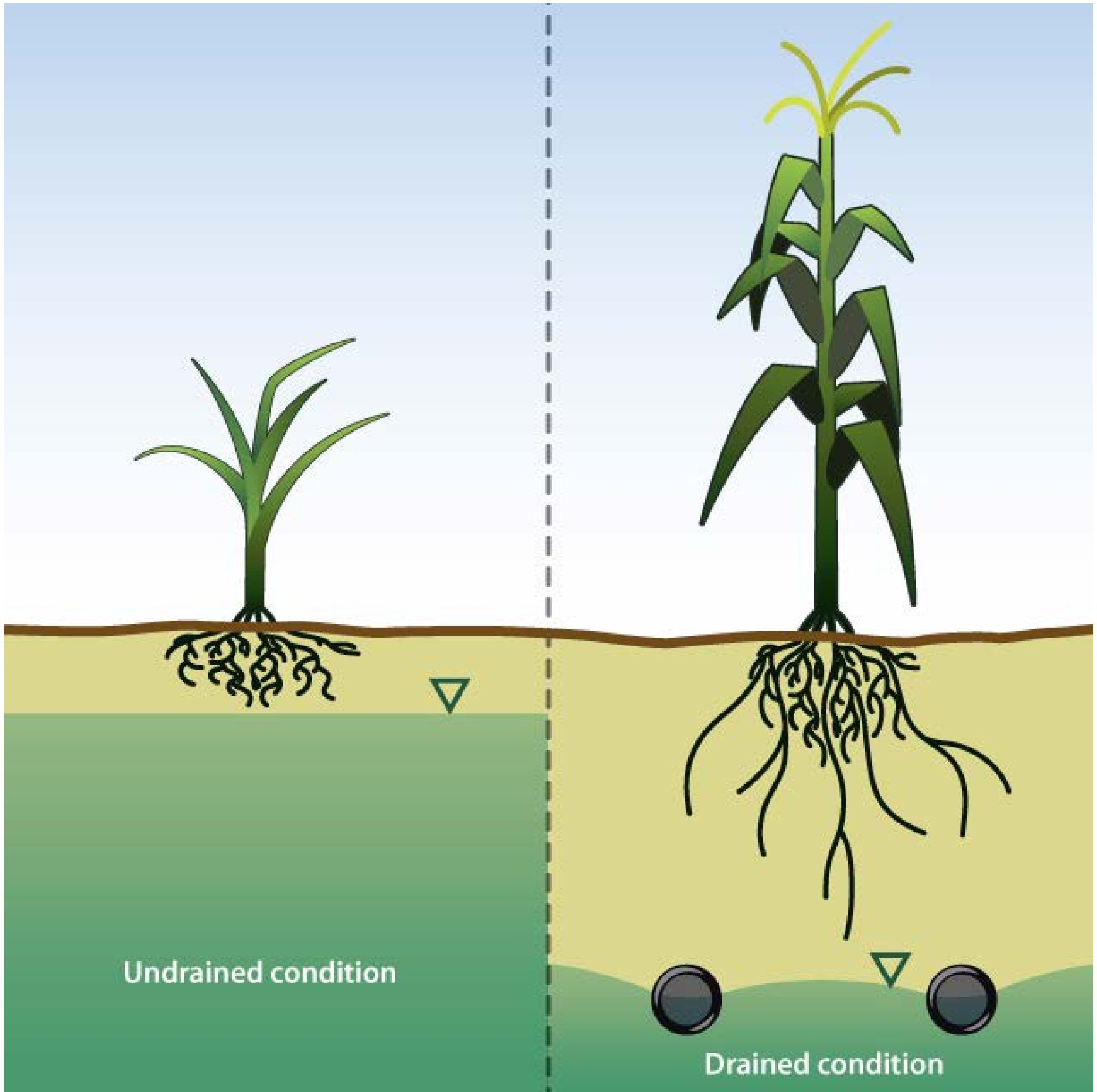
Transforming Drainage: Retaining Water for Increased Resiliency

Jane Frankenberger, Purdue University

With ideas and contributions from a large project including Eileen Kladivko, Laura Bowling, Bernard Engel, Linda Prokopy, **Purdue University**; Matt Helmers, Lori Abendroth, Giorgio Chigladze, **Iowa State University**; Jeff Strock, **University of Minnesota**; Dan Jaynes, **USDA-ARS**; Kelly Nelson, **University of Missouri**; Mohamed Youssef, **NC State University** ; Larry Brown, Brent Sohngen, **Ohio State University**; Xinhua Jia, **North Dakota State University**, Laurent Ahiablame, **South Dakota State University**

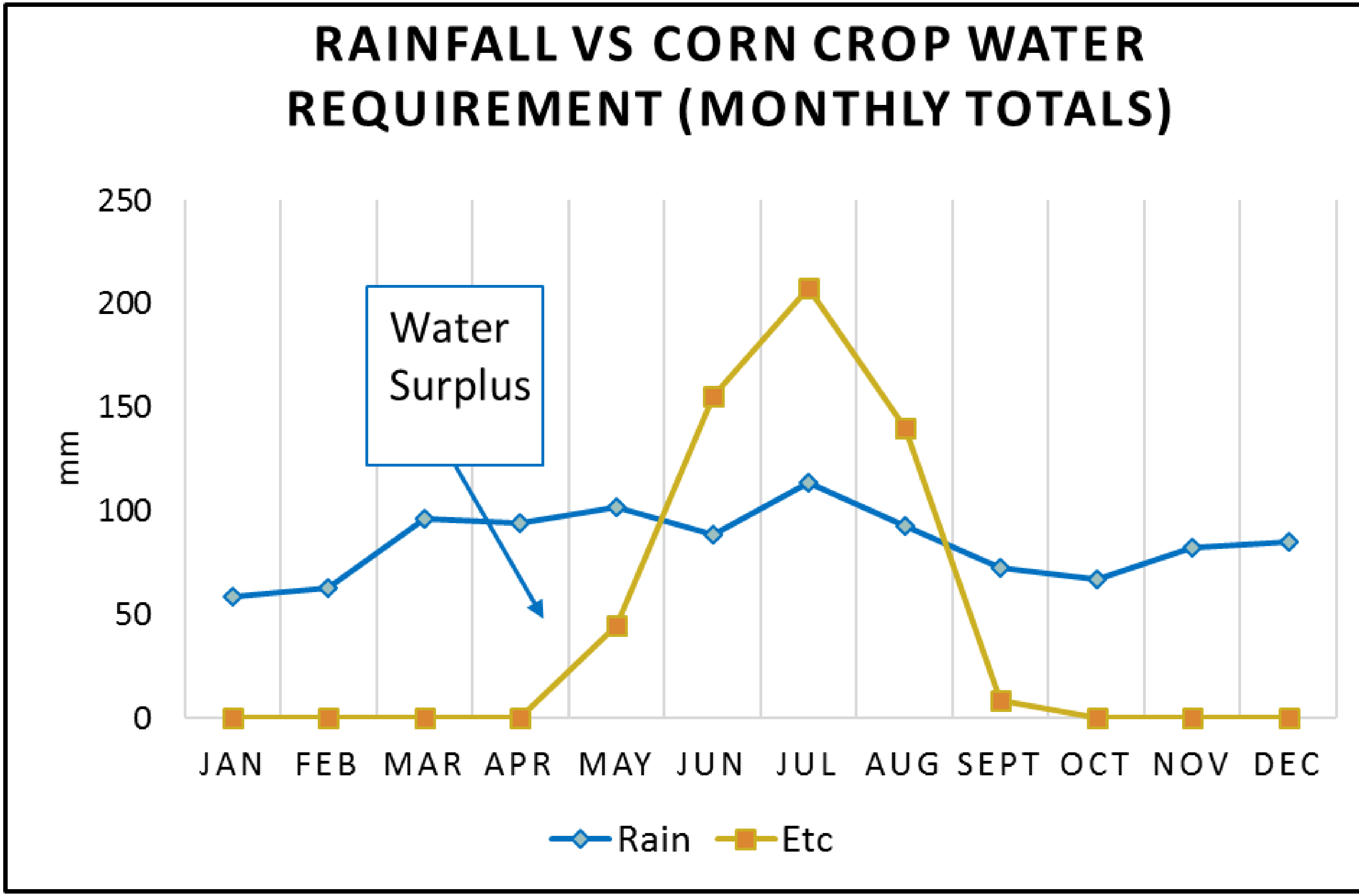
Drainage is essential for crop production in much of Indiana

