

Chris Jones, Research Engineer, IIHR Hydroscience and Engineering

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

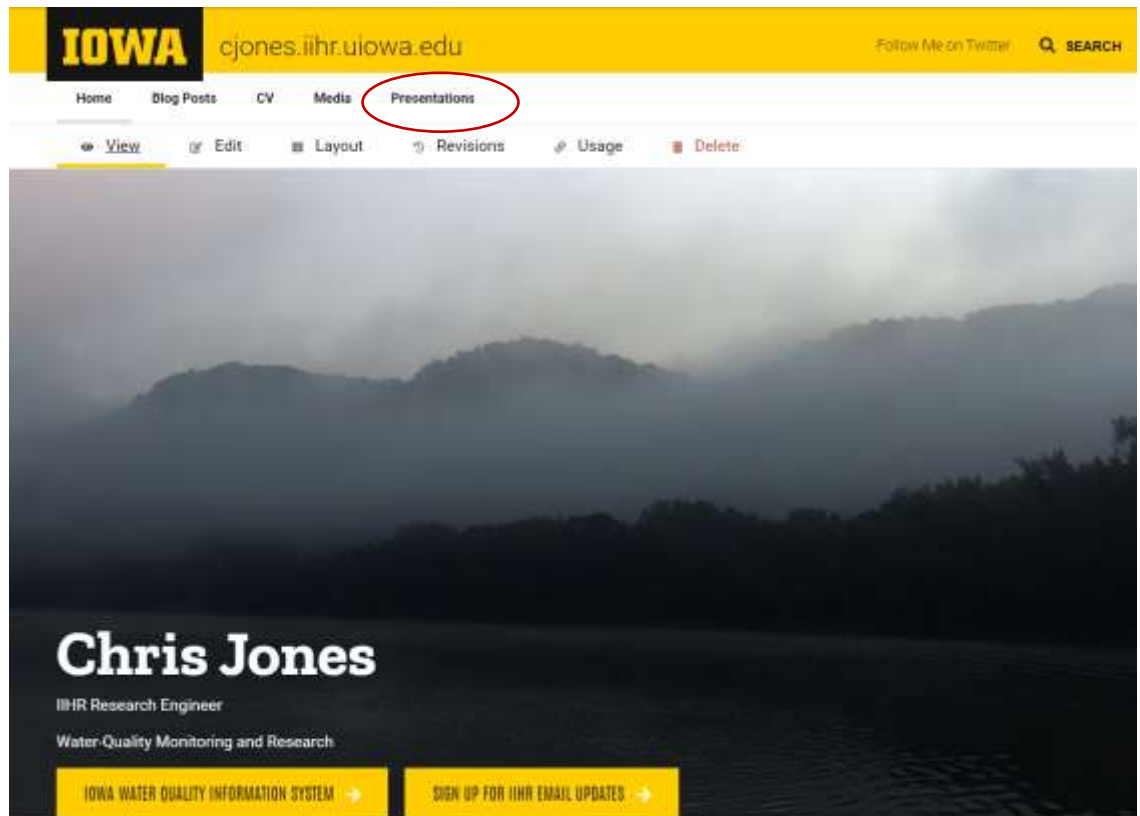
February 6, 2023

Drake OLLI

## 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 scientists, 2011-2015
- UI, 2015-present



# IIHR Water Quality Sensor Network

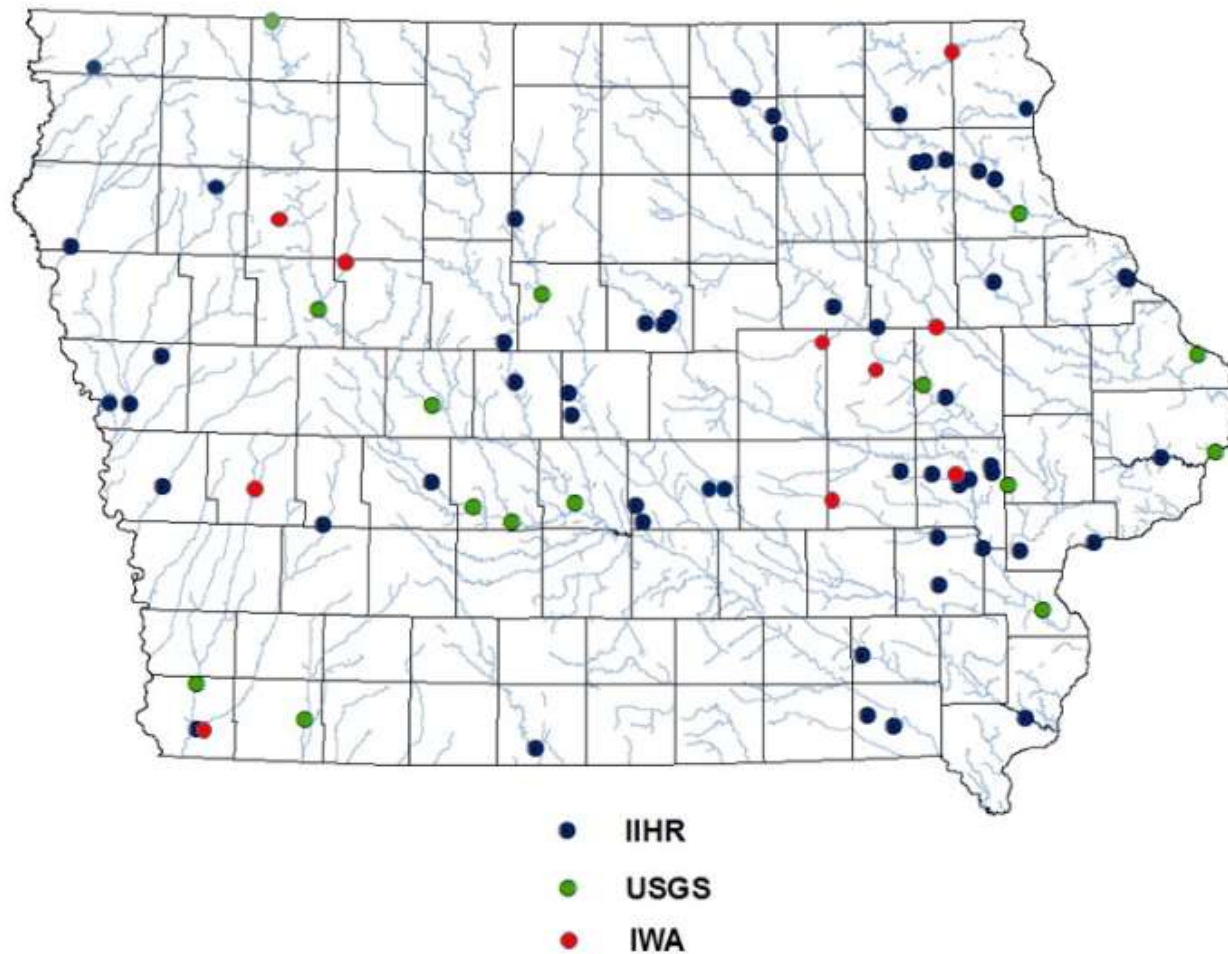


# Sites

70+ sites  
Nitrate-N

20-25 sites

- Temperature
- pH
- SC
- DO
- Turbidity

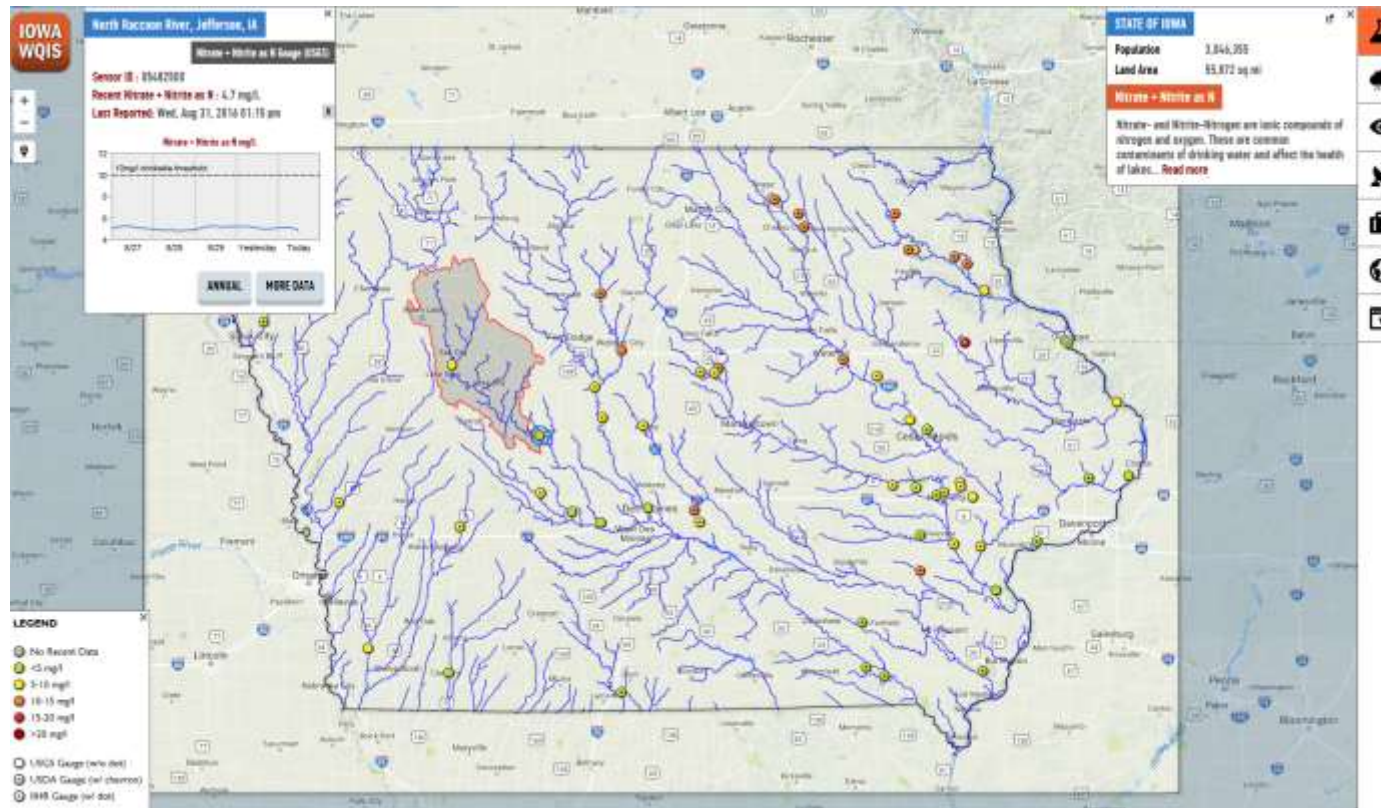


# Site infrastructure

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# Iowa Water Quality Information System



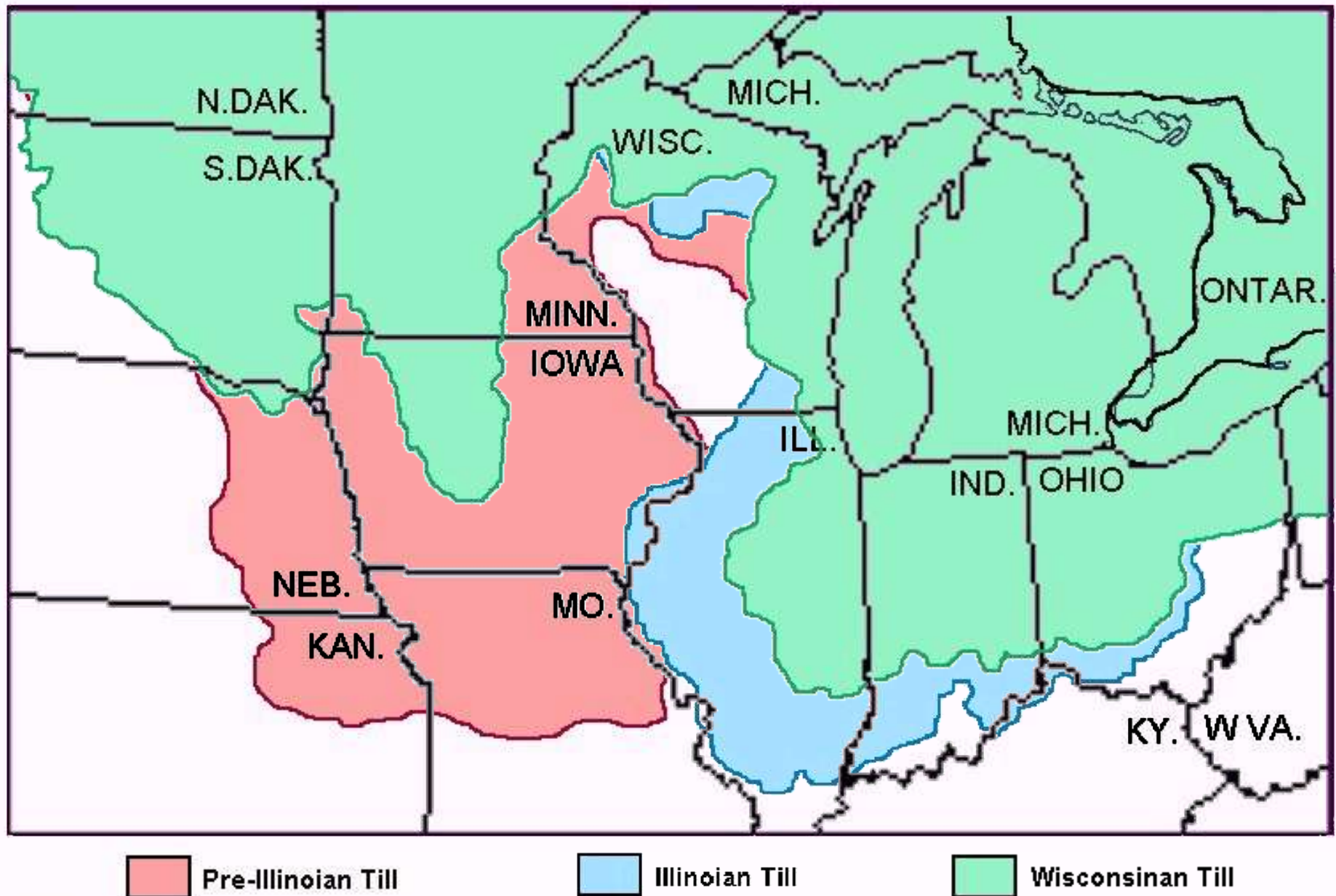
[iwqis.iowawis.org/](http://iwqis.iowawis.org/)

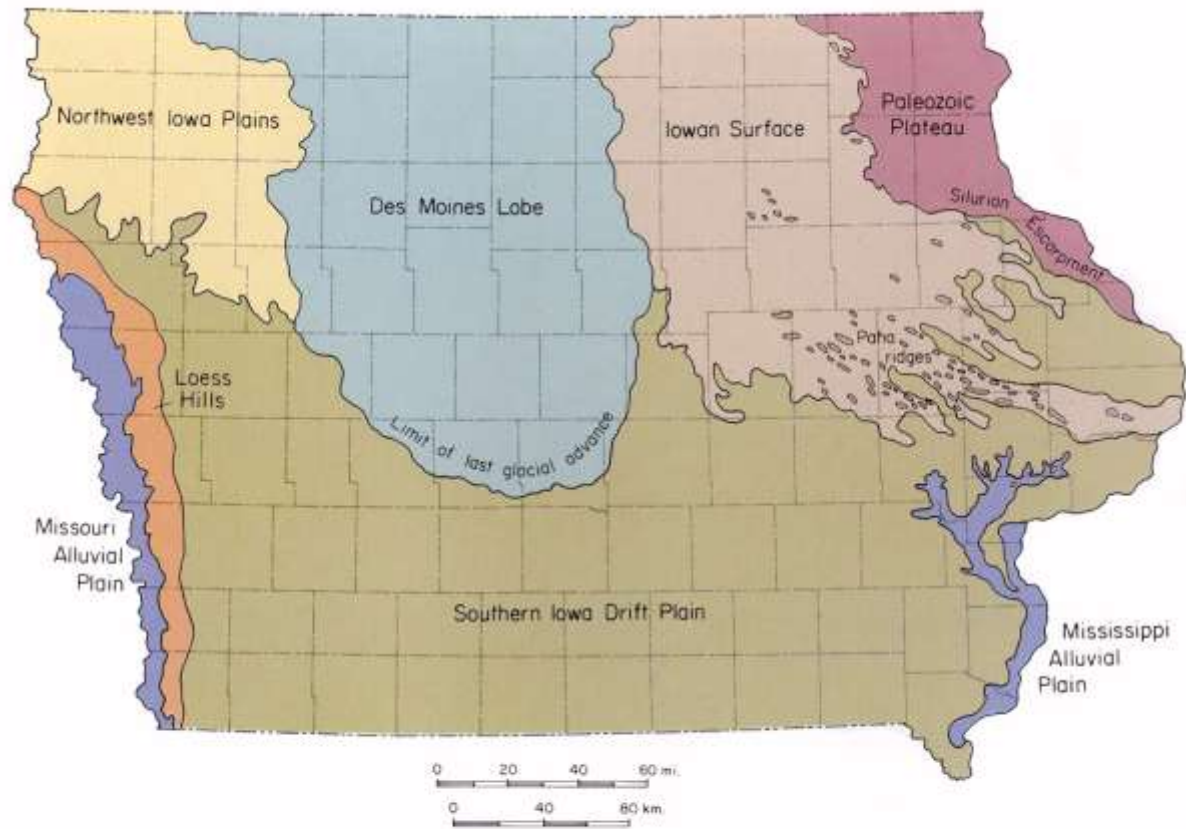
<http://iwqis.iowawis.org/app/?datetime=2017-06-06T13:00>

