	37.9
Cedar Creek at Oakland Mills	19	19	37.4
North Skunk River at Sigourney	20	20	37.1
Beaver Creek at Grimes	21	12	36.8
South Raccoon River at Redfield	22	13	36.4
South River at Ackworth	23	15	36.2
South Skunk River at Oskaloosa	24	18	36.1
North Raccoon at Sac City	25	10	35.0
English River at Riverside	26	21	33.5
W. Nodaway at Shambaugh	27	8	33.3
North River at Norwalk	28	14	33.1
E. Nishnabotna at Shenandoah	29	7	32.8
Middle River at Indianola	30	15	32.4
Rock River at Rock Valley	31	1	32.2
Little Sioux River at Smithland	32	4	31.6
N. Fork Maquoketa R. at Hurtsville	33	36	29.9
Floyd River at Sioux City	34	2	26.8
Soldier River at Pisgah	35	5	26.4
Boyer River at Missouri Valley	36	6	26.0

What do we want our production system to look like?

Commerce

Nutrition?


West Des Moines
Prague
Fresno
Toledo (OH)
Bangkok
Mexico City
Alabama
Oklahoma
Maine
Vienna
West Virginia
Madrid (Spain)
London
New York City
Delaware
Utah
Berlin
Rome
Iowa
Casablanca
Jacksonville
Brisbane
Tokyo
New Jersey
Alexandria (Egypt)
Puerto Rico
Wichita
Paris
Los Angeles
Osaka
Phoenix
San Diego
Chicago
Bakersfield
Idaho
Toronto
Hamburg
Buenos Aires
Minneapolis
San Jose
Philadelphia
Buffalo
Sioux Falls
Montana
Dallas
Kabul
Anaheim
Wyoming
0
25
50
100 Miles
N
Urbandale
New Orleans
Colorado Springs
Fort Worth
Albuquerque
Ankeny
Cedar Rapids
St. Louis

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

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