Good drainage in spring allows aeration, needed for root development



Drainage is required to provide trafficable conditions for field operations

Photo: R.W. Skaggs


RAINFALL VS CORN CROP WATER REQUIREMENT (MONTHLY TOTALS)
250
200
150
100
50
0
mm
Water Surplus
JAN
FEB
MAR
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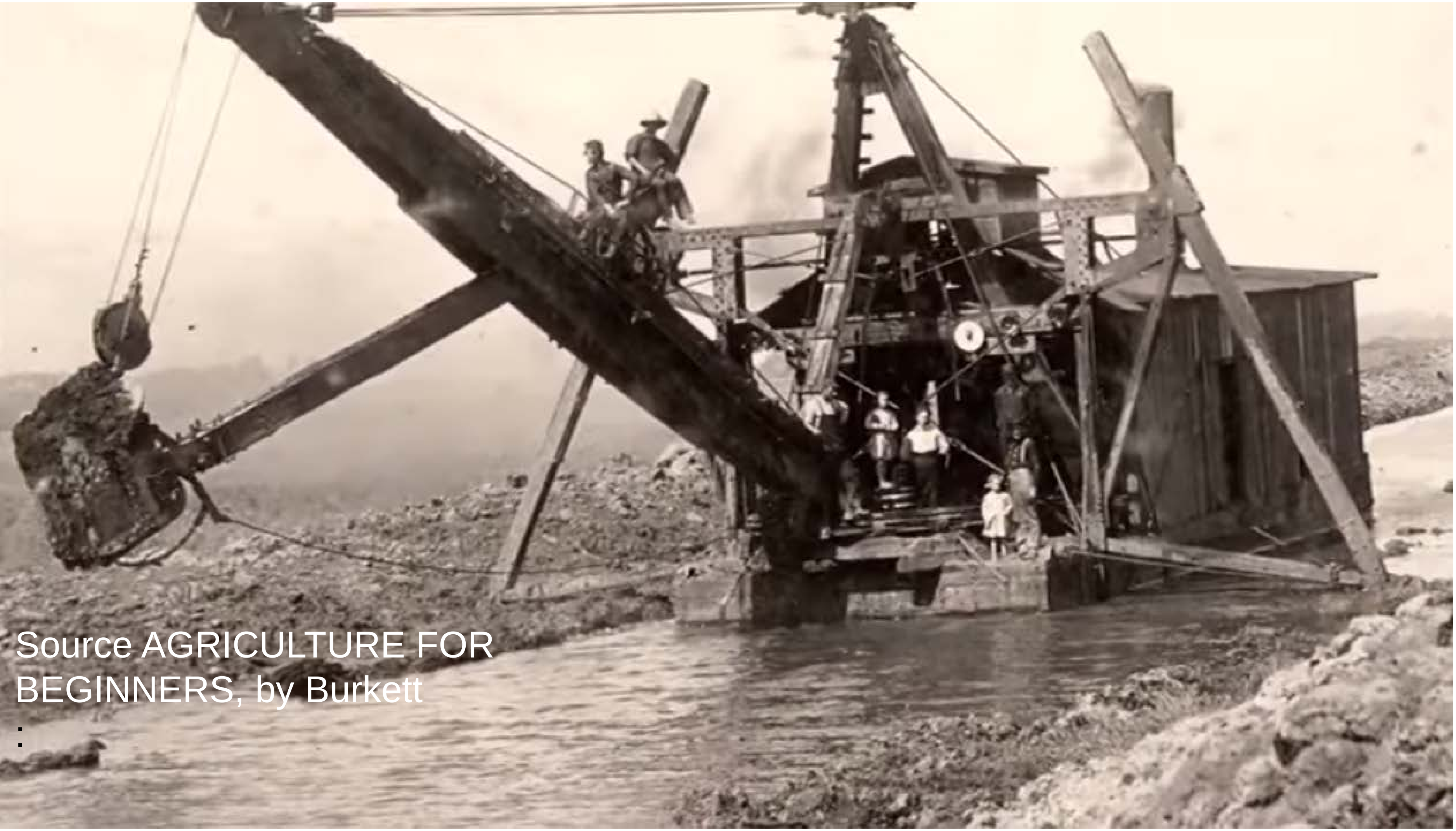
Rain
Etc

Draining Indiana's wetlands was a triumph of early 20th century technology



Source AGRICULTURE FOR BEGINNERS, by Burkett

:

Once drained, wet soils are among the most productive in the world

So why should we think about "transforming drainage"?

Issue 1: Nutrient loss from tile drainage is causing issues of national concern.

- Tile drains greatly increase loss of **nitrate** to streams.
- Recent research is showing more clearly that phosphorus also moves through tiles.

Critical national issues are linked to nutrient losses from subsurface tile drainage

- Hypoxia in the Gulf of Mexico

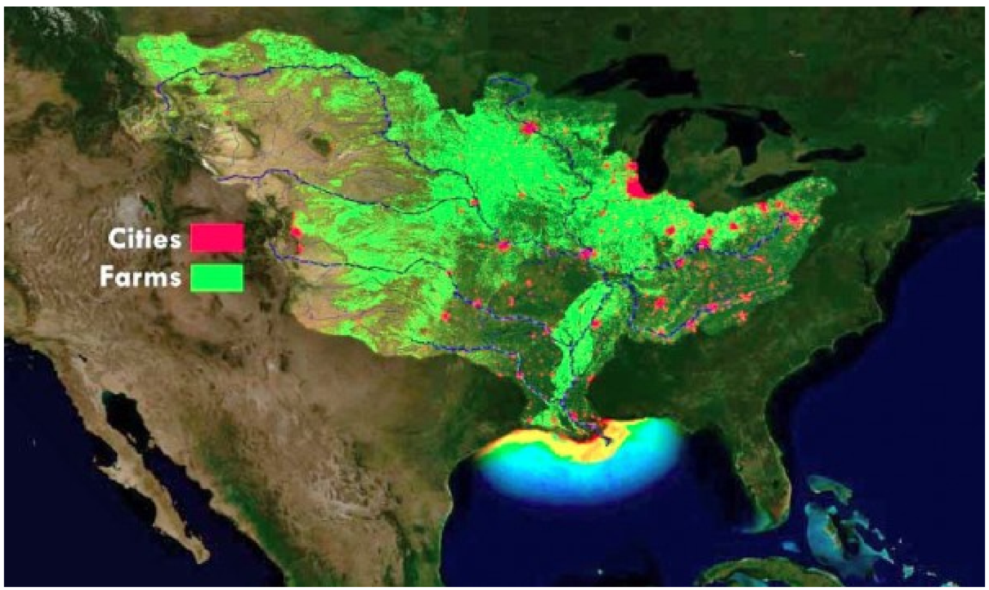


Image from NOAA

- Toxic algae in Lake Erie

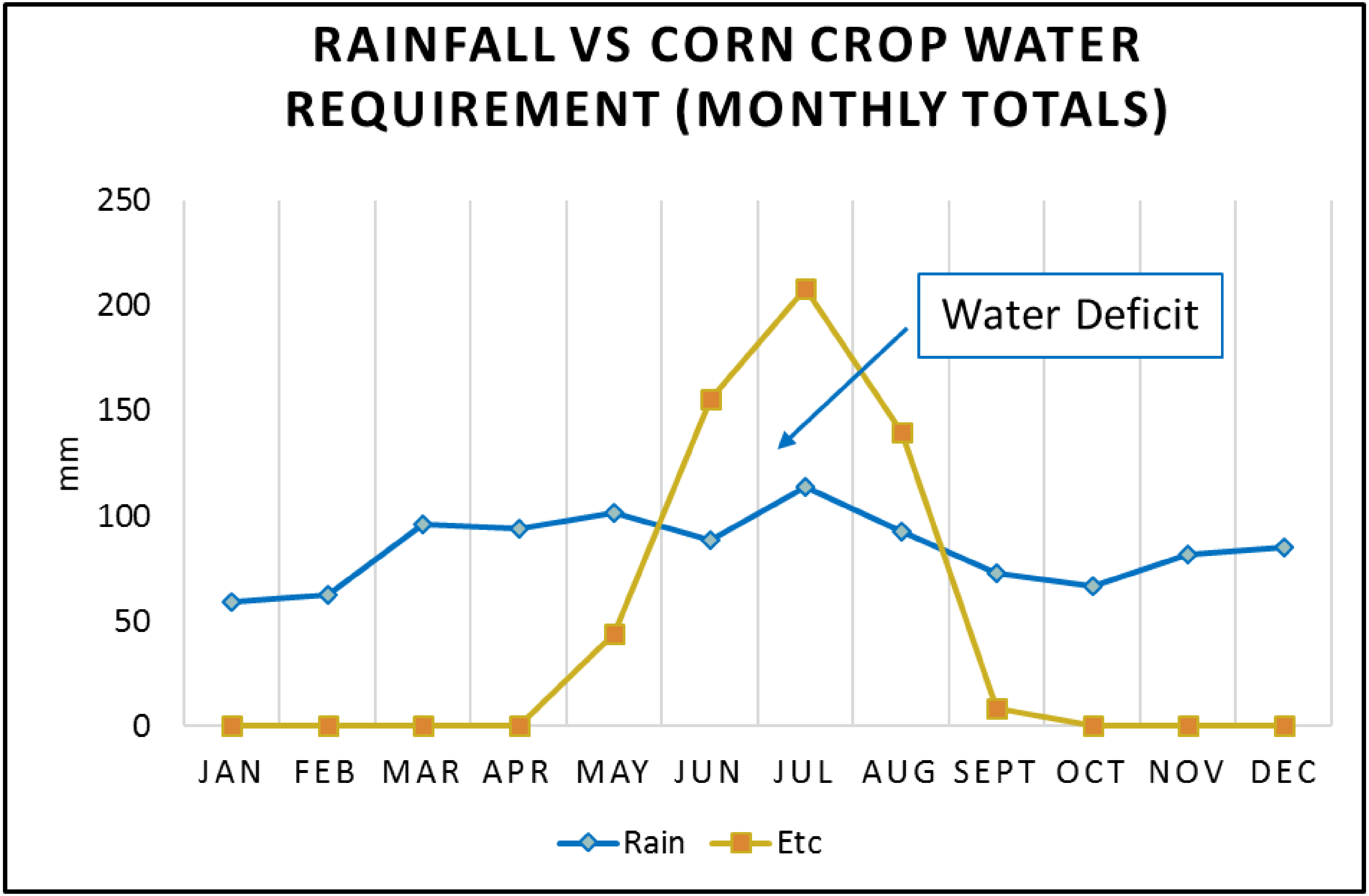
August 2014 Headline:
"Toxin leaves 500,000 in northwest Ohio without drinking water"