**IOWA**

IIHR-Hydroscience & Engineering

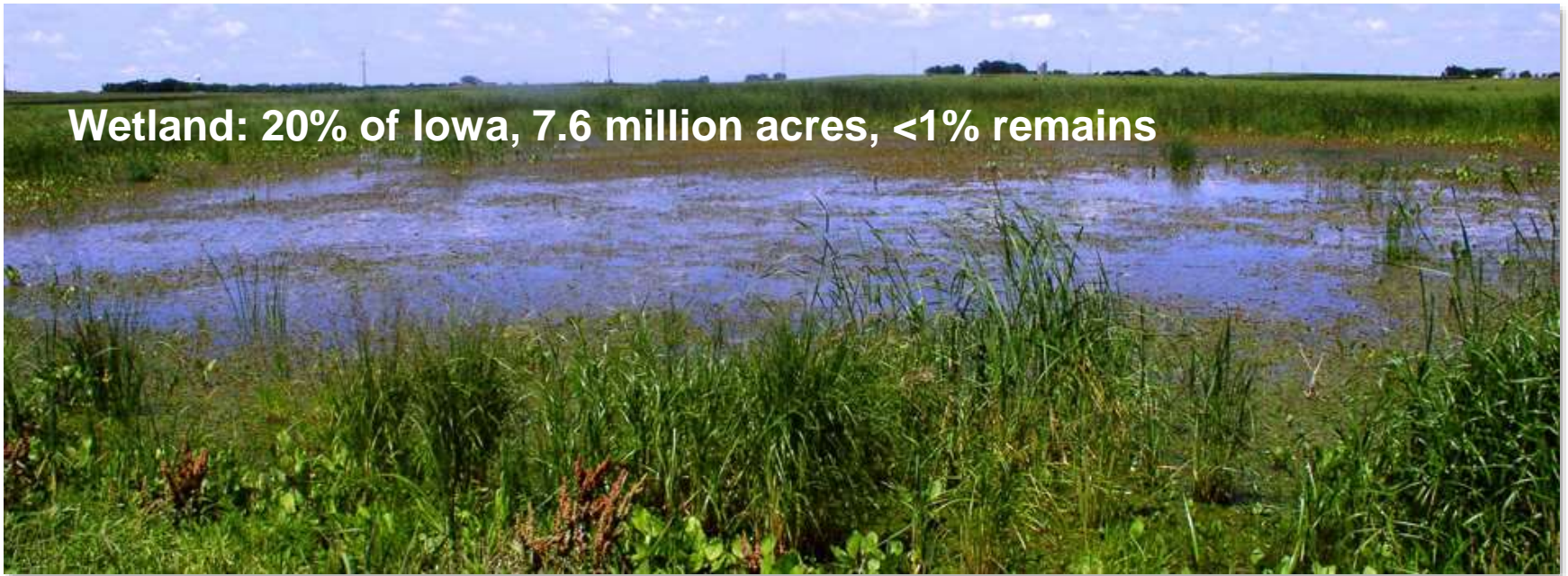
30,000 – 10,500 years





Landform Regions of Iowa

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



**Prairie: 70%, 0.1% Remains**

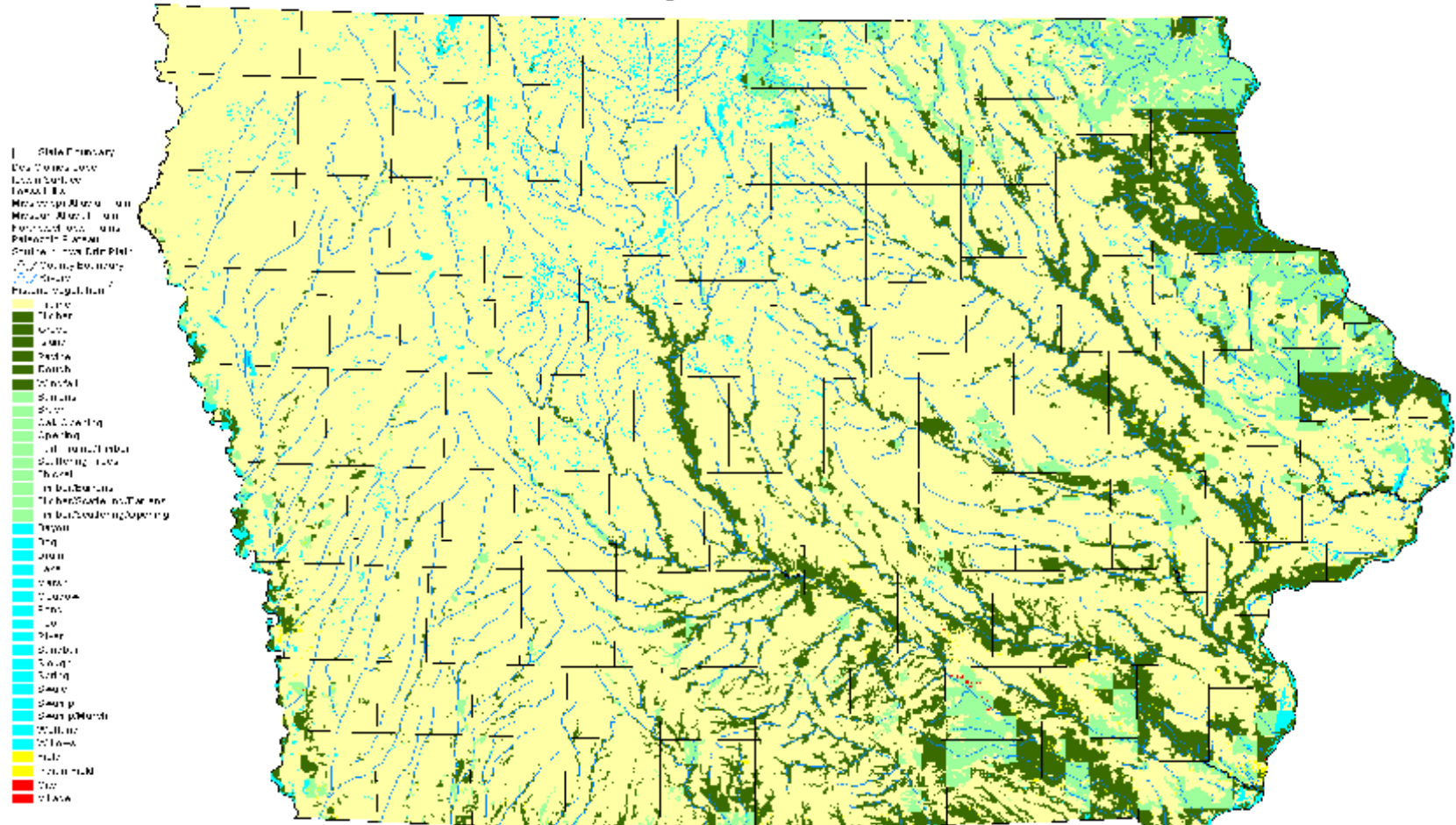


**Oak Savannah: ~5%, < 1% remains**



## Land Cover in Iowa around 1850

## Historic Vegetation of Iowa, 1832 - 1859



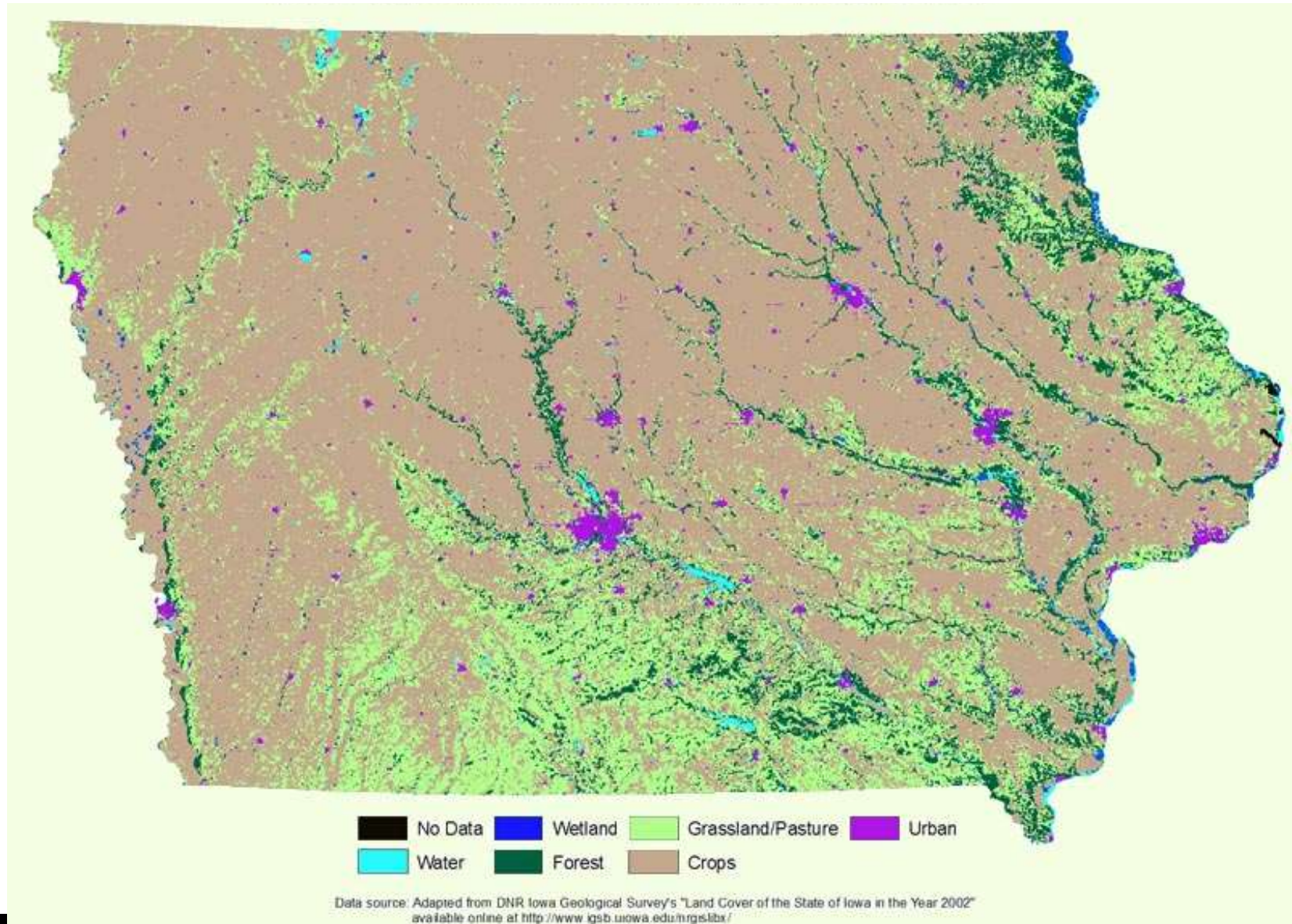
UNITED STATES OF AMERICA  
 DISTRICT COURT OF THE DISTRICT OF COLUMBIA  
 In re: [Name], Defendant.  
 [Name] vs. [Name]

# Grassland

# Forest

# IOWA

# Iowa Land Cover



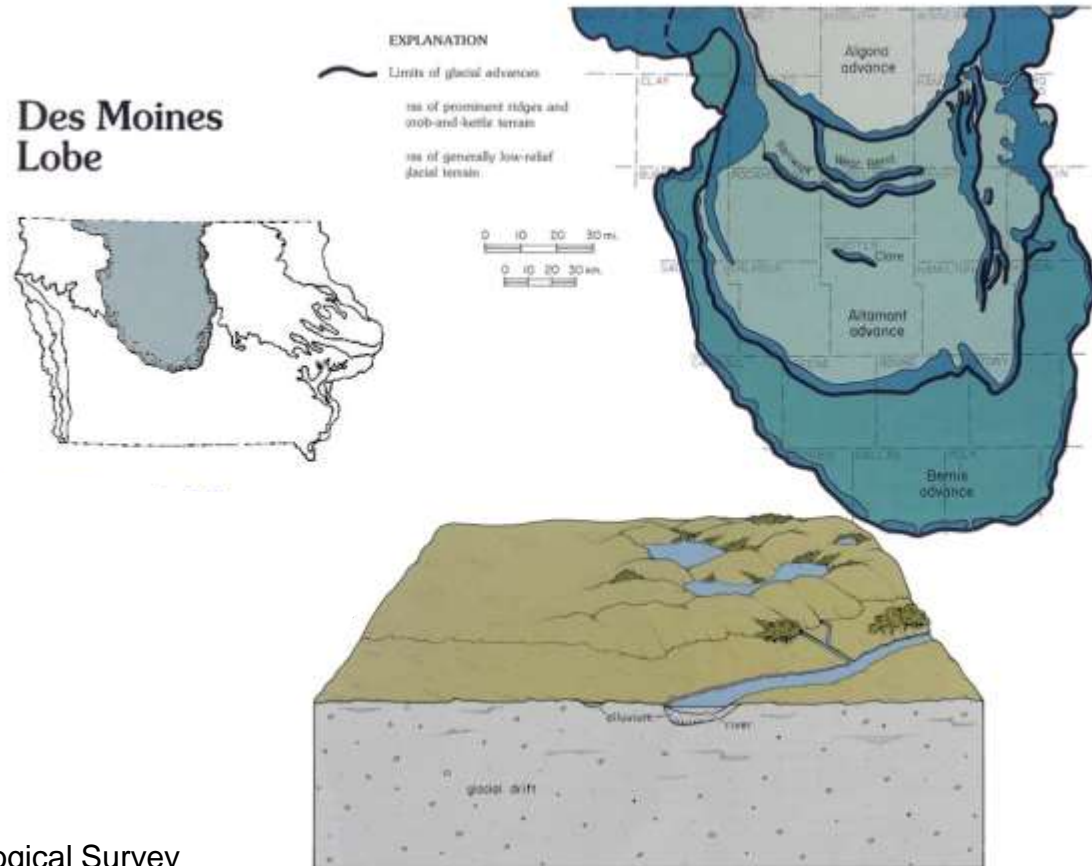
# Landforms

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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

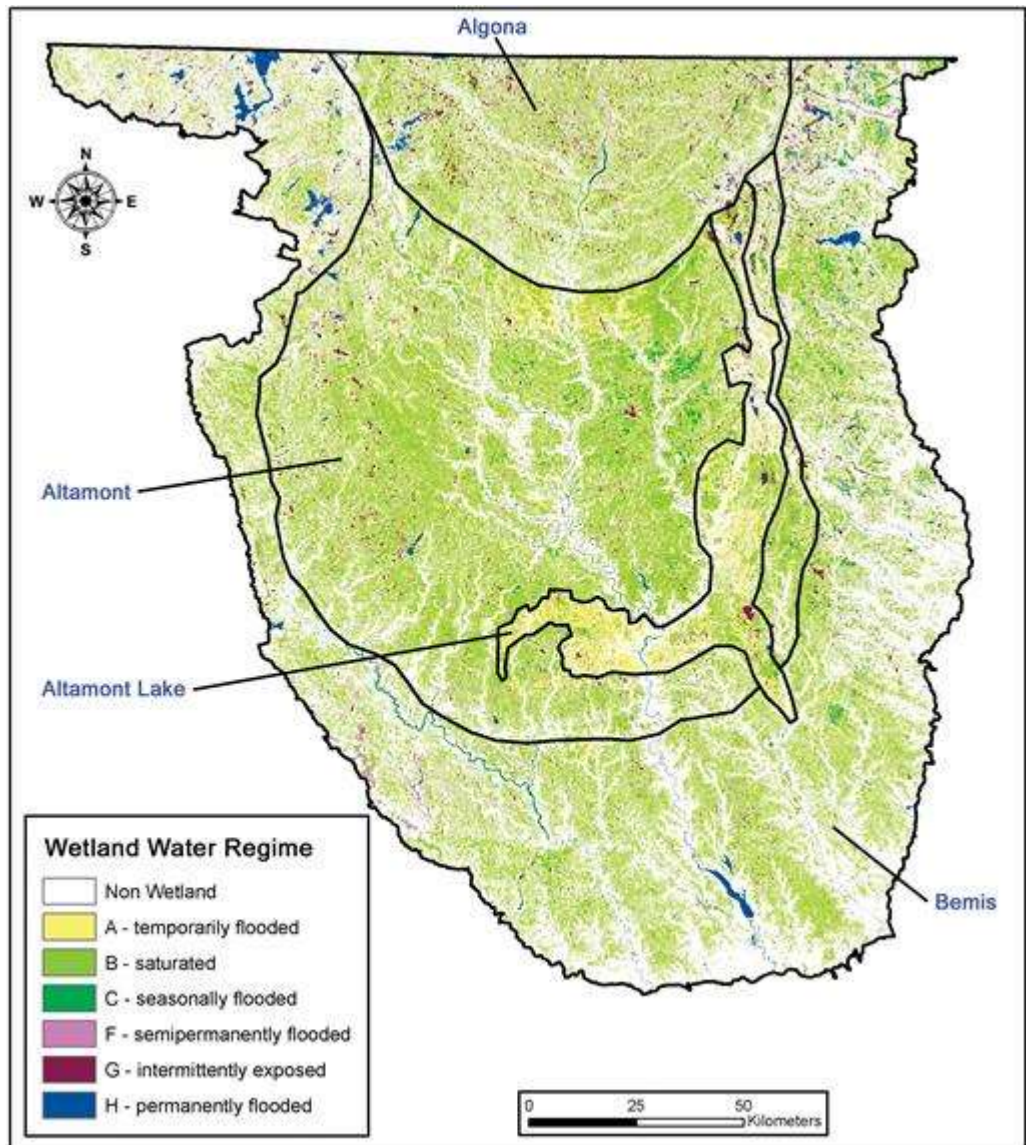
[https://www.geocaching.com/geocache/GC7FY8J\\_glacial-evidence-algona-advance?guid=de7c76f4-a3f7-4e47-af0d-aa28c57243a4](https://www.geocaching.com/geocache/GC7FY8J_glacial-evidence-algona-advance?guid=de7c76f4-a3f7-4e47-af0d-aa28c57243a4)