Image from Tom Bridgemen

Issue 2: Despite excess water in spring, yields are often limited by lack of water in late summer.

Even in wet springs, summers can be dry (2015).

Images:
Wikimedia
commons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Etc

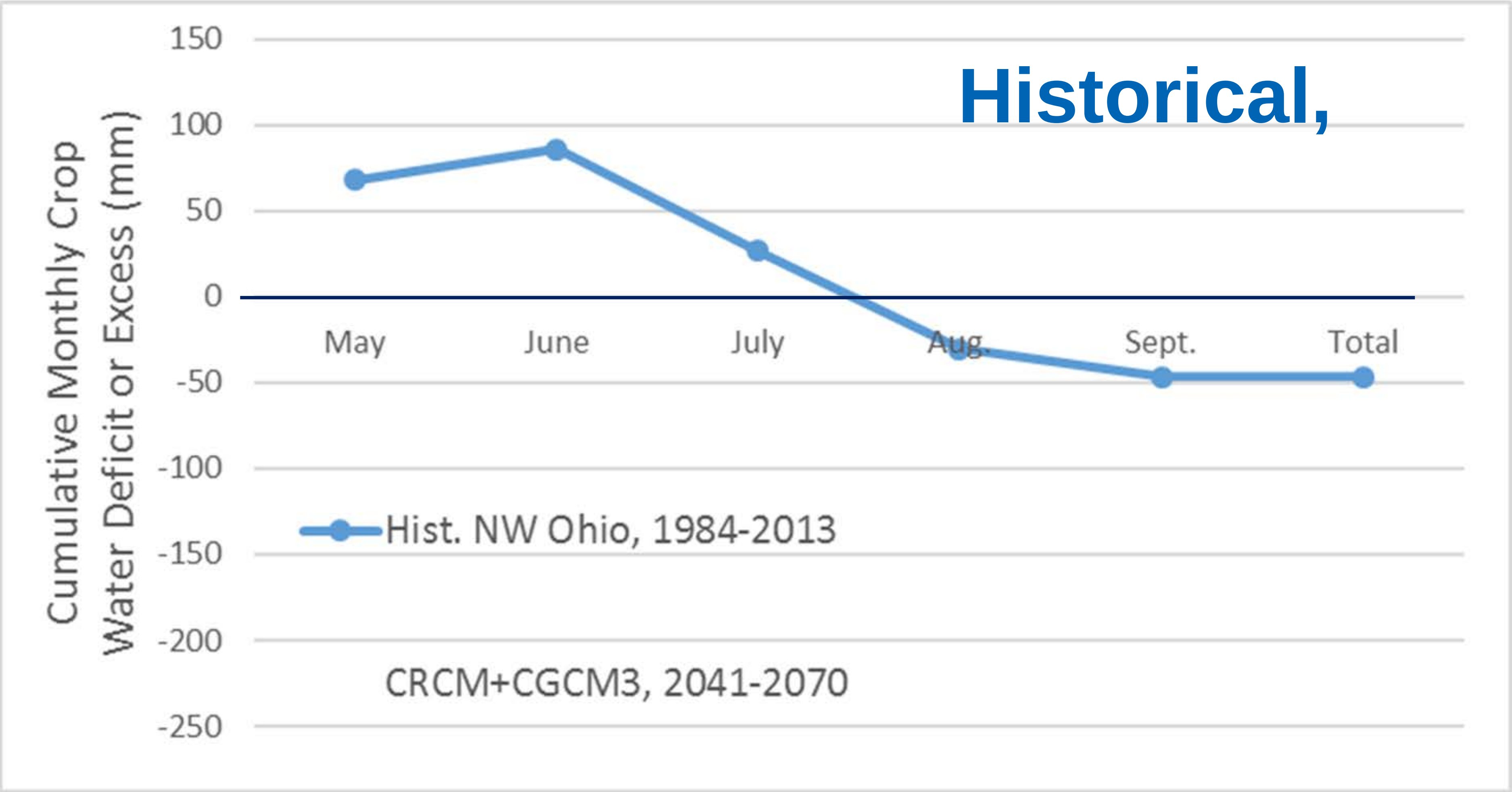
Two issues; both are expected to be exacerbated by climate change

- **Excess nutrients in spring will increase** as winter and spring becomes warmer and wetter

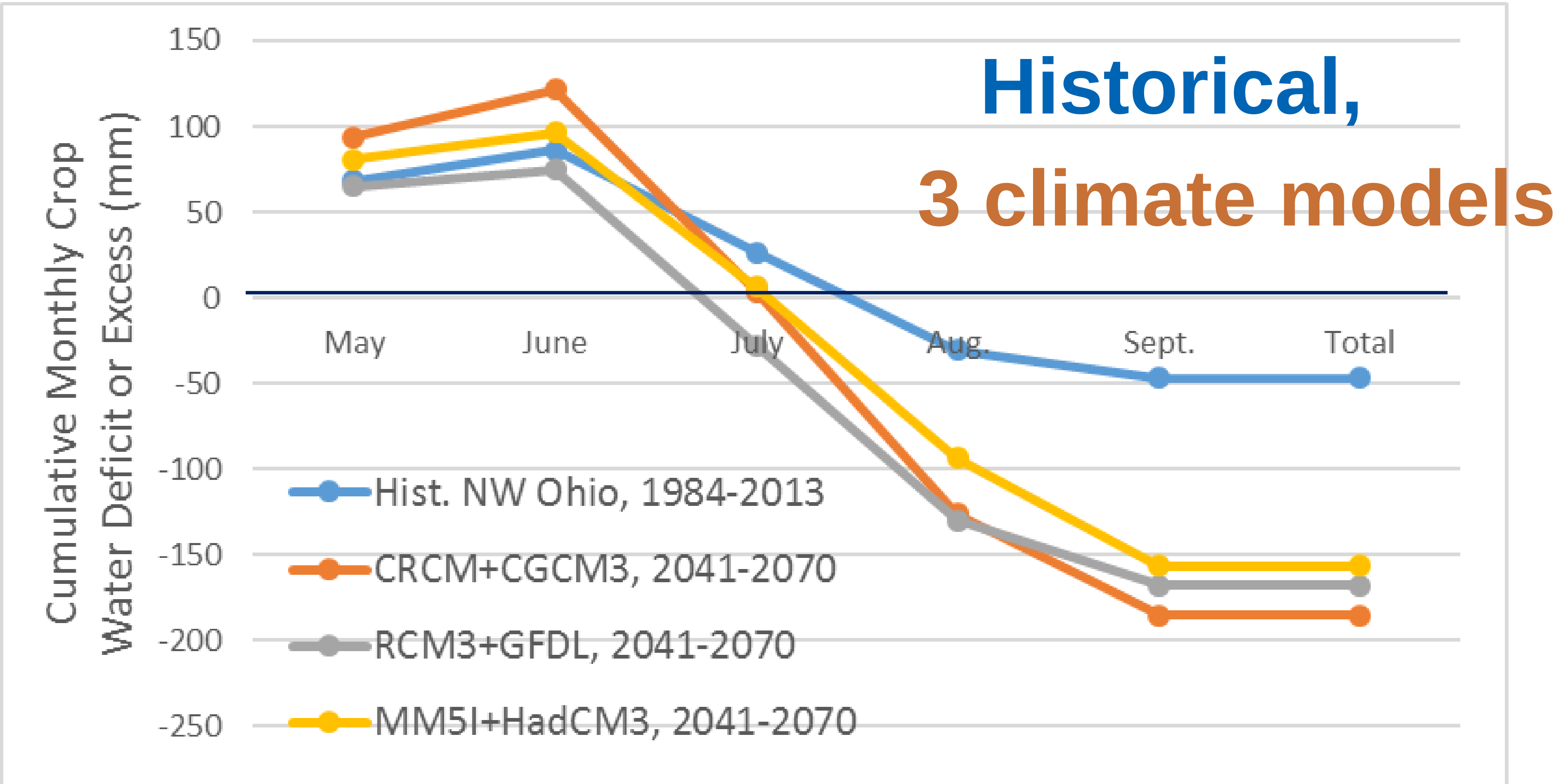
Photo: Tom Bridgeman

- **Water availability in late summer will decrease** with warmer summers and increased flashiness of precipitation

Crop water deficit or excess for corn (P – PET)



Crop water deficit or excess for corn (P – PET)



Transforming Drainage: Resilient agriculture means meeting water needs under future extreme weather

Images: Wikimedia commons

Retaining drained water in the landscape addresses both these issues.

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Managing Water for Tomorrow's Agriculture

Longer-term vision: The process of designing and implementing agricultural drainage will be **transformed** to include water retention and even water recycling.

Where can we store water in drained landscapes like this?

Photo: Dan Jaynes

Storing water in the soil: Soil health initiatives are promoting opportunities to increase water storage capacity of soils.

- Increasing soil organic matter increases water holding capacity.

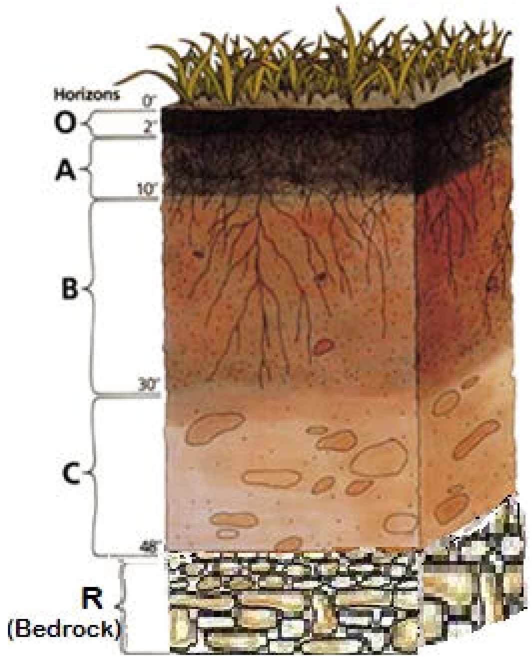


Image: Wikimedia Commons, Wilsonbriggs

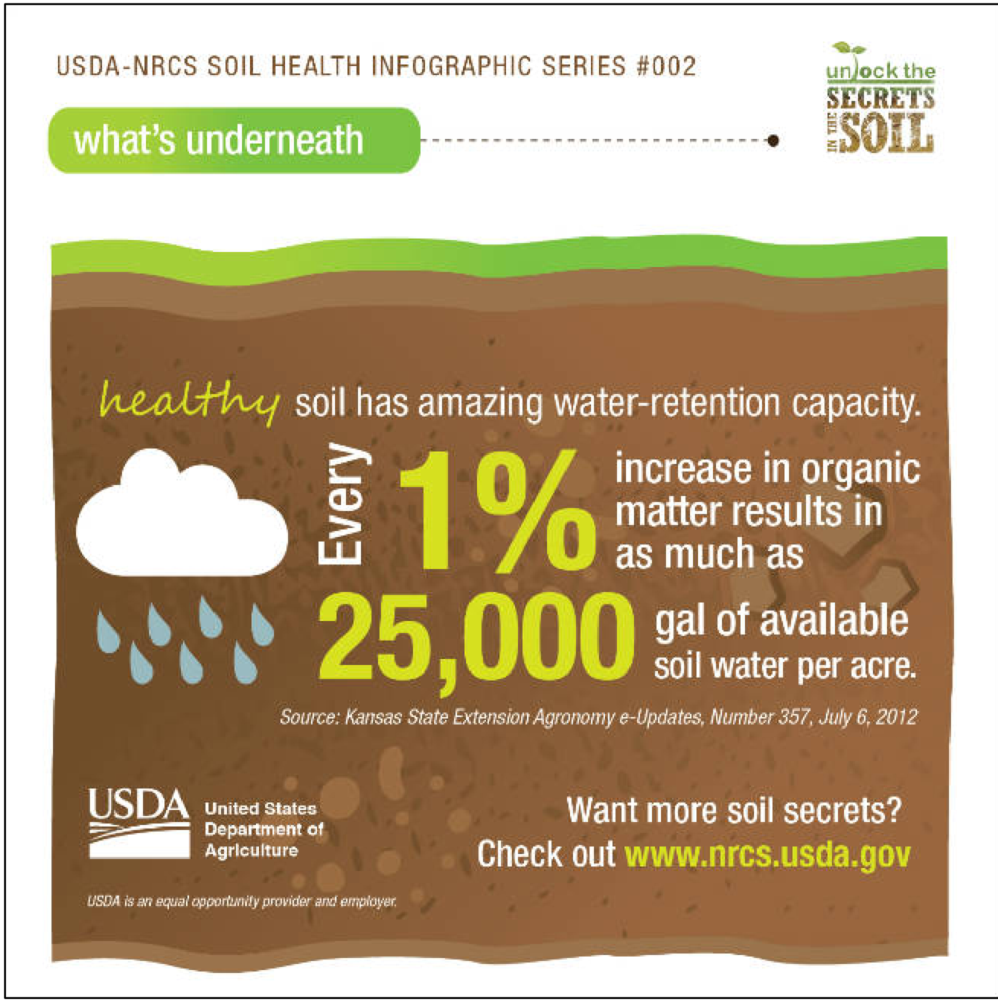


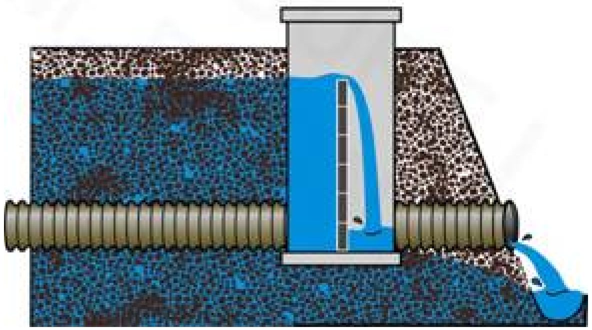
Image: NRCS

Storing water in wider ditches: **Two-Stage Ditches**

Storing water in the field:

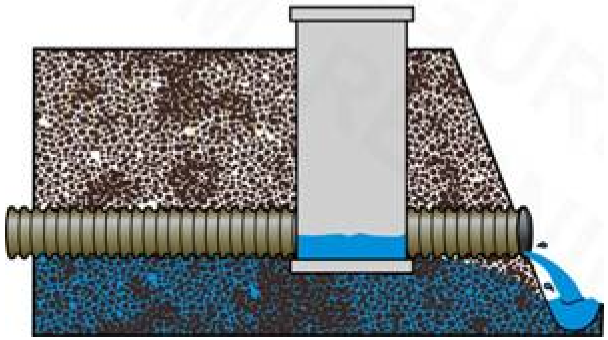
Controlled drainage

After harvest



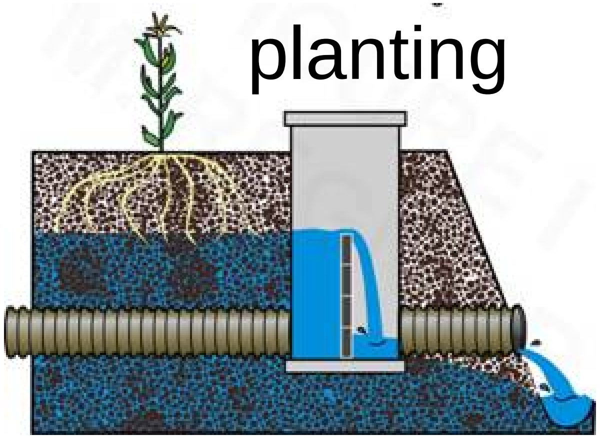
The outlet is raised after harvest to reduce nitrate delivery.