1 December 2009

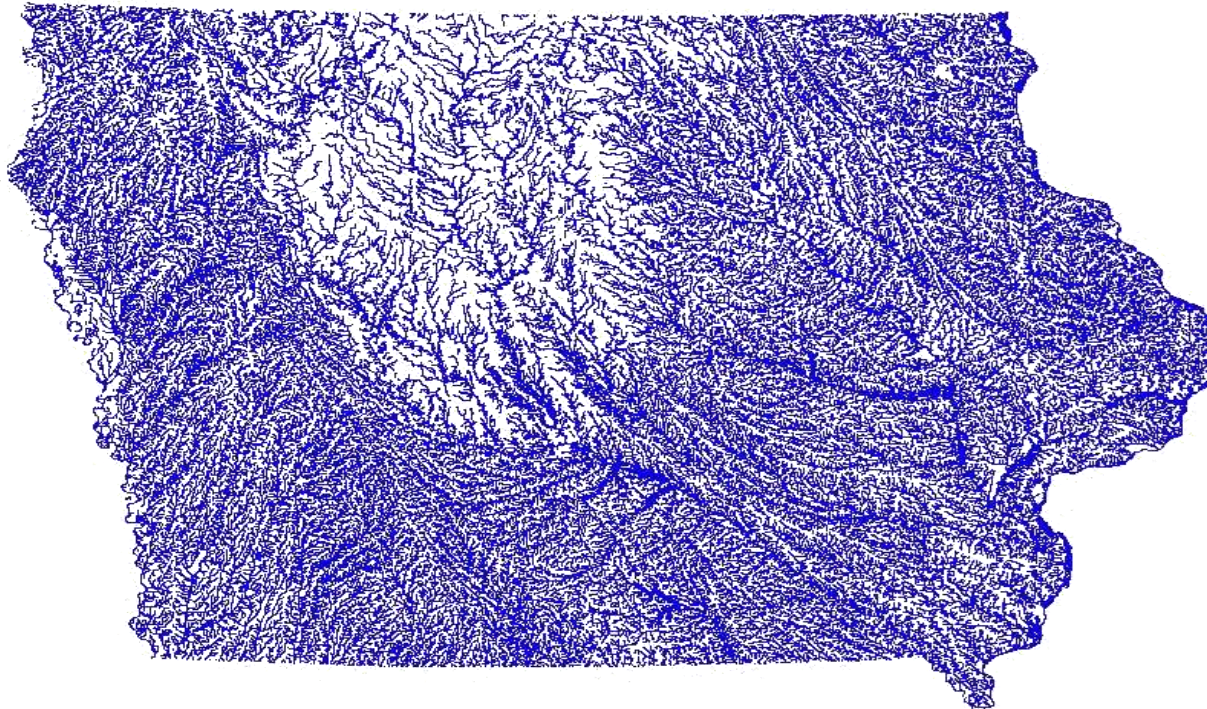
## Spatial Distribution of Historical Wetland Classes on the Des Moines Lobe, Iowa

Bradley A. Miller, William G. Crutsinger, 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

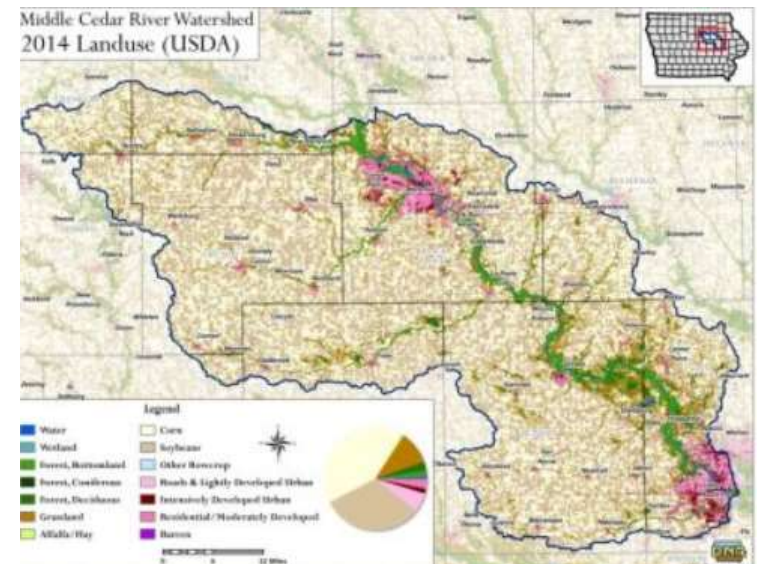




Landform	% of Iowa's Area	\$/year spent on new tile
Iowan Surface	16.9	\$24,500,000
Des Moines Lobe	21.4	\$5,845,000
Northwest Iowa Plains	8.3	\$2,272,545
Paleozoic Plateau	4.6	\$3,580,862
Southern Iowa Drift Plain	41.3	\$33,837,580
<b>Total</b>	<b>92.5</b>	<b>\$70,064,878</b>



2 million miles of tile in Iowa



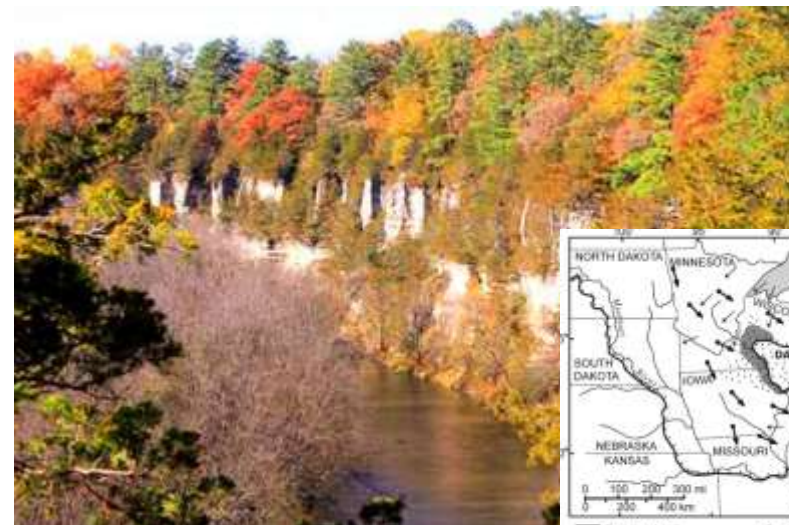
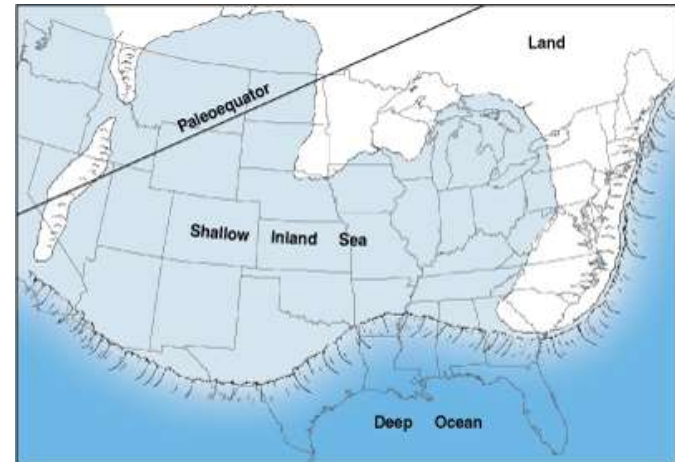
1200 miles new tile/year!



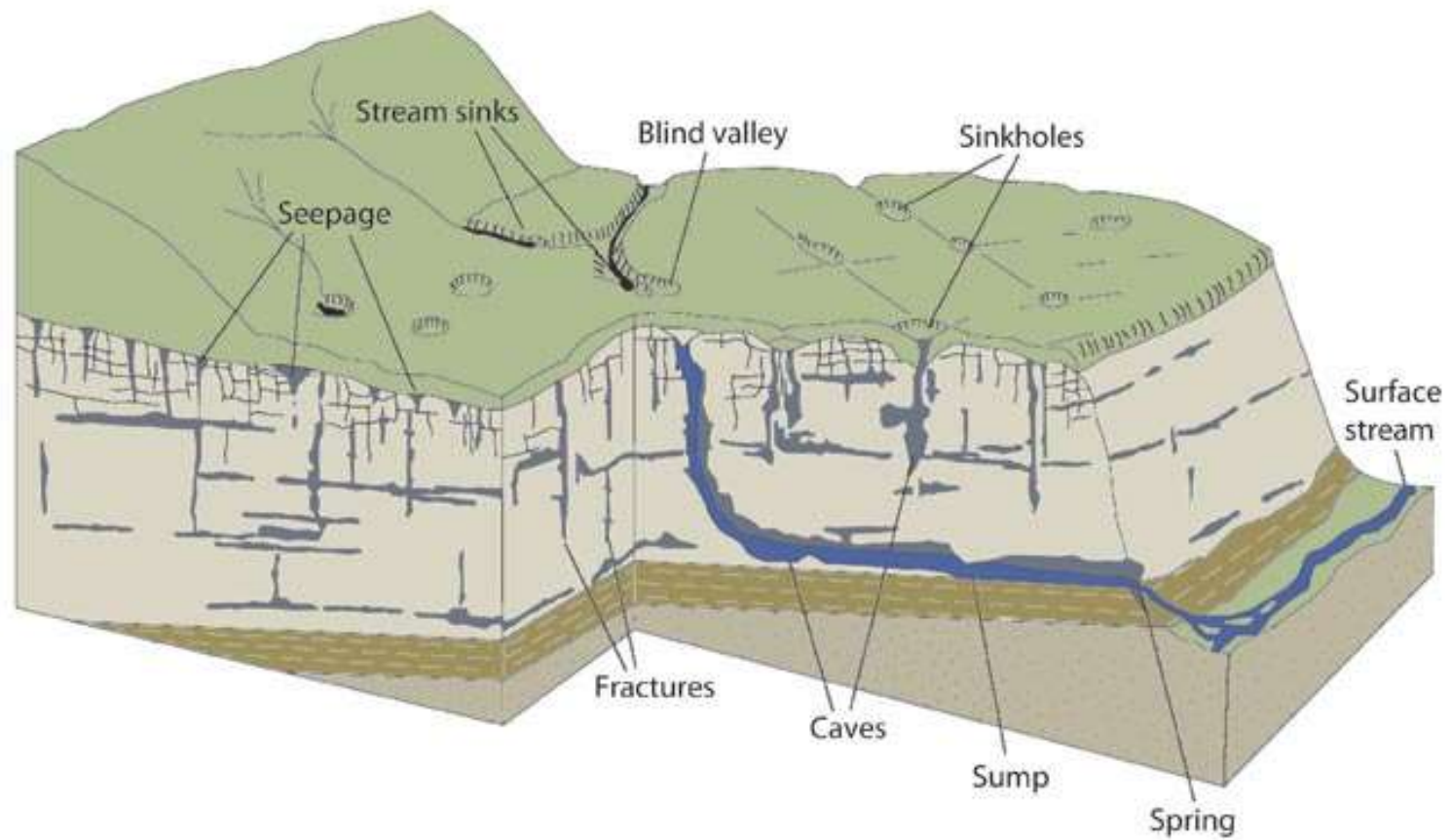
## Paleozoic Plateau



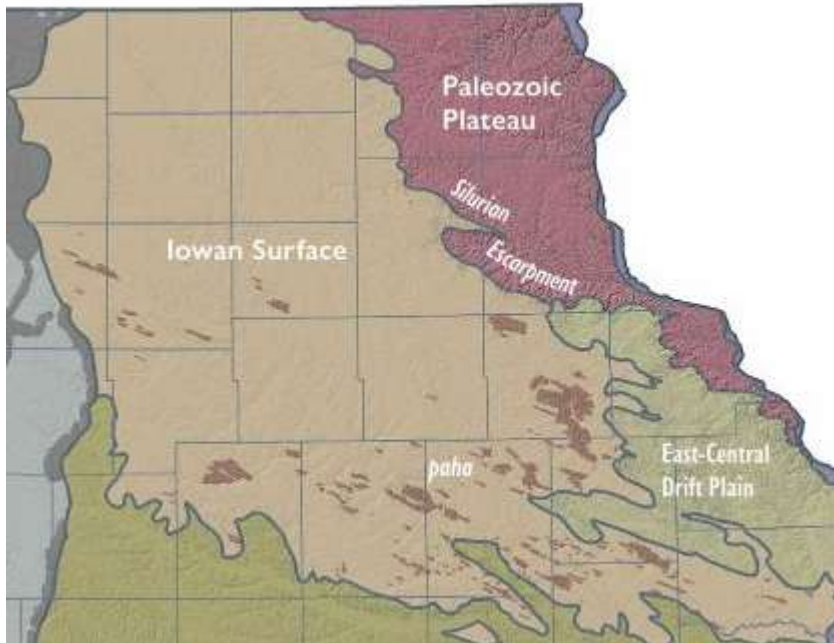
## Driftless (Paleozoic Plateau)



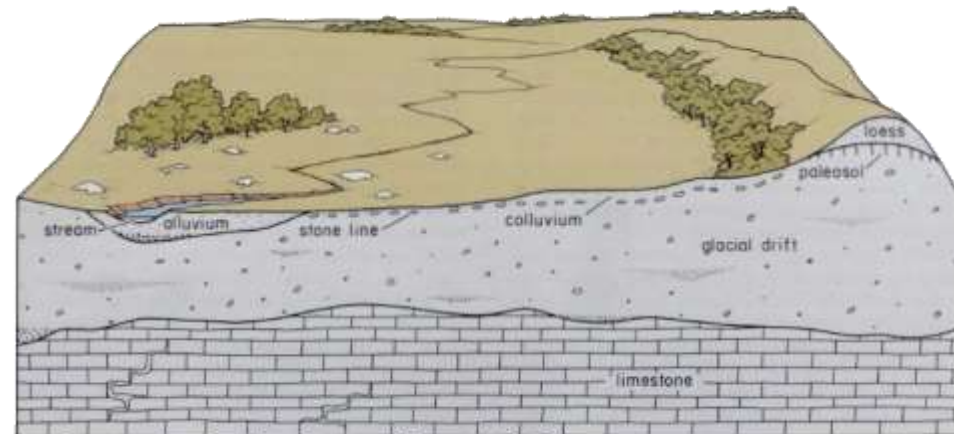
## Karst



## Iowan Surface



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



## Glacial Erratics



## Northwest Iowa Plains



Very similar to Iowa Surface

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

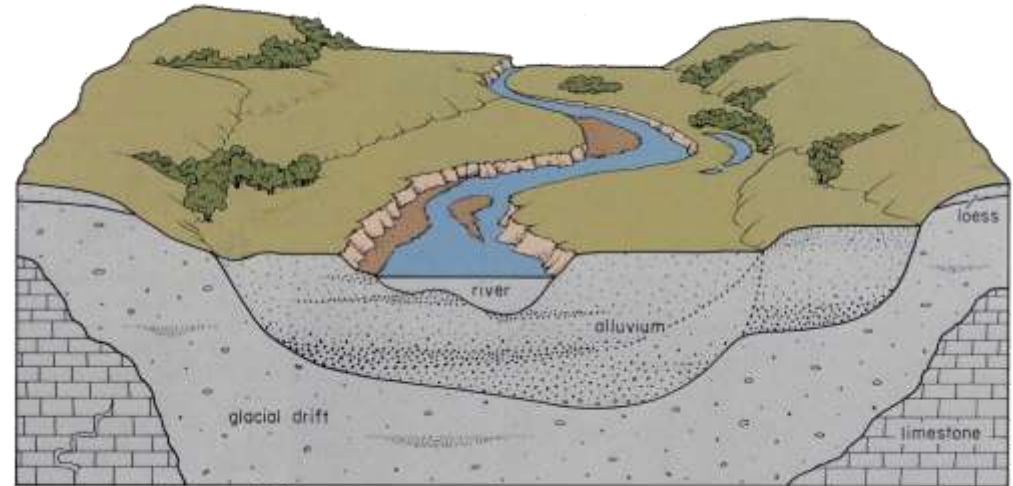
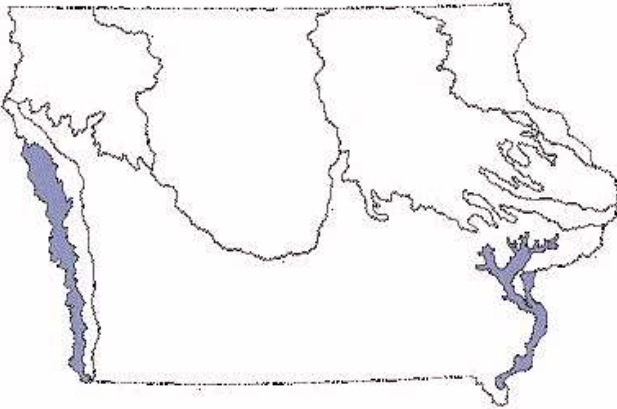
Differences

- Thick loess
- Very few trees here

## Sioux Quartzite

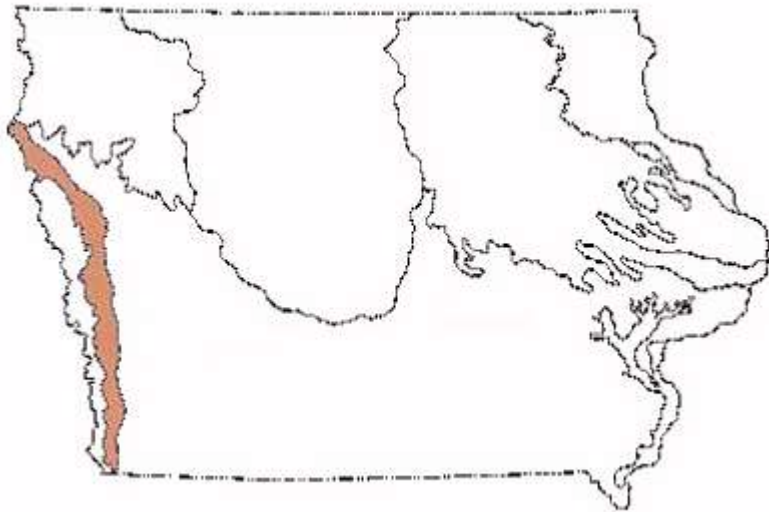


# Alluvial Plains



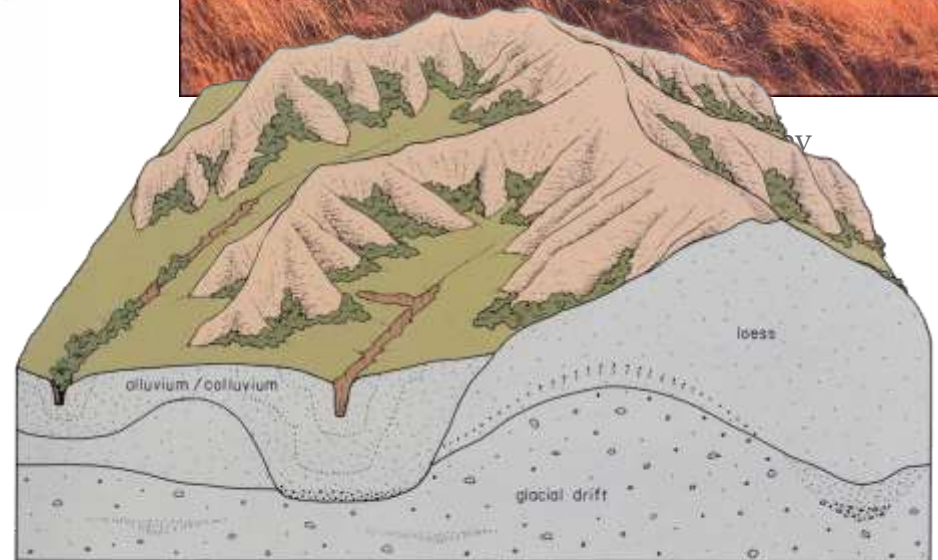
- Thick alluvial deposits
- level terrain along valleys  
includes stream channels,  
floodplains, oxbow lakes,  
terraces, alluvial fans,  
sand dunes