Before planting or harvest



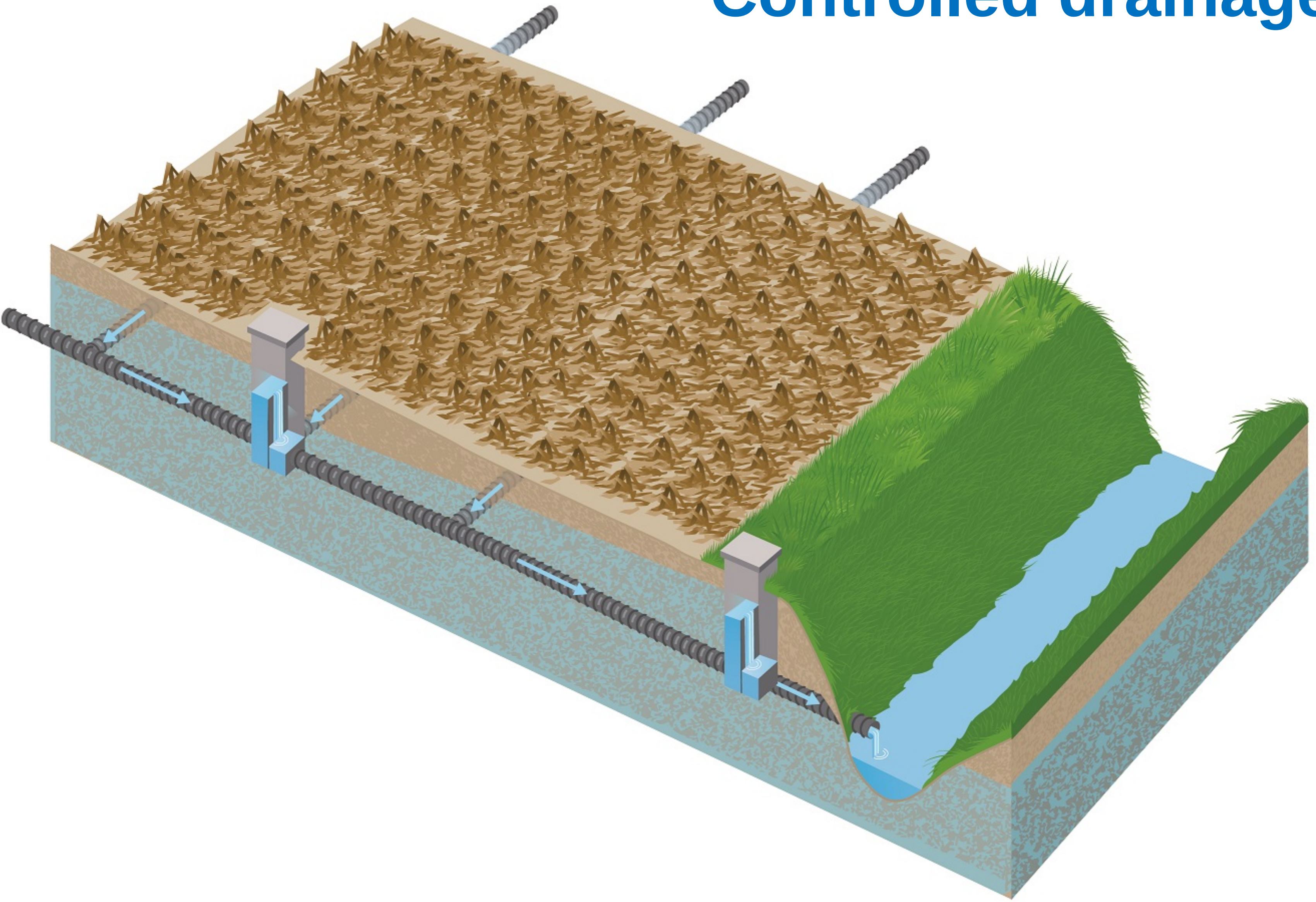
The outlet is lowered a few weeks before planting and harvest to allow the field to drain more fully.

After planting



The outlet is raised after planting to potentially store water for crops.

Storing water in the field:
Controlled drainage



Storing water in buffers: Saturated buffers

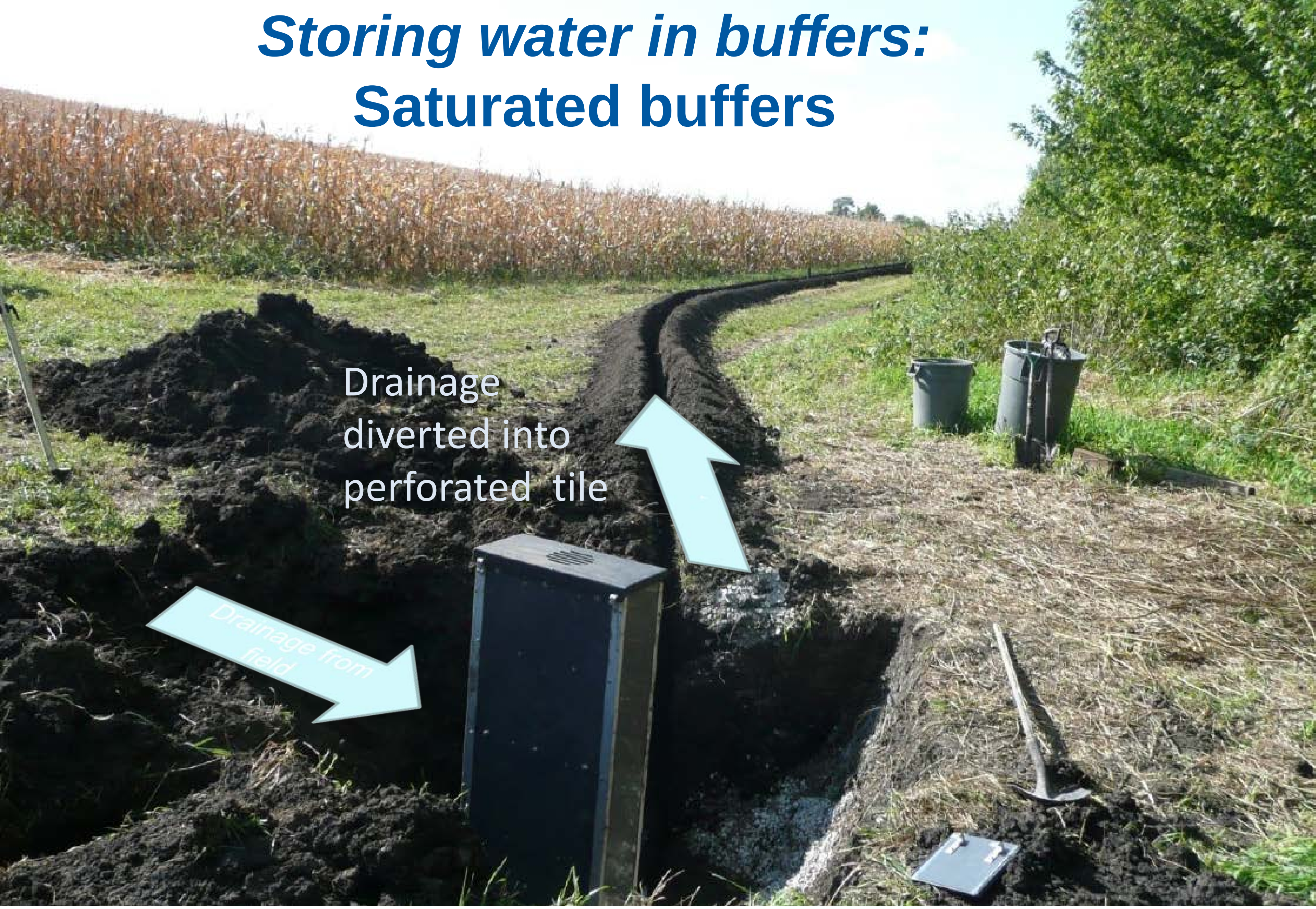
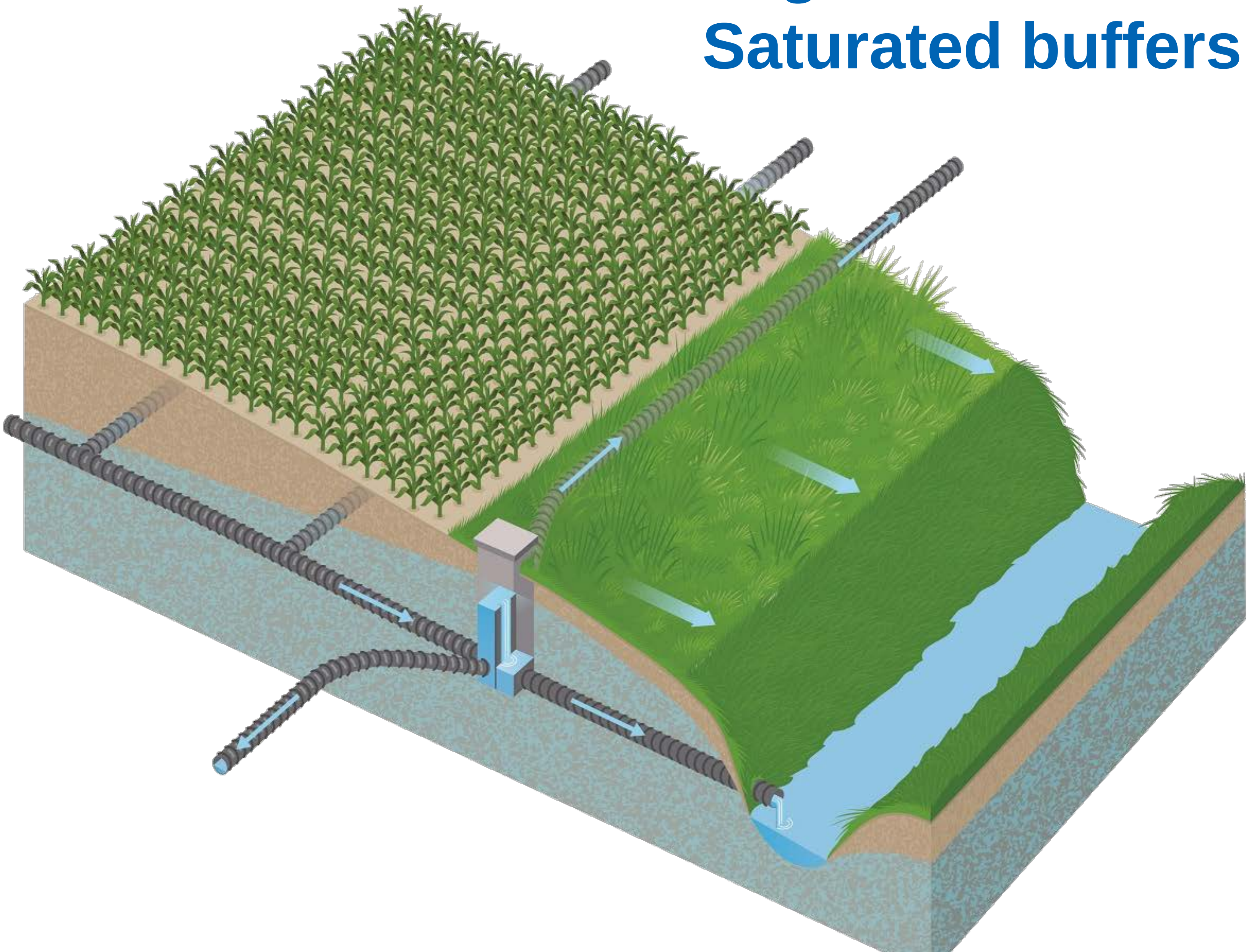


Photo courtesy Dan Jaynes, USDA-ARS)

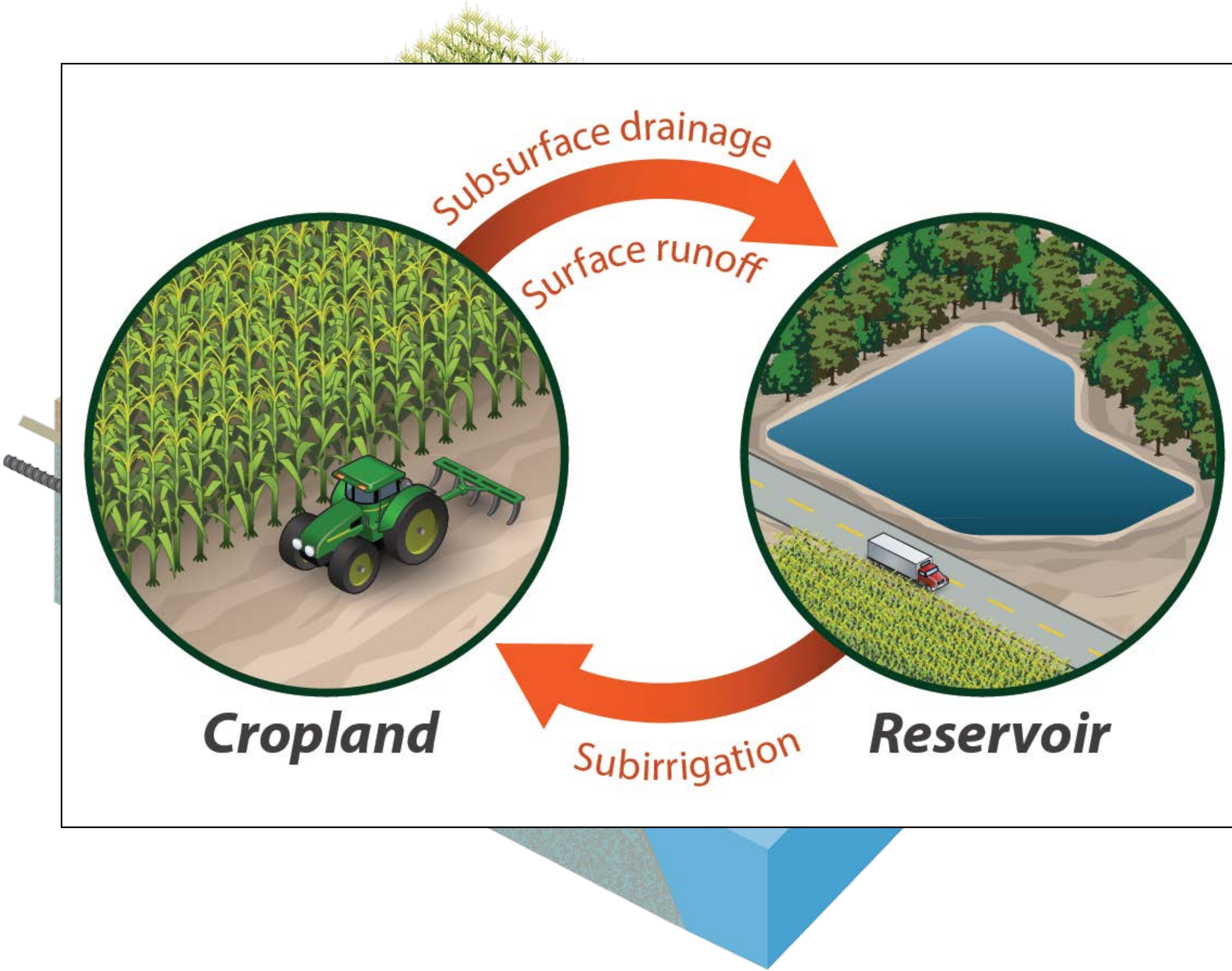
Storing water in buffers:
Saturated buffers



Could we just capture the drain flow?

Storing water in ponds or reservoirs:

Drainage water recycling



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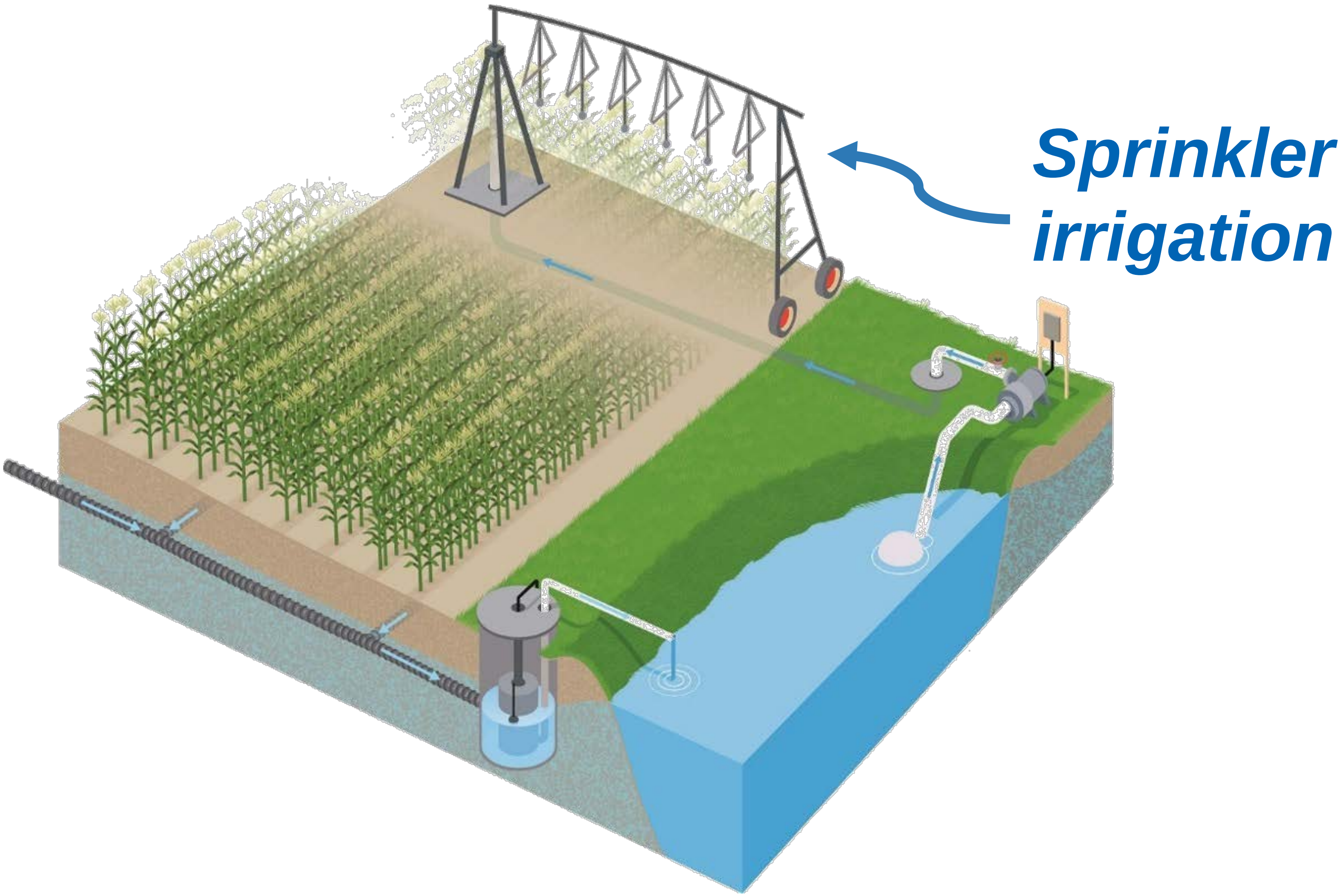