## Loess Hills



### Terrain Characteristics

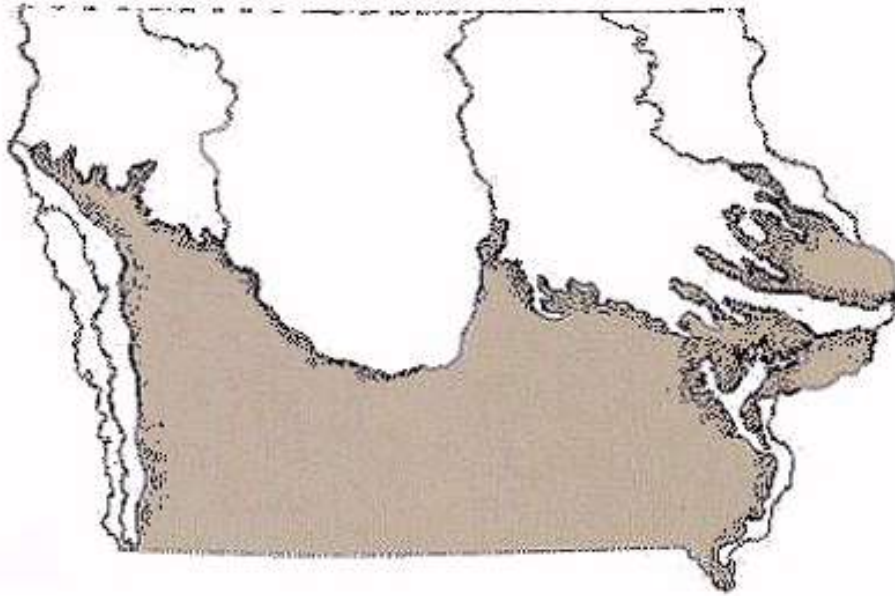
- \* thick loess cover
- \* sharply ridged terrain
- \* high drainage density
- \* rapid surface runoff
- \* gully development



## Loess deposits can be very thick in Iowa

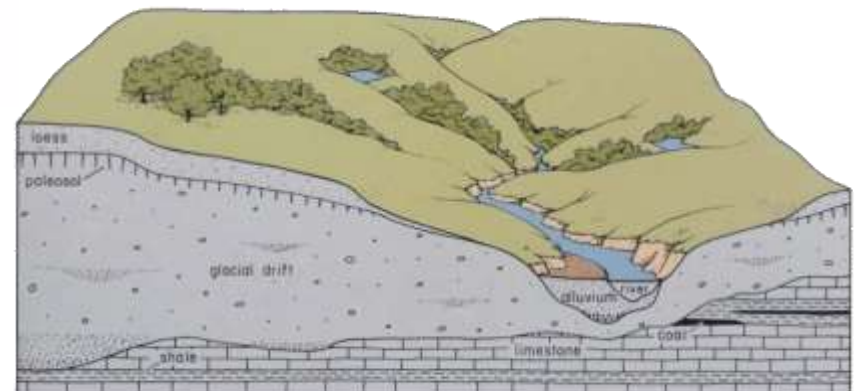


## Southern Iowa Driftplain



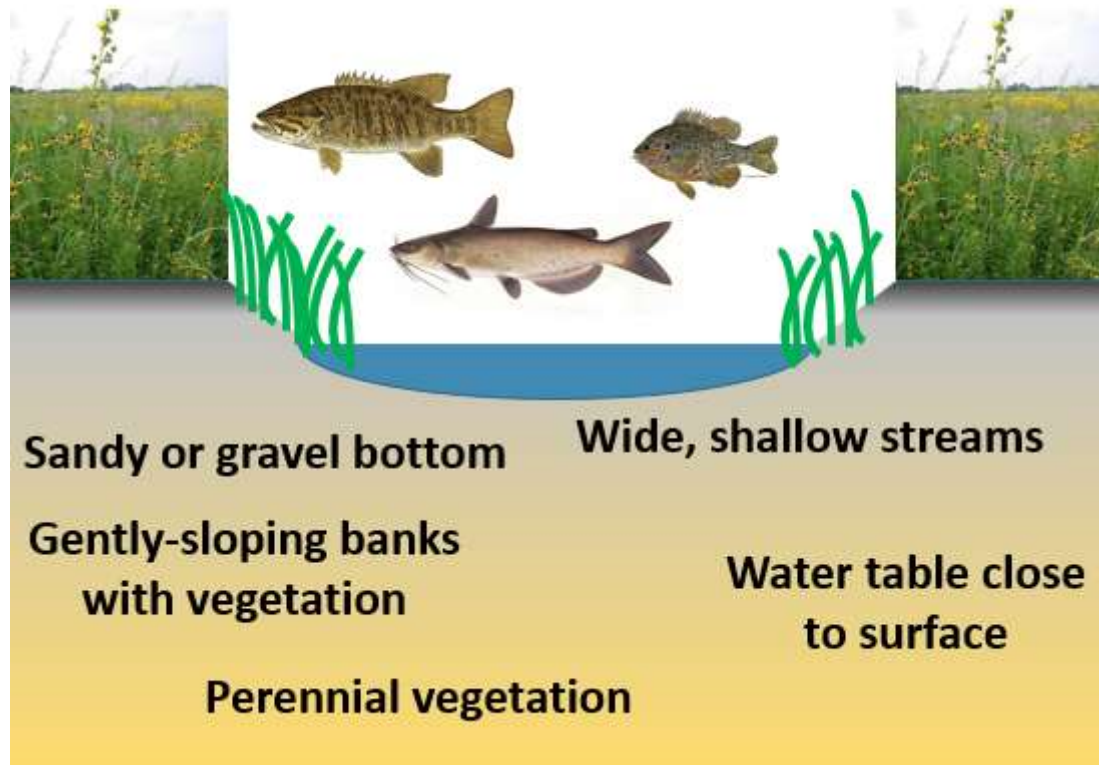
### Terrain Characteristics

- \* Loess of varying thicknesses
- \* stepped erosion surfaces
- \* bedrock exposed in deeper valleys



# Pre-European Settlement Streams

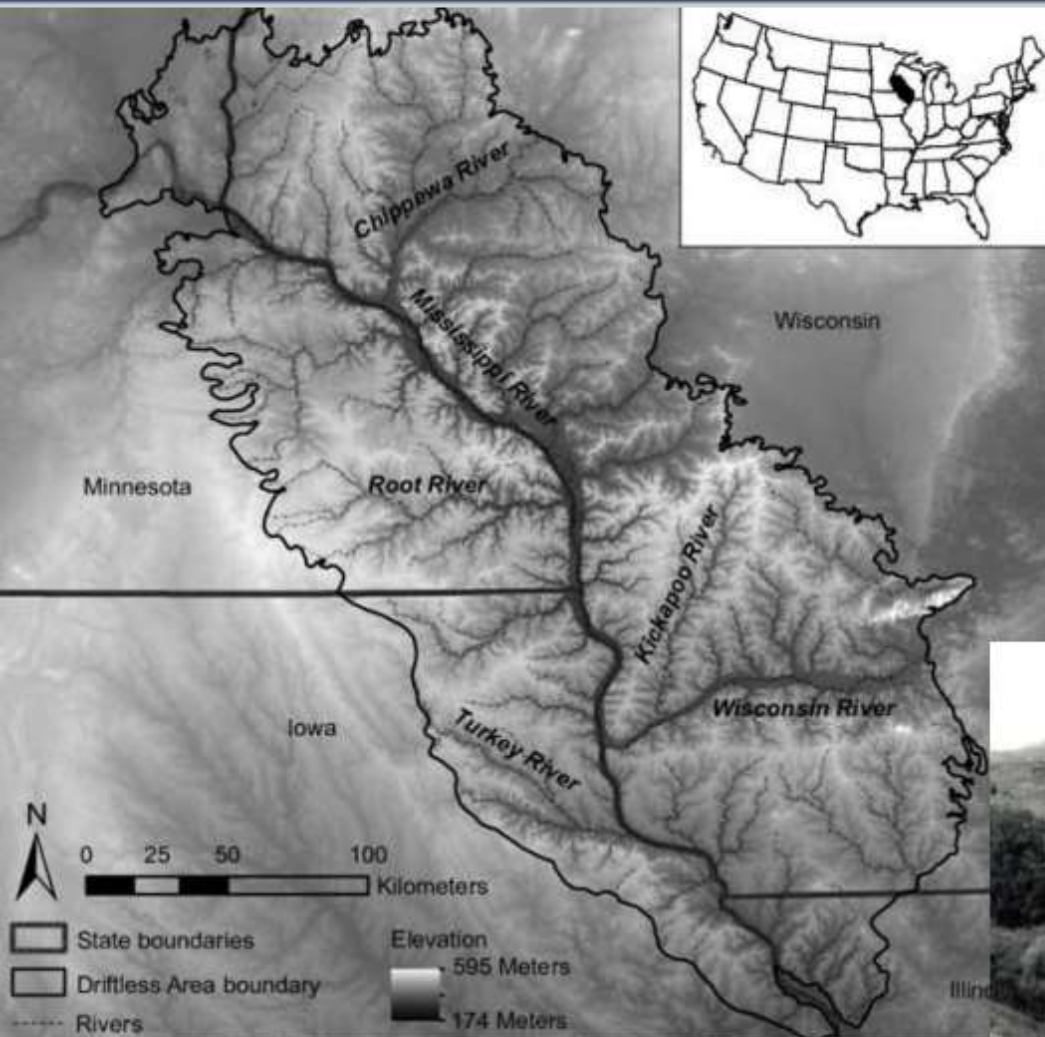
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# Breaking the prairie

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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.**

# Hydrology of Drained (tiled) Wetlands



# Tiling field now

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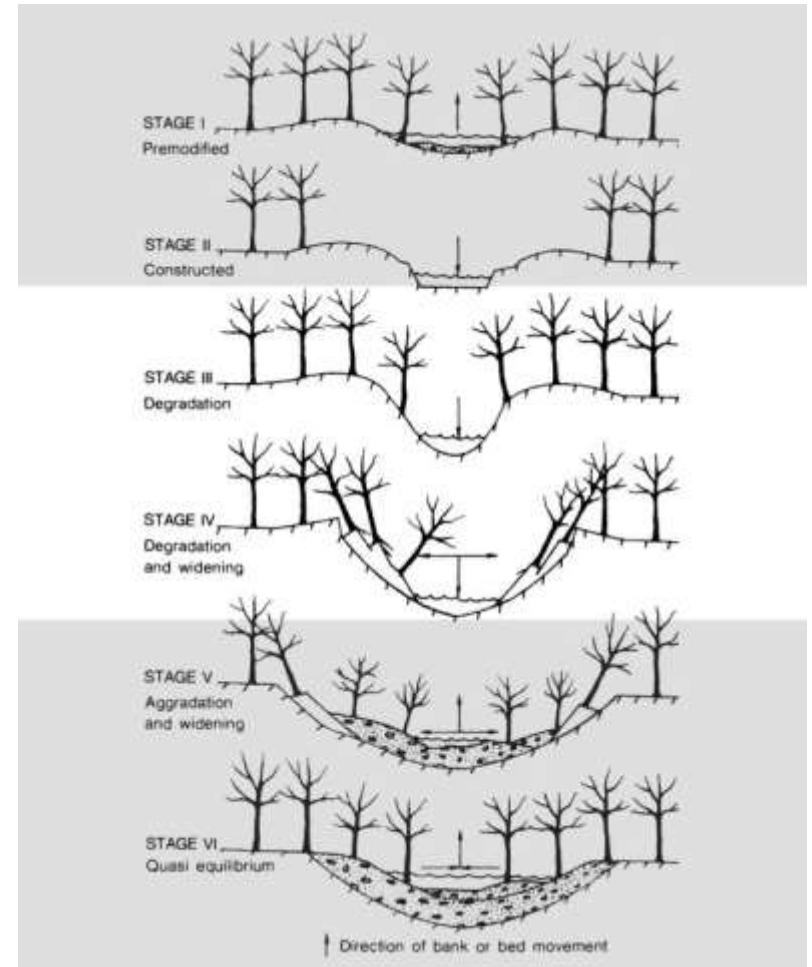
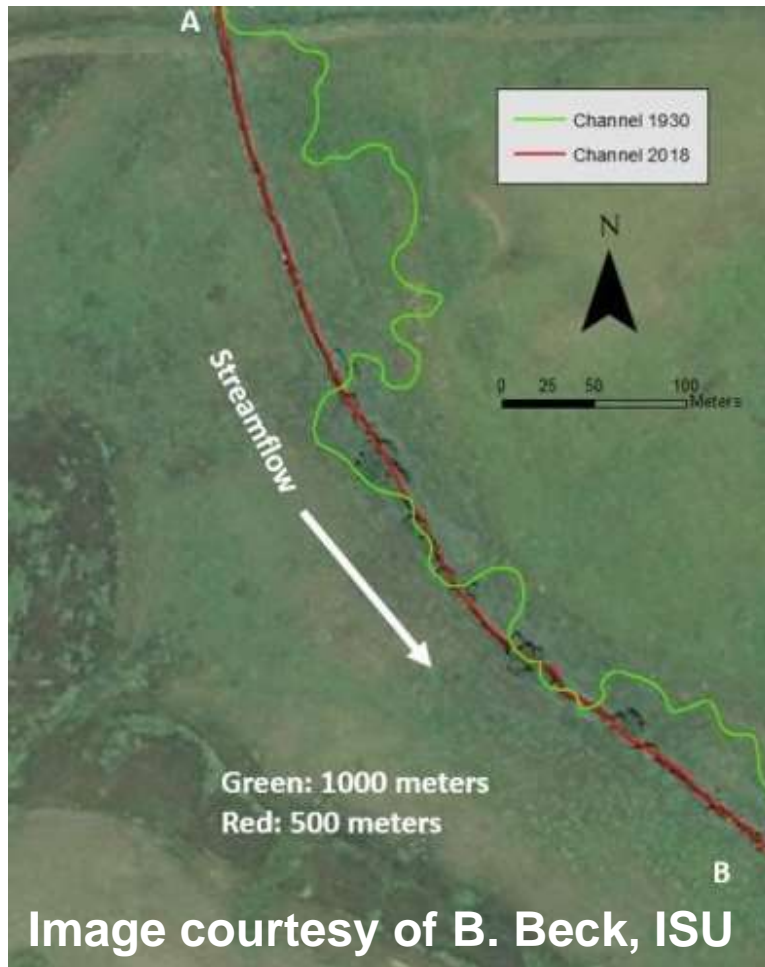




# Source of the Iowa River



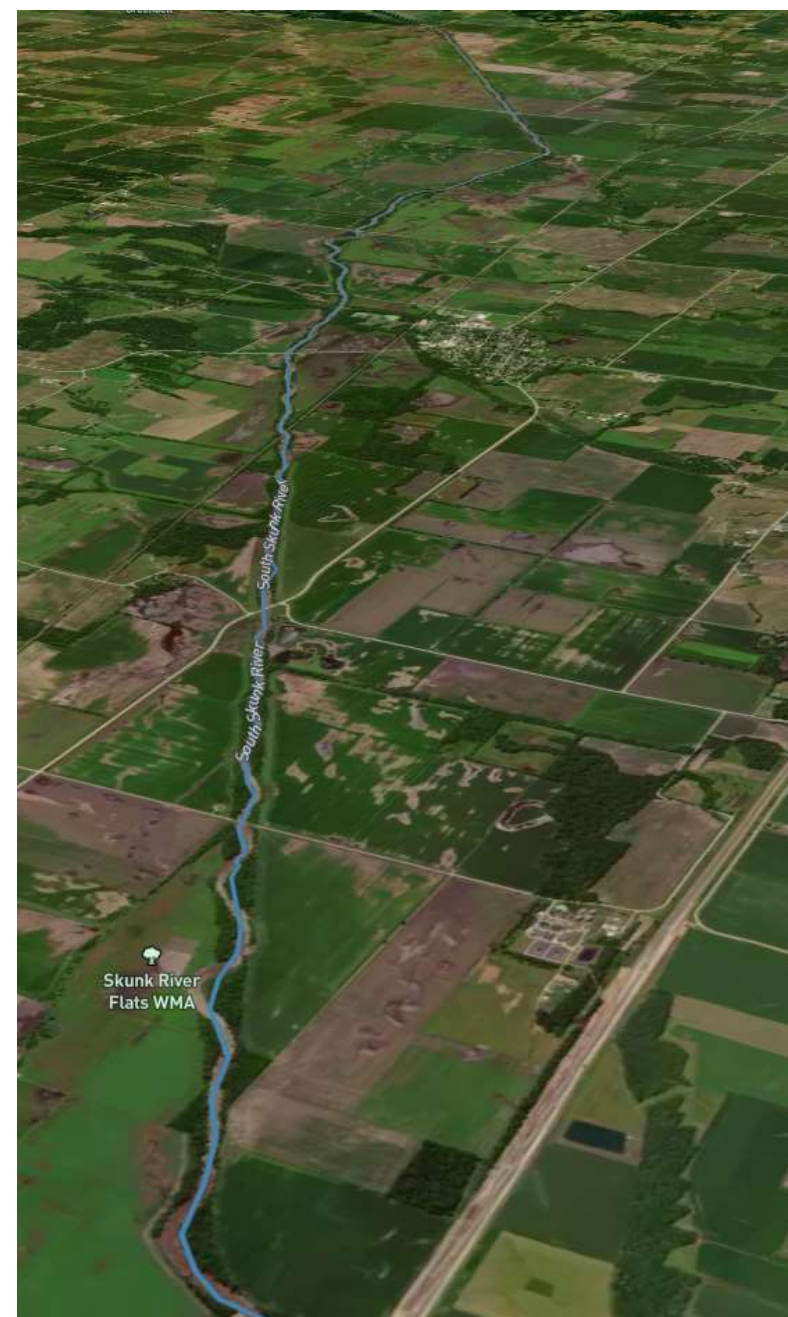
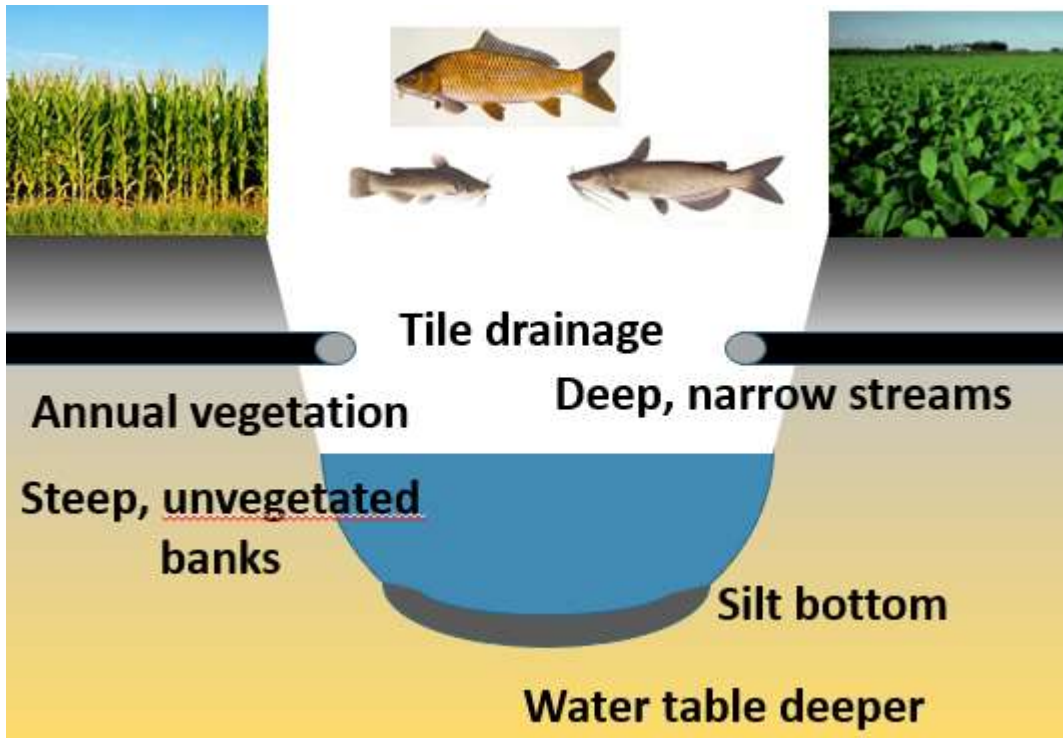
# Stream Straightening, 1930-1975





Images courtesy  
of B. Beck, ISU

# Modified Streams



# Transformation of Iowa Farms

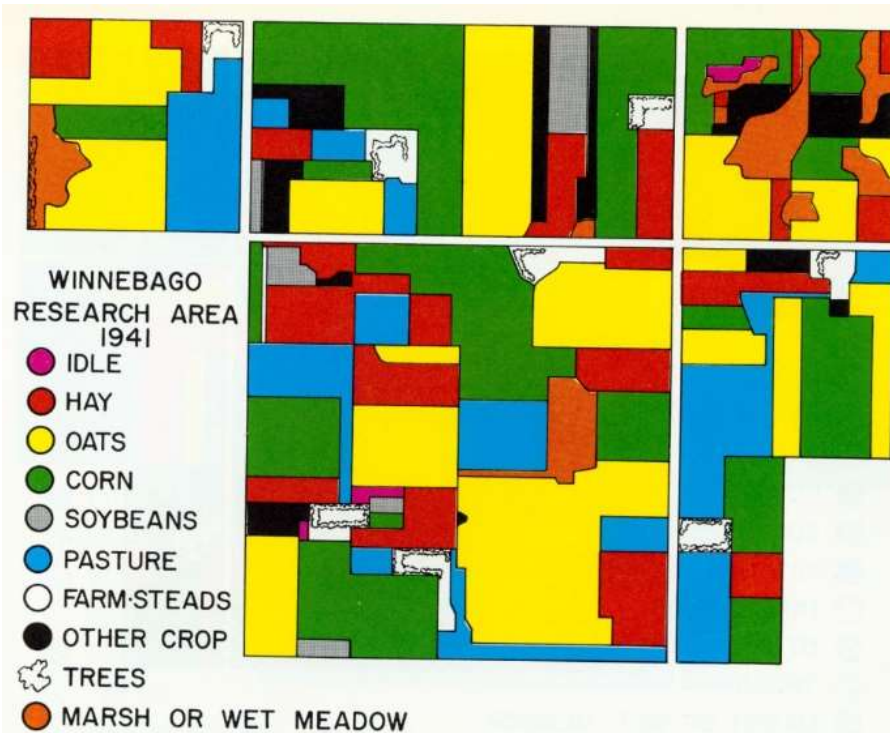


Figure 19. Cover map of the Winnebago pheasant study area, 1941.

1941

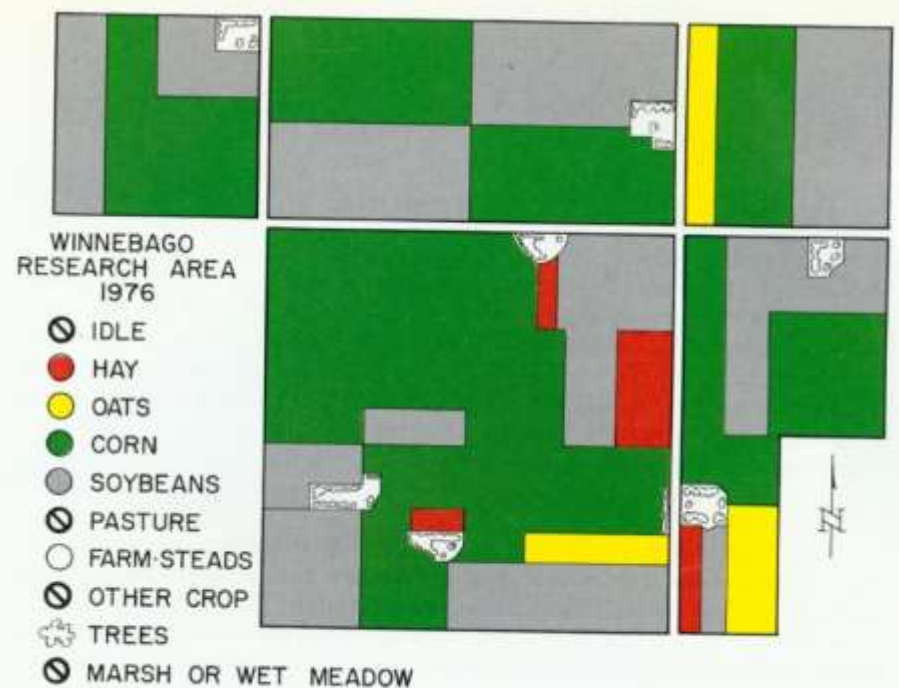


Figure 23. Cover map of the Winnebago pheasant study area, 1976.

1976

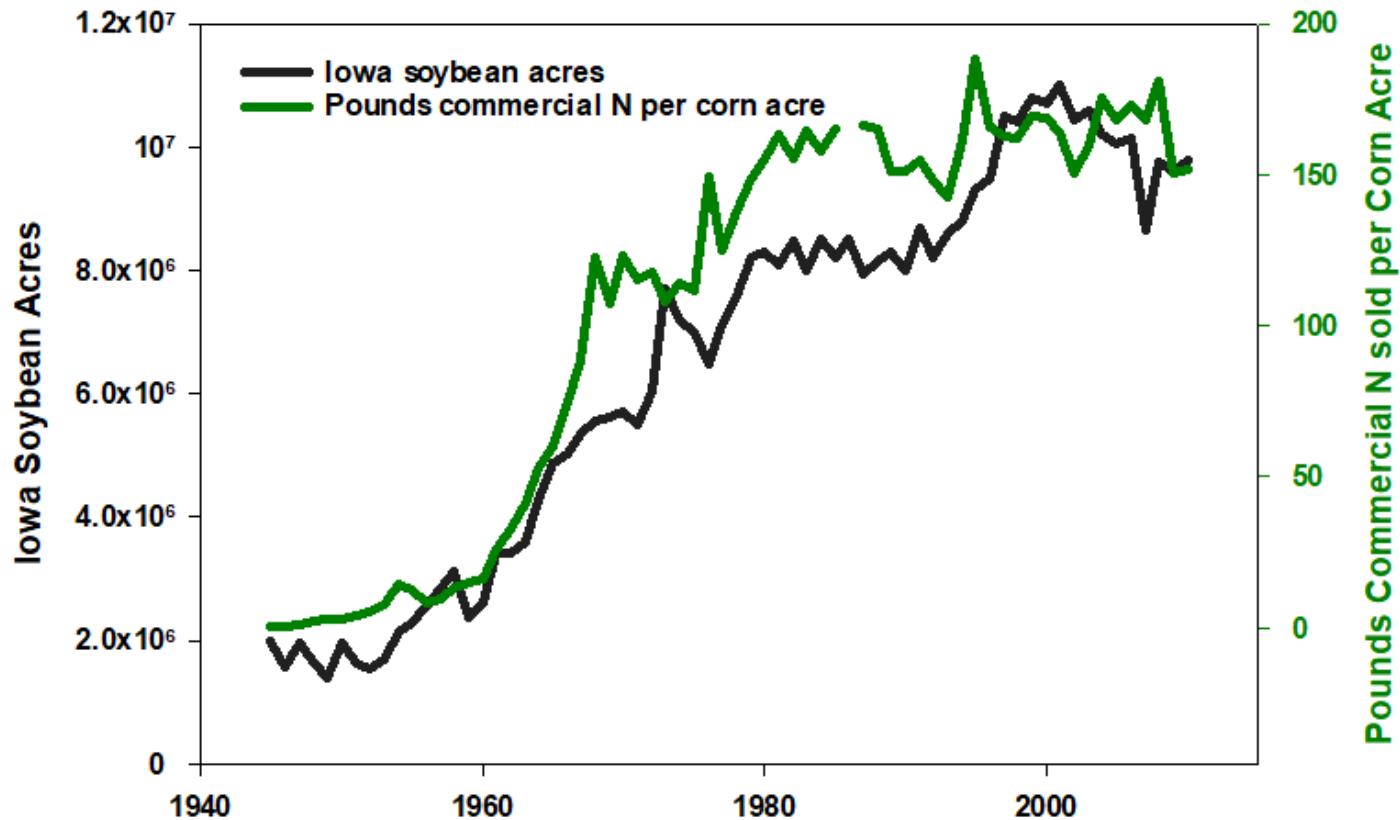


# Transformation required Simplification

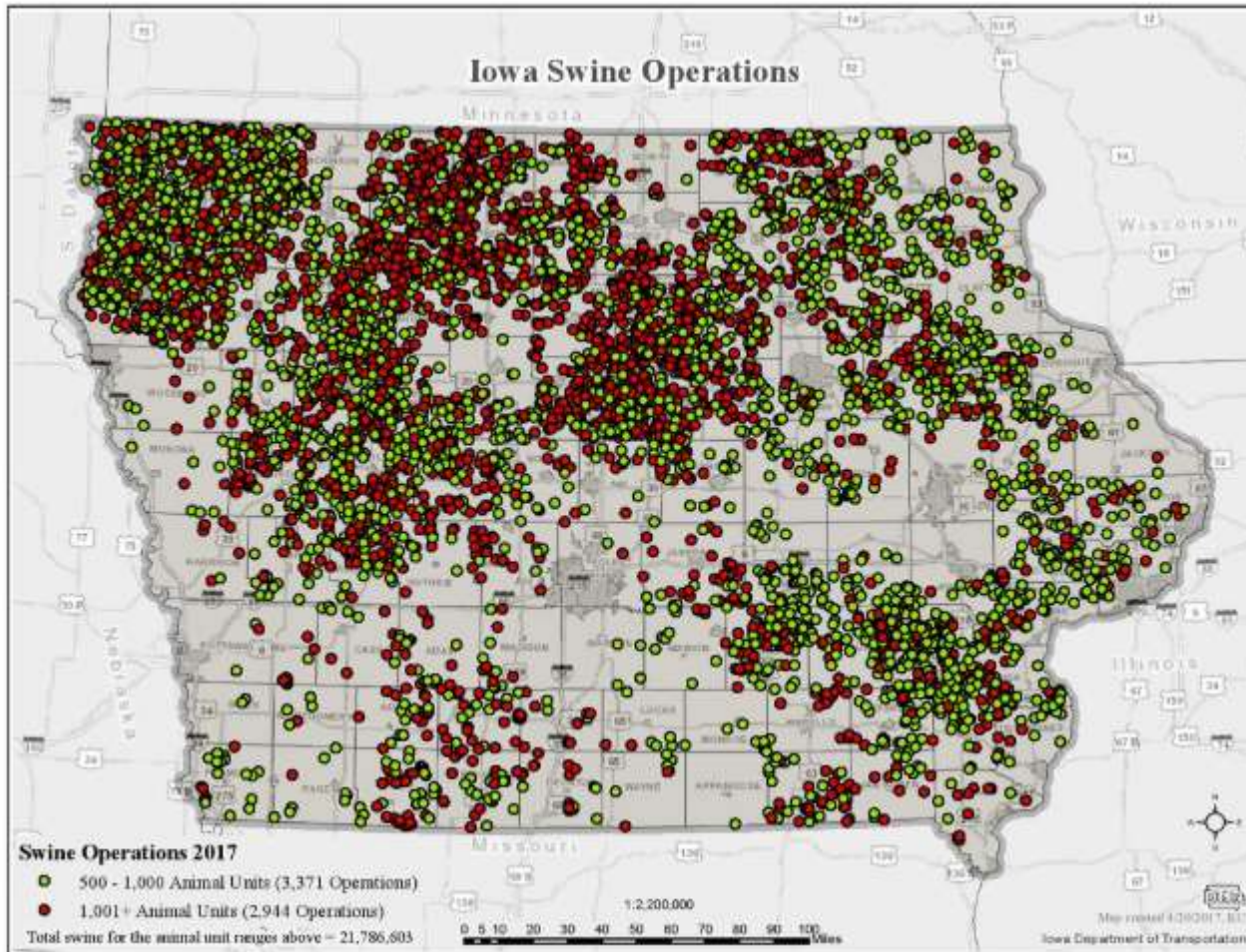
- Many crops to two crops
- Plant-based energy to fossil fuel energy
  - Animals to tractors and other machinery, 80% had a tractor by 1950
- Organic Fertilizers to Inorganic Fertilizers (Post WWII)
- Many farmers (230,000 in 1951) to Fewer farmers (85,000 today)
- Livestock on almost all farms to livestock 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)



# Role of Soybeans



# 8000 CAFOs



# Problem of Scale

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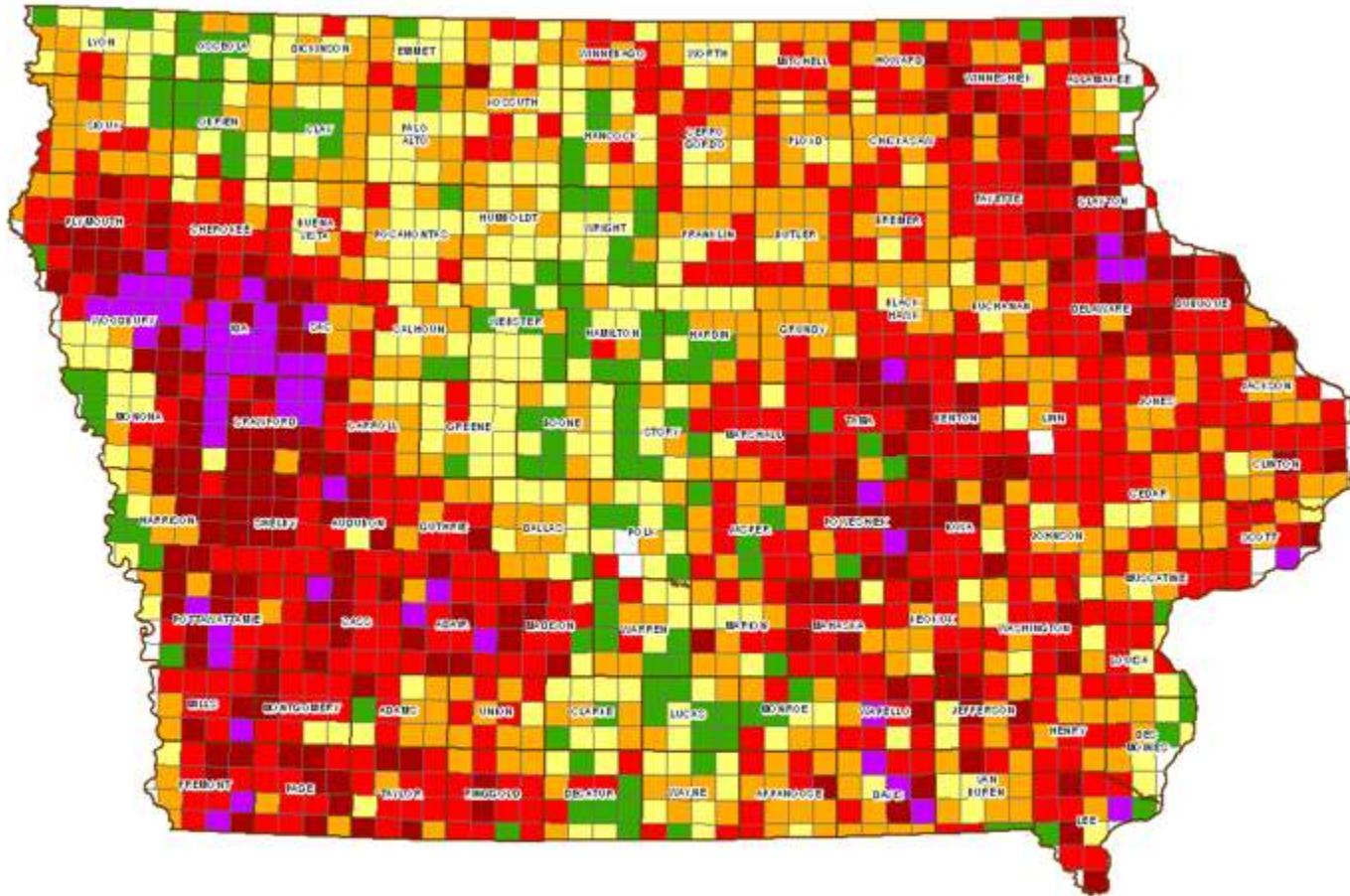
- 70% of land in corn-soy rotation
- 11,000 square miles used for ethanol production
- 25 million hogs
- 4 million beef cattle
- 80 million laying chickens
- 5 million turkeys
- 4 million broiler chickens
- 220,000 dairy cows