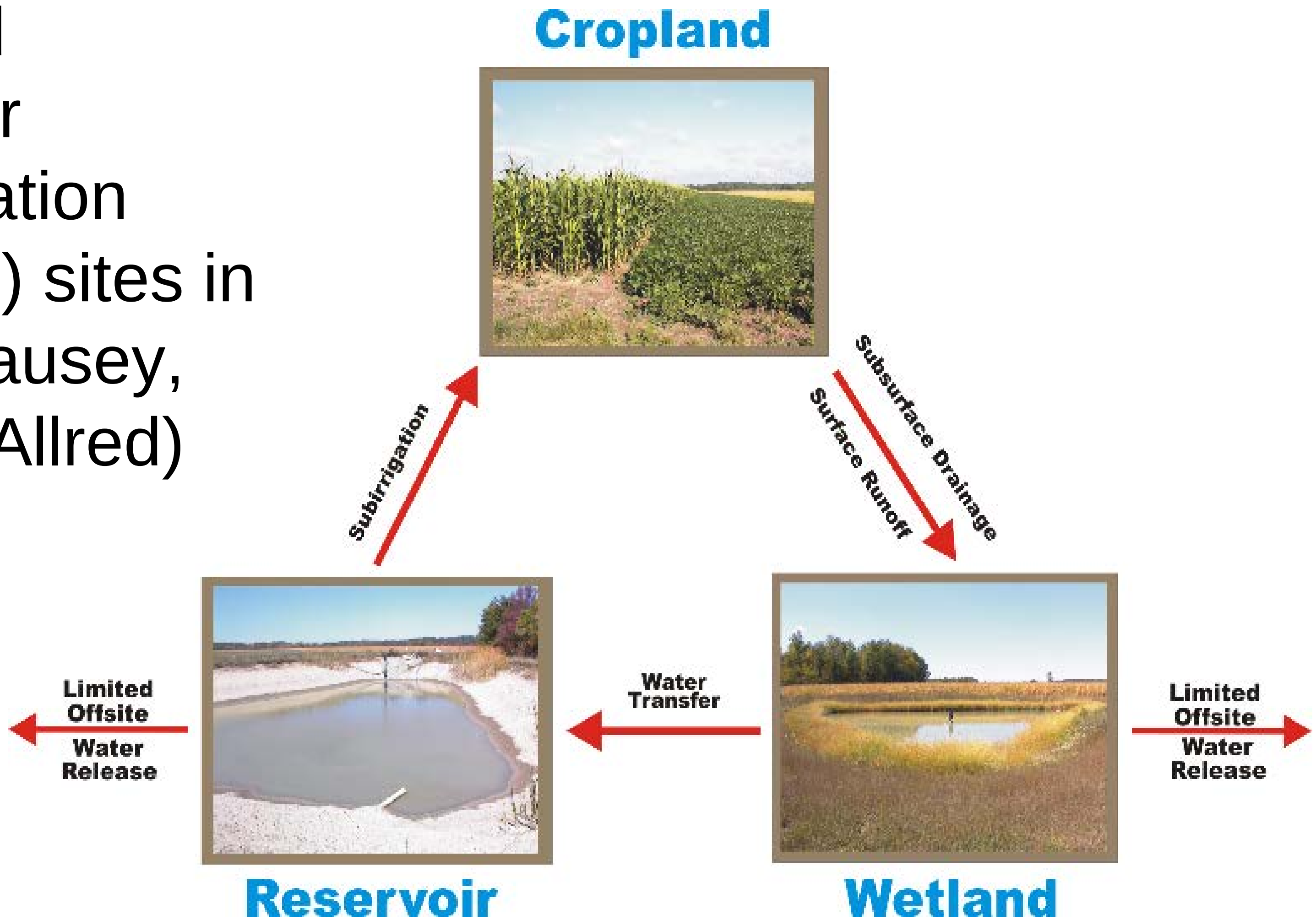
Few examples of drainage water recycling

Irrigation has seen a surge of interest in recent years as the potential of drought has become more evident.

- For example, irrigated acreage increased by 75% in Indiana, 51% in Michigan, and 49% in Illinois from 1997 to 2012.

Little published research on drainage water recycling

- Wetland reservoir subirrigation (WRSIS) sites in Ohio (Fausey, Brown, Allred)



Year In	Growing Season Classification	**Corn Yield - kg/ha**		
		Sub-irrigated	Control	% Increase
1996	dry	11711	6839	71.2
1997	very wet	11962	10705	11.7
1998	wet	13232	11711	13.0
1999	dry	12025	8536	40.9
2000	very wet	11409	10328	10.5
2001	wet	12063	4570	164.0
2002	very dry	12214	5393	[illegible]
2003	[illegible]	[illegible]	52	[illegible]
2004	[illegible]	[illegible]	72	[illegible]
2005	[illegible]	[illegible]	71	[illegible]
2006	[illegible]	[illegible]	09	[illegible]
2008	near normal	10812	7480	[illegible]
Average		**12160**	**8981**	**35.4**

Soybean increase averaged 16.3% over the same period.

35.4% increase in corn yield

Year	Growing Season Classification	Corn Yield - kg/ha (bu/acre)[1]		
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2002	very dry	12214	5393	126.5
2003	very wet	14615	14552	0.4
2004	wet	12698	8172	55.4
2005	dry	11610	9171	26.6
2006	very wet	11566	10309	12.2
2007	wet	-	-	
2008	near normal	10812	7480	44.5
Dry season average		**11890**	**7484**	**66.3**

- Drainage water recycling in Ontario, Canada; Missouri, Minnesota

A $5 million USDA NIFA-funded Coordinated Agricultural Project

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Managing Water for Tomorrow's Agriculture

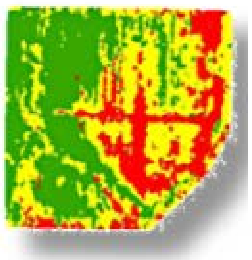
Purdue University
The Ohio State University
NC State University
University of Minnesota
NDSU North Dakota State University
Iowa State University
USDA United States Department of Agriculture
South Dakota State University
University of Missouri

USDA
United States Department of Agriculture
National Institute of Food and Agriculture

This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award number 2015-68007-23193, "Managing Water for Increased Resiliency of Drained Agricultural Landscapes", http://transformingdrainage.org. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