# Water Quality Consequences

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# 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

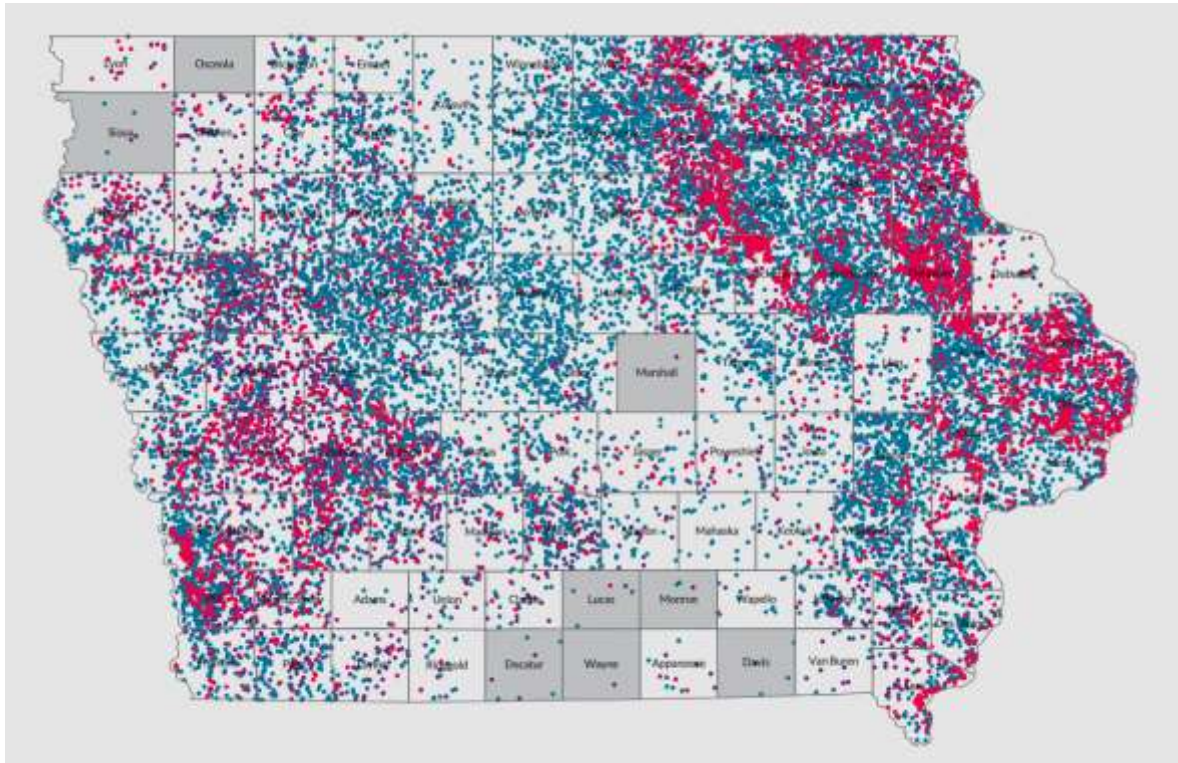
Nitrate:  $\text{NO}_3^-$

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



# Surface Water

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Lake Erie Algae Blooms



Gulf of Mexico Hypoxia

# Mississippi River/Gulf of Mexico Hypoxia Task Force



## Hypoxia Task Force

[2008 Action Plan](#)

- Home >
- Strategy documents >
- News releases >
- Resources >
- Contacts >
- Submit comments >
- Comments and responses >
- 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 STATE UNIVERSITY

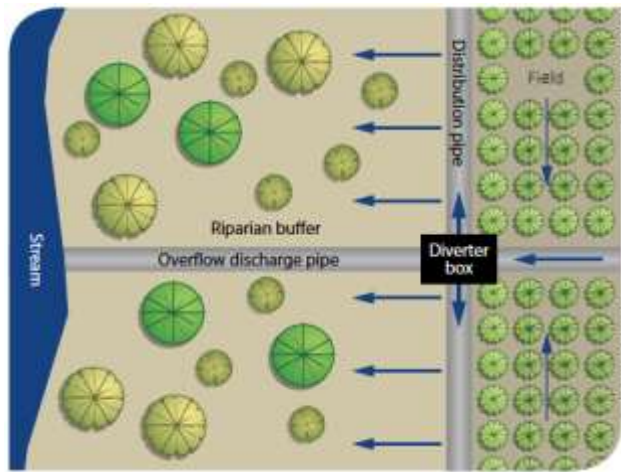
# Practices



Cover crops

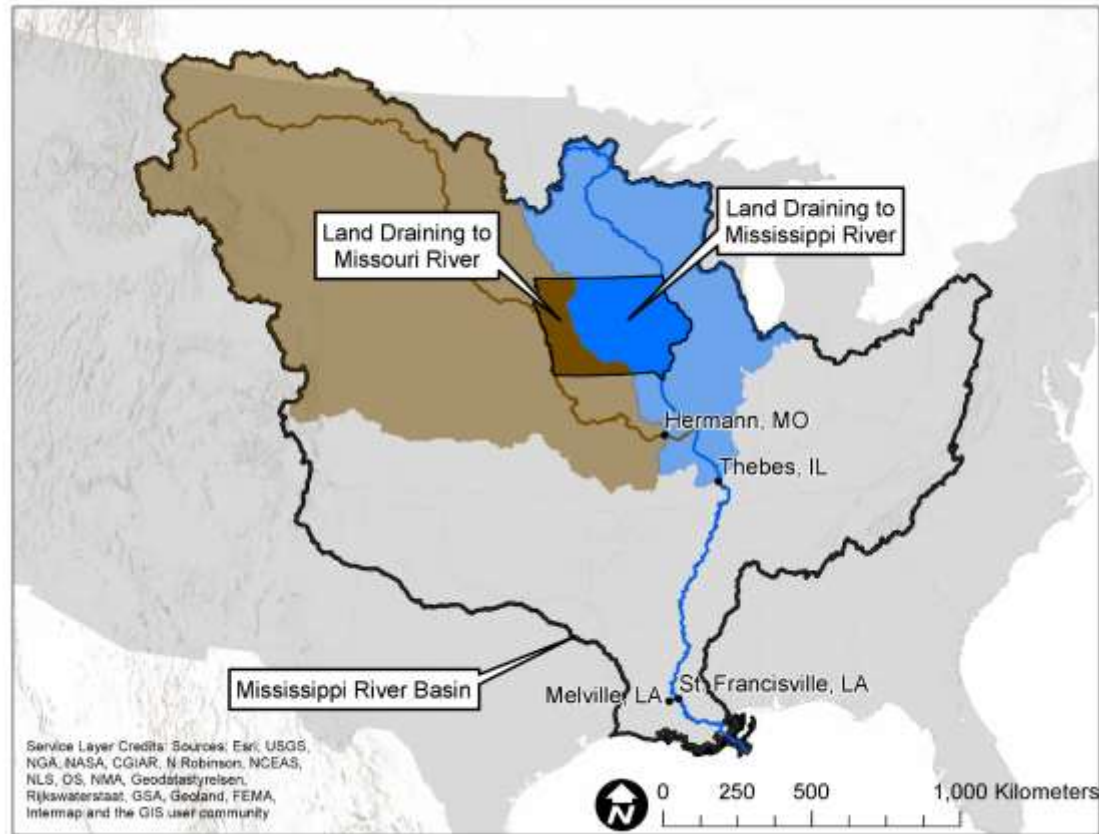


Wetland  
construction

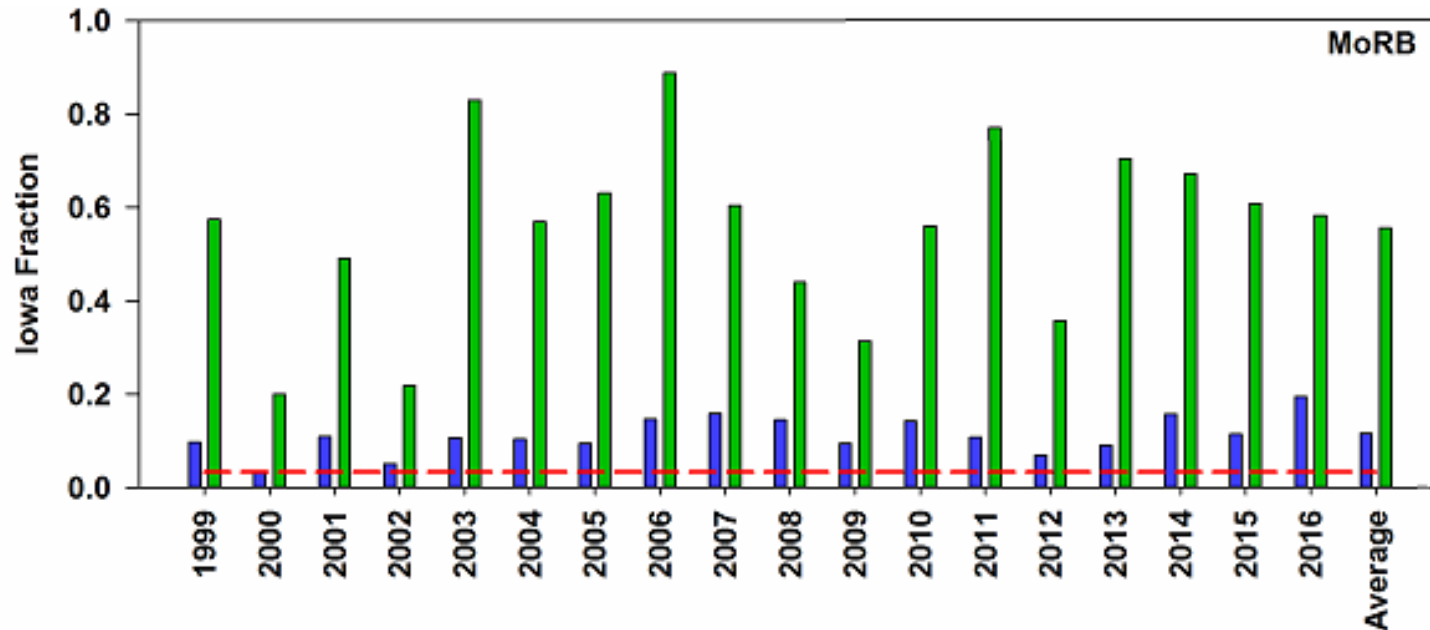


Saturated  
Buffer

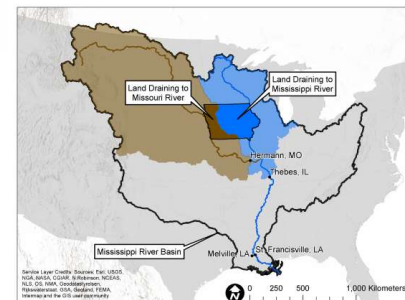
# Iowa Contributions



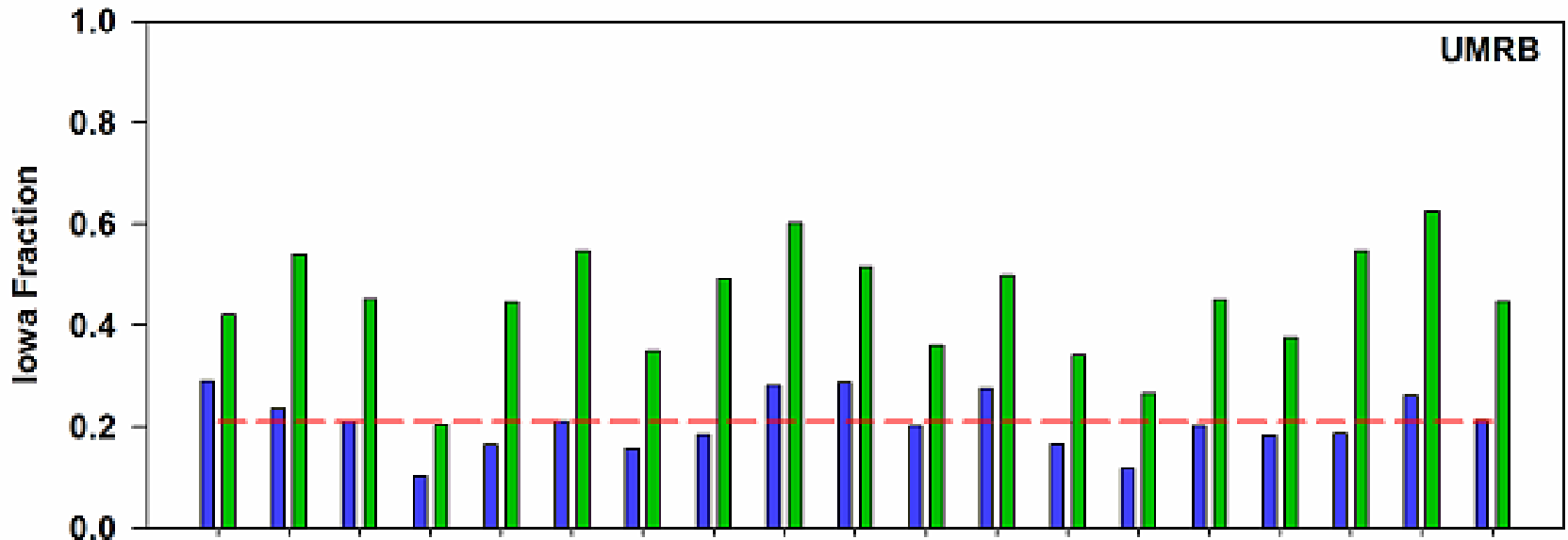
# Missouri Basin: Nitrogen



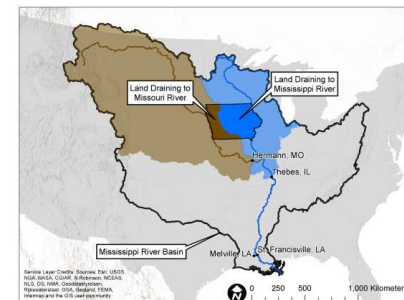
3.3% of the land  
12% of the water  
55% of the nitrate



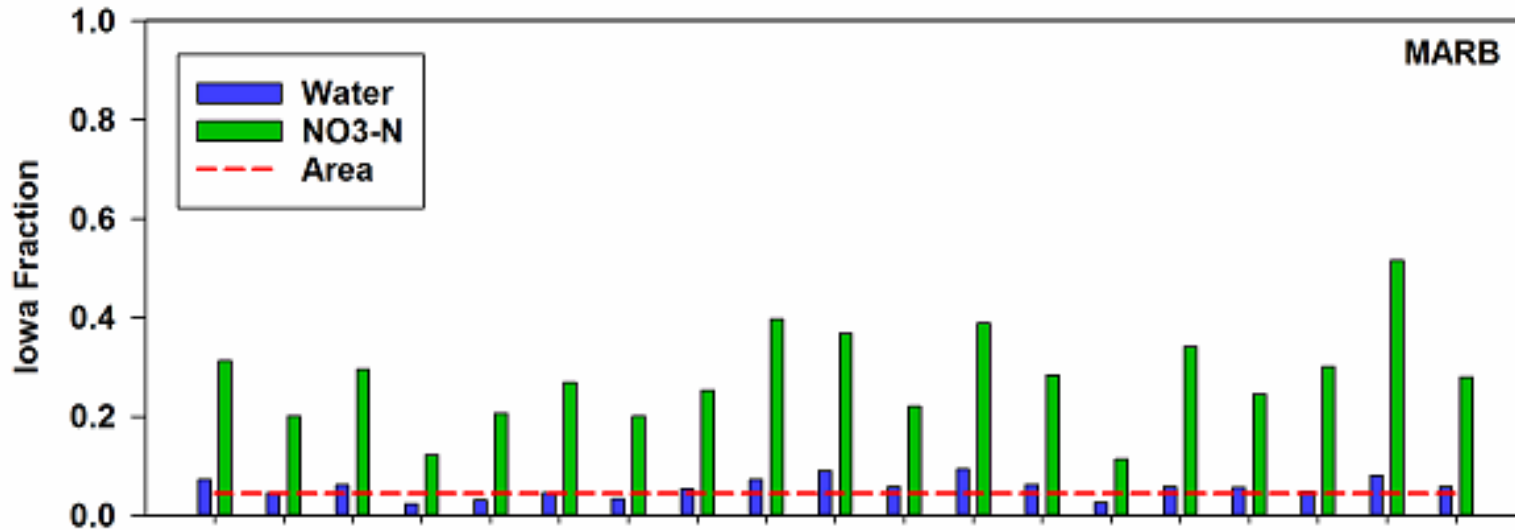
# Upper Mississippi: Nitrogen



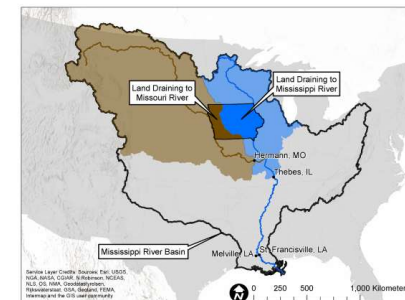
21% of the land  
21% of the water  
45% of the nitrate



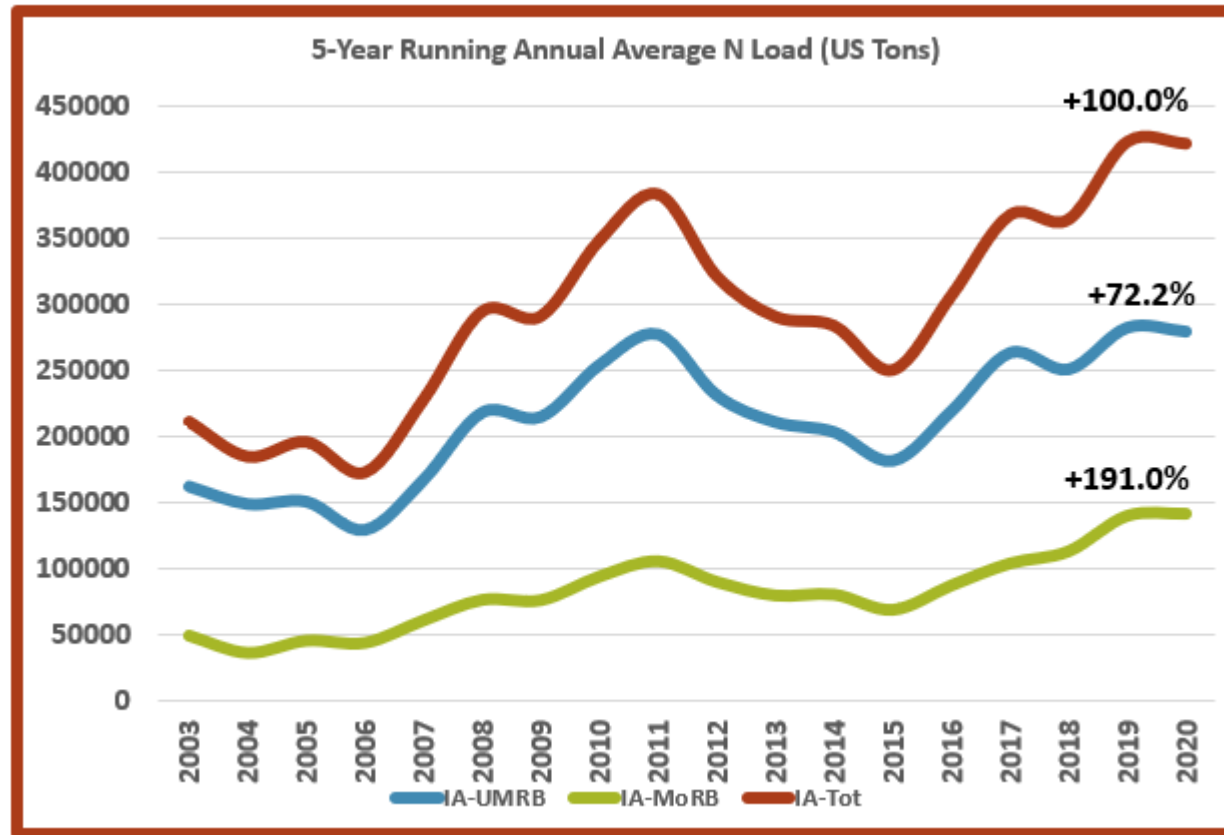
# Mississippi-Atchafalaya: Nitrogen



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



# How Much Nitrogen Leaves Iowa?



RESEARCH ARTICLE

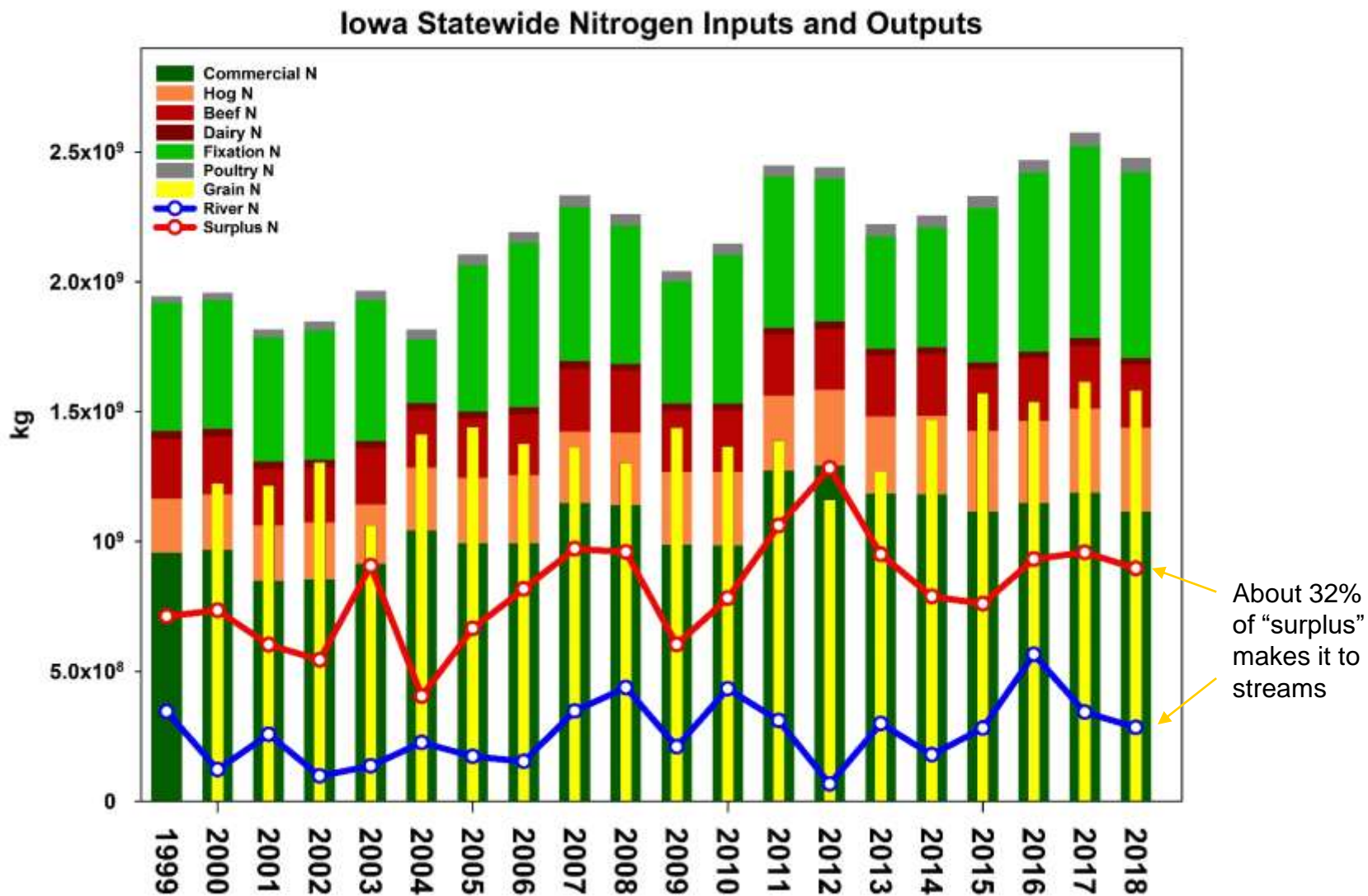
# Iowa stream nitrate and the Gulf of Mexico

Christopher S. Jones<sup>1</sup>\*, Jacob K. Nielsen<sup>1</sup>, Keith E. Schilling<sup>2</sup>, Larry J. Weber<sup>1</sup>

**1** IIHR-Hydrosience 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](mailto:Christopher-s-jones@uiowa.edu)



# 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”



## Research papers

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

Keith E. Schilling<sup>a,\*</sup>, Matthew T. Streeter<sup>b</sup>, Anthony Seeman<sup>c</sup>, Christopher S. Jones<sup>d</sup>, Calvin F. Wolter<sup>e</sup>

<sup>a</sup> Iowa Geological Survey, University of Iowa, Iowa City, IA, United States

<sup>b</sup> Iowa Soybean Association, Ankeny, IA, United States

<sup>c</sup> IRIH Hydroscience and Engineering, University of Iowa, Iowa City, IA, United States

<sup>d</sup> Iowa Department of Natural Resources, Des Moines, IA, United States



## 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

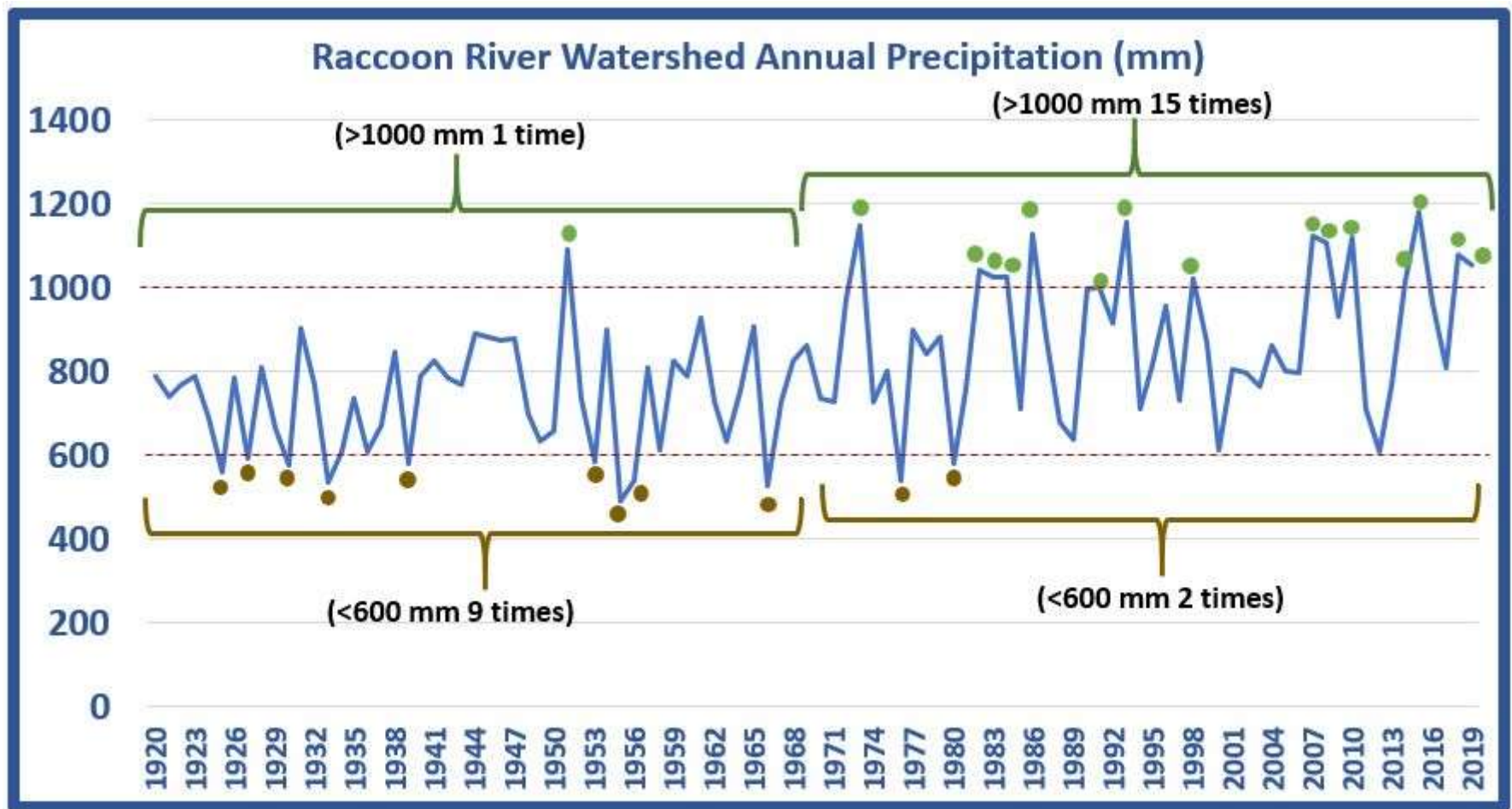
Watershed	2002	2007	2016
Middle Cedar	\$1,900,000	\$5,100,000	\$5,600,000
Upper Wapsi	\$1,800,000	\$2,200,000	\$6,600,000
English River	\$187,000	\$492,000	\$1,124,000
North Raccoon	\$536,000	\$936,000	\$1,175,000
Upper Iowa	\$106,000	\$231,000	\$931,000
Clear Creek	\$9,350	\$4,300	\$50,500

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

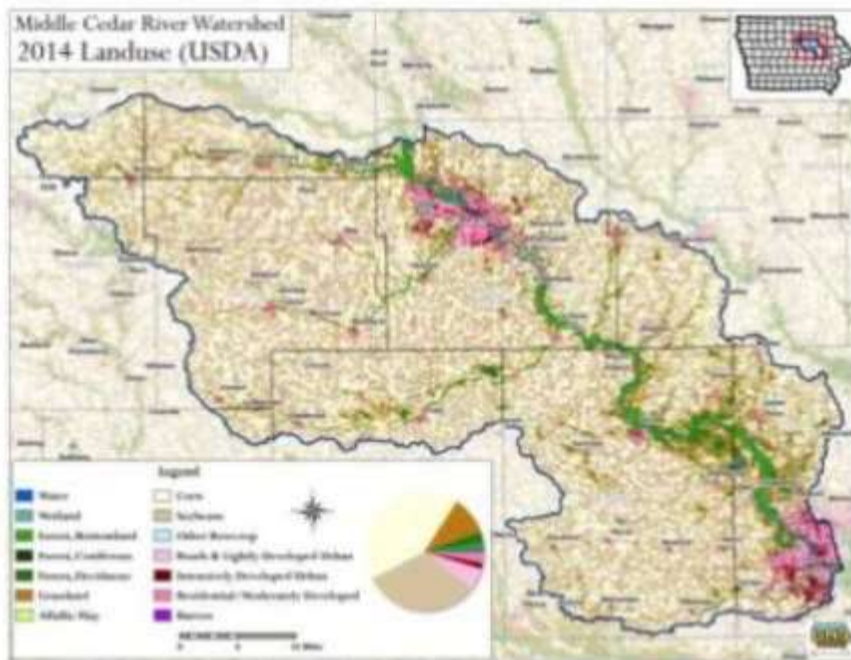
Landform	% of Iowa's Area	\$/year spent on new tile
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Paleozoic Plateau	4.6	\$3,580,862
Southern Iowa Drift Plain	41.3	\$33,837,580
Total	92.5	\$70,064,878

*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

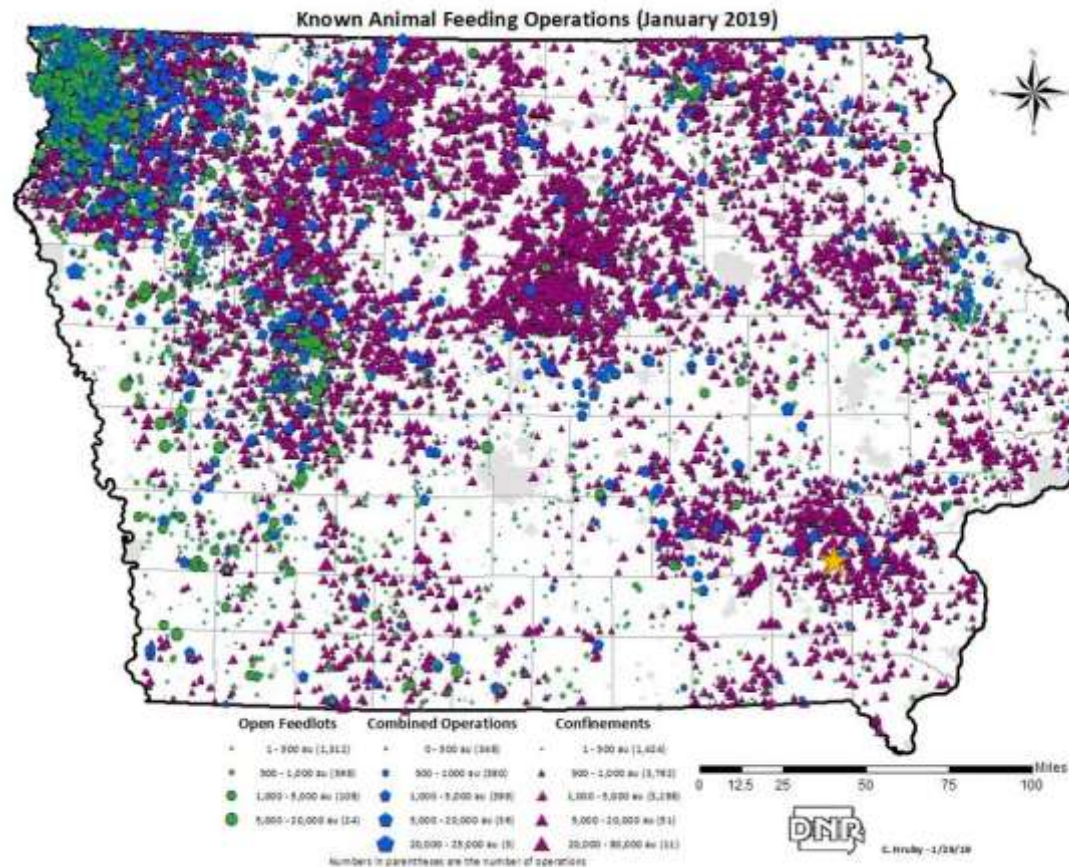
2018 N loss = 31.5 lbs/ac

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



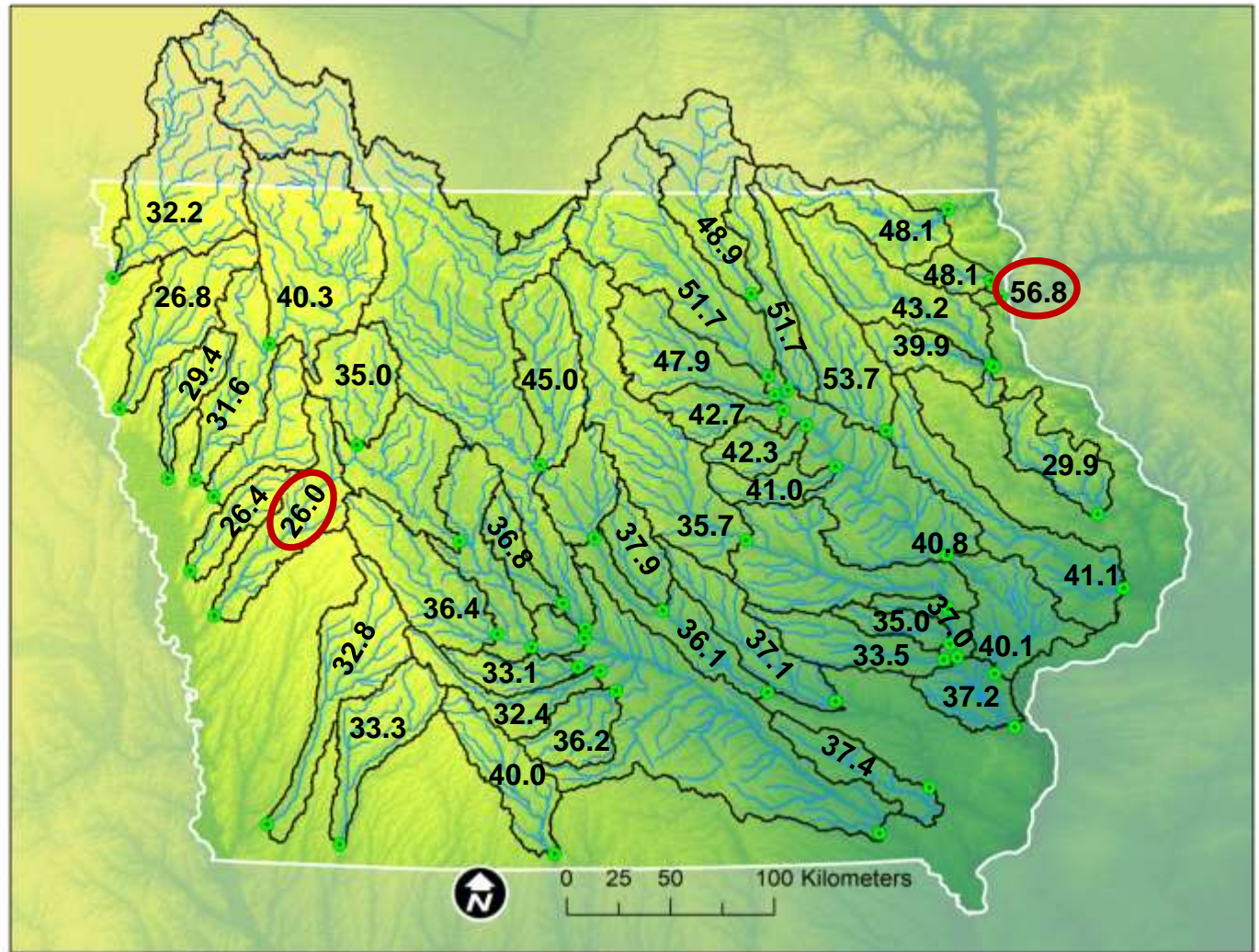
# Regulations?

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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

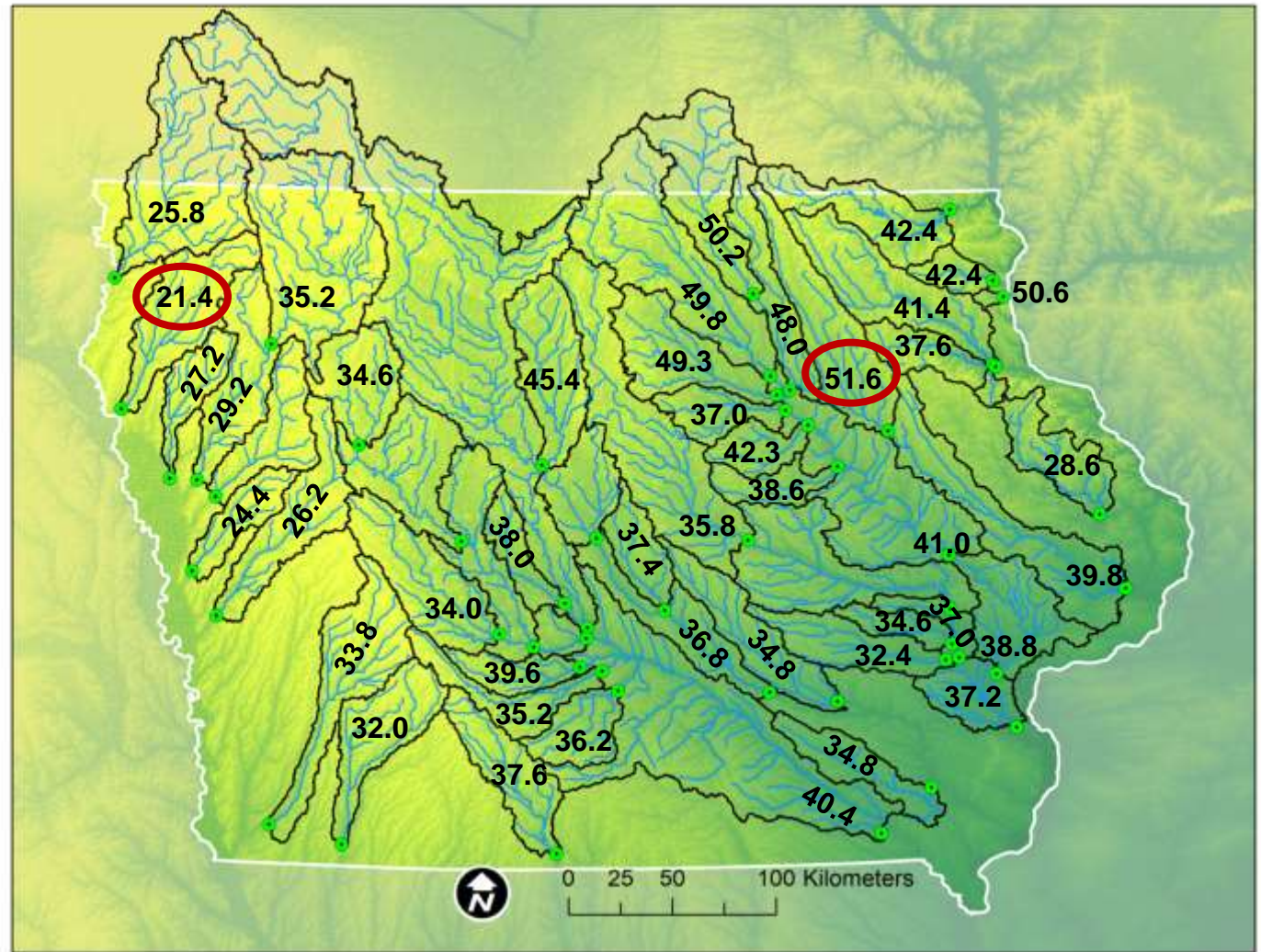
2000-2020

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



2016-2020

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



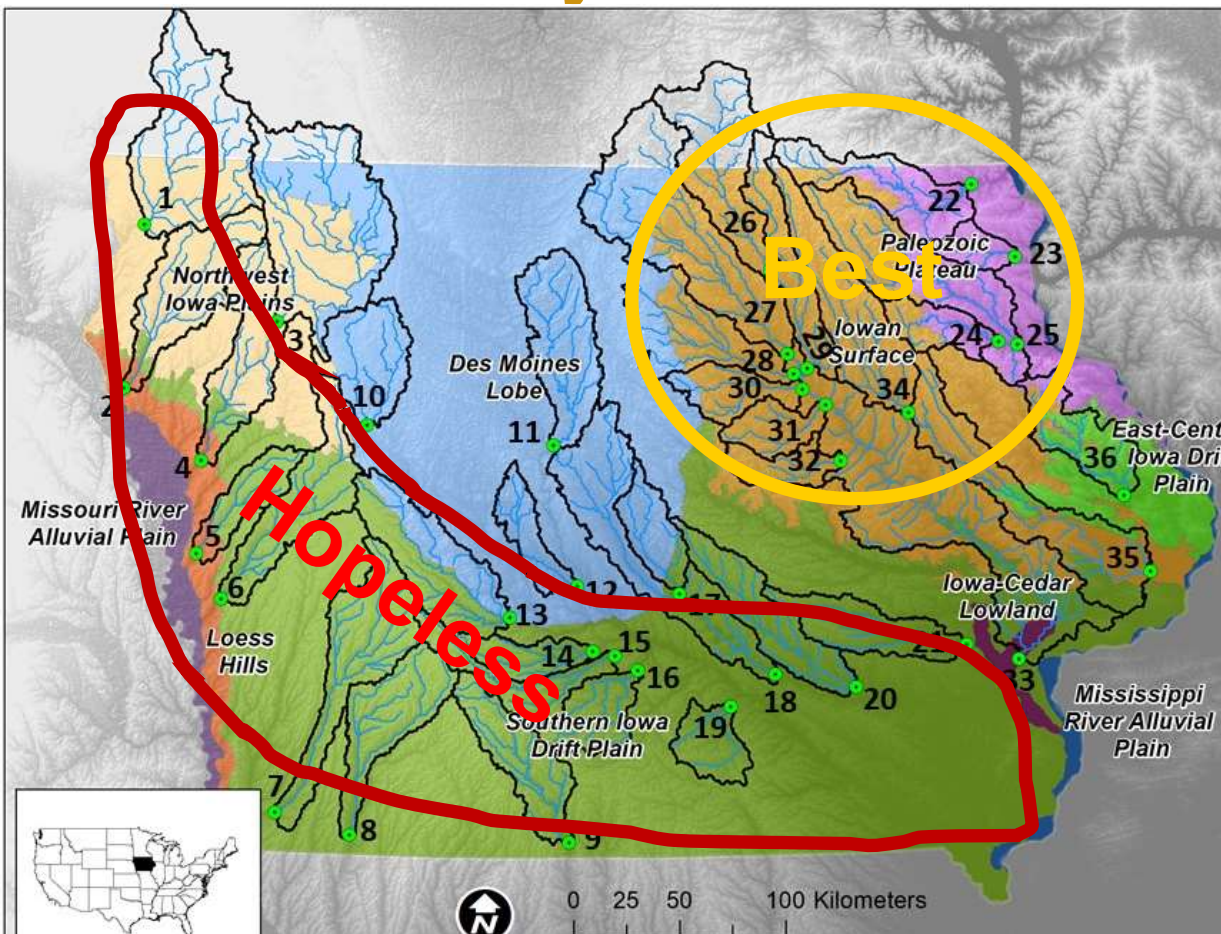
# Stream Water Quality Since 1999

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

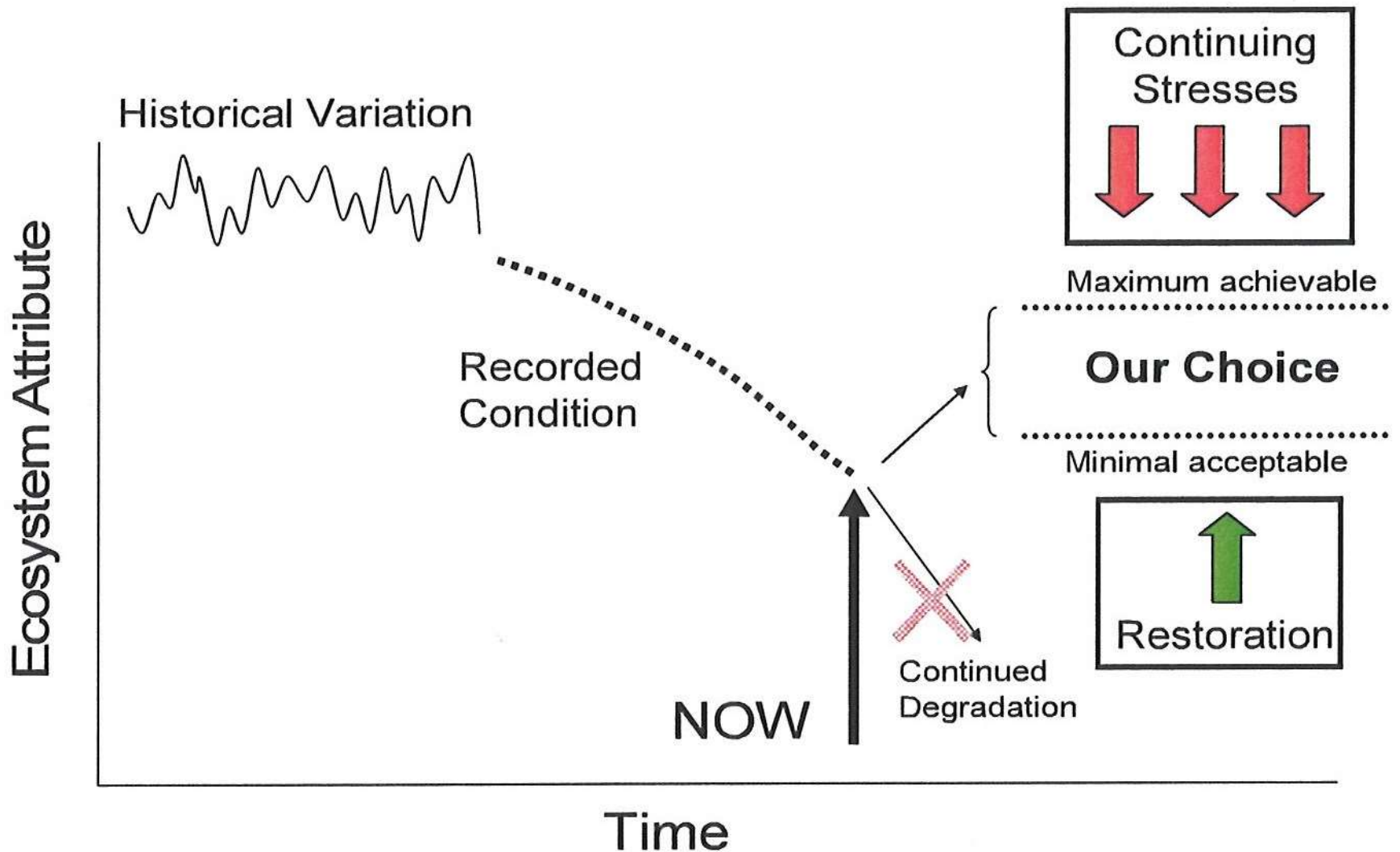
What do we want our production system to look like?

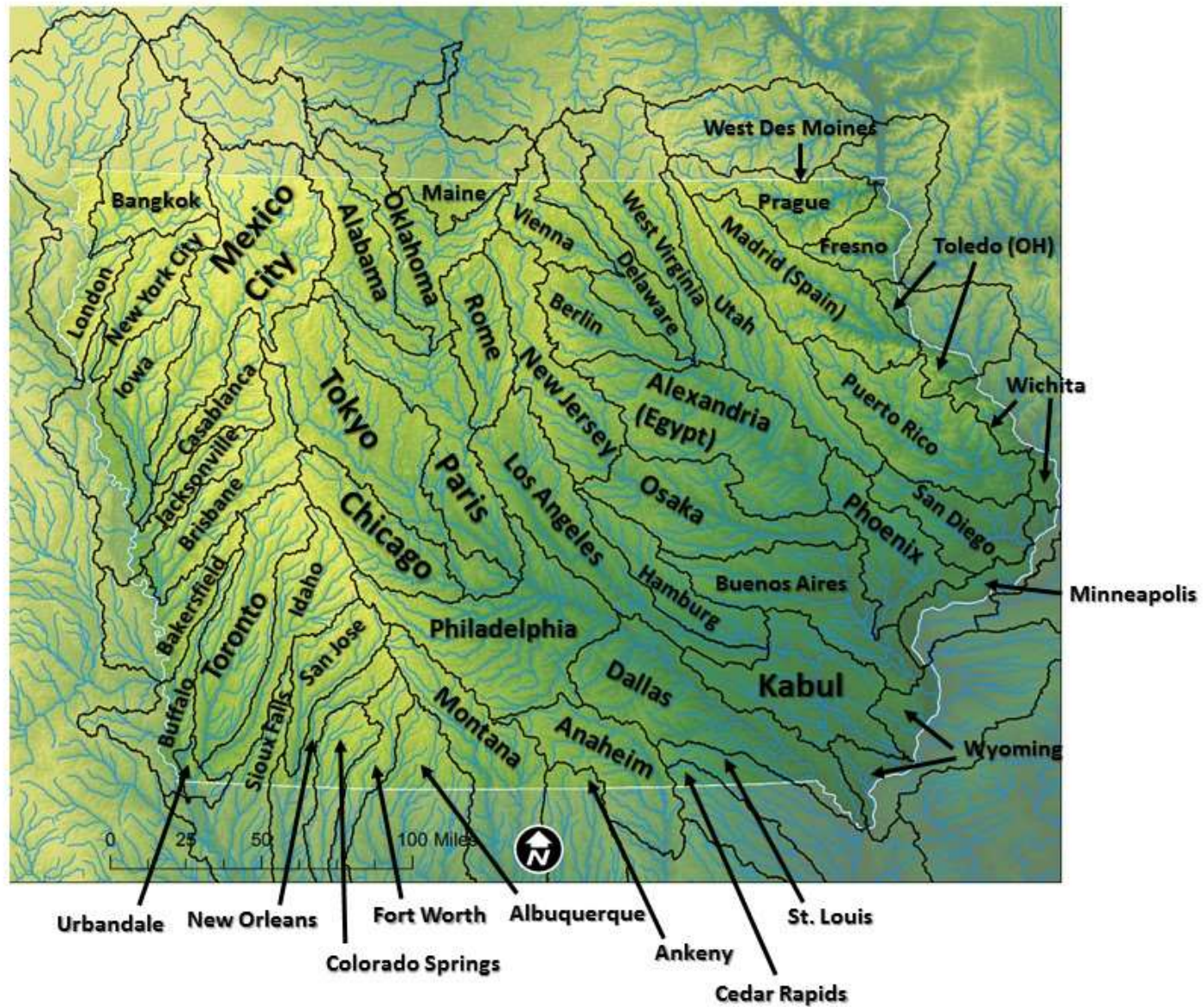
Commerce



Nutrition?







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

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