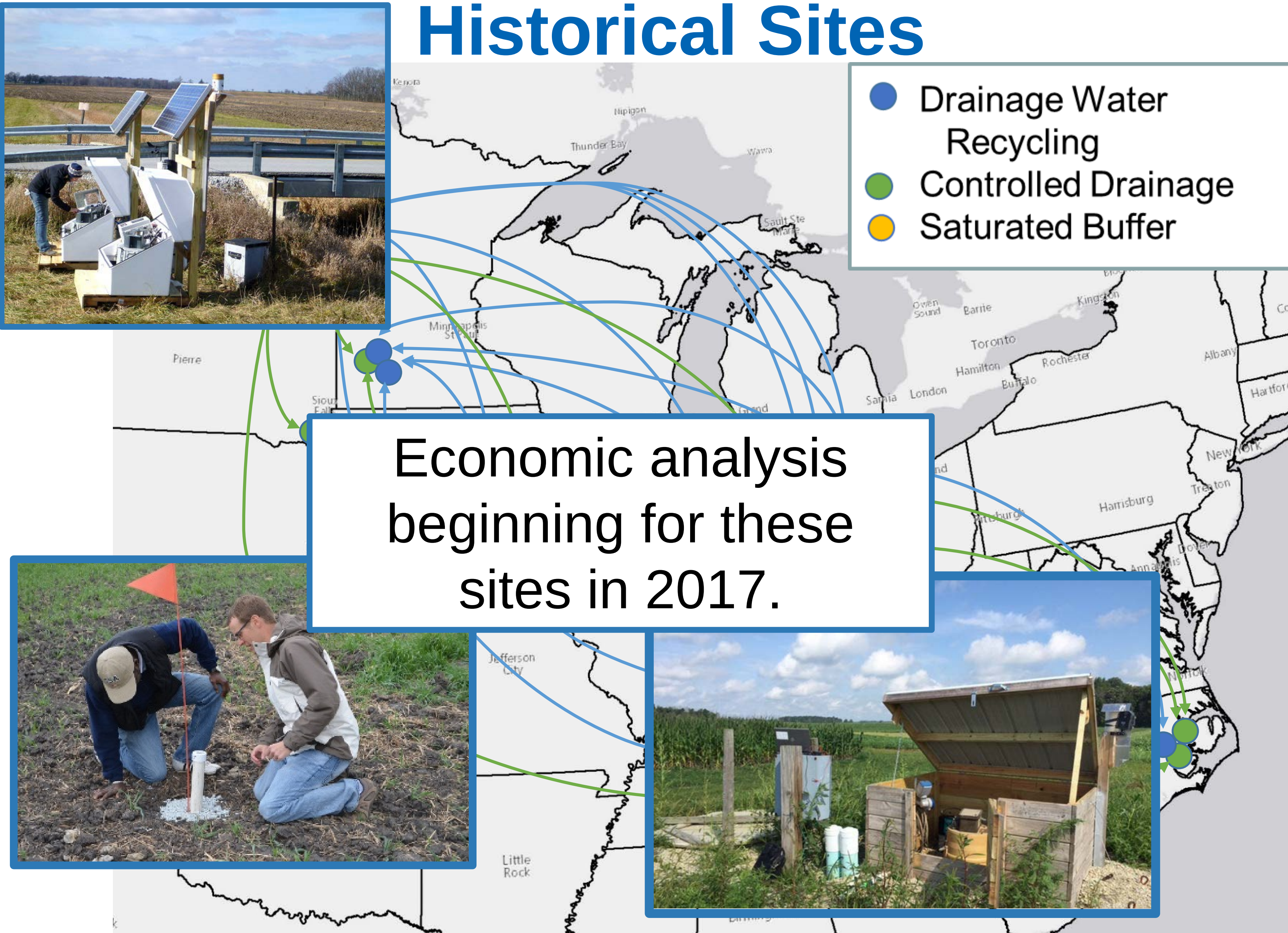
An integrated project to transform drainage

Field
Research



Strengthen and Broaden the Network
(Researchers, Industry, Contractors, Agencies**)**

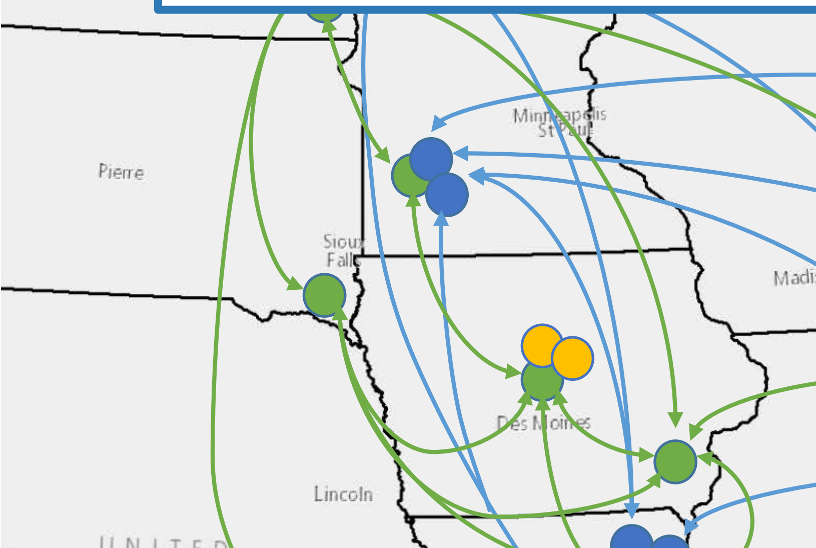
Field Research – Existing, New, Historical Sites

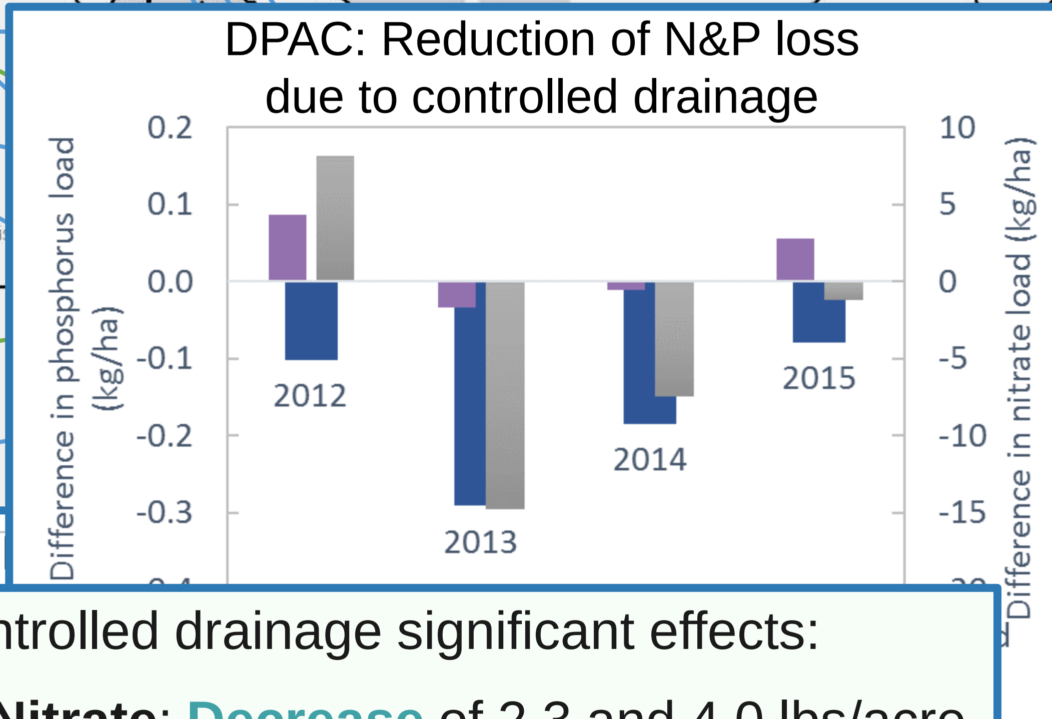


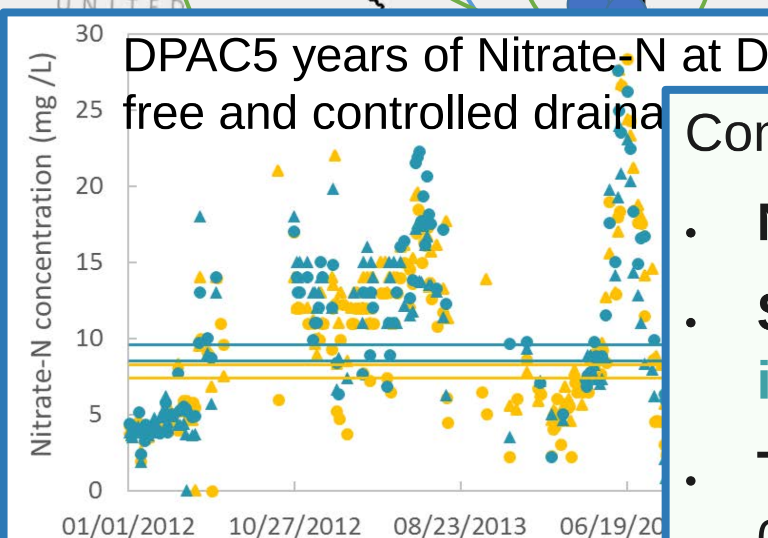
Economic analysis beginning for these sites in 2017.

Next step: Synthesis across sites

Our database now holds **186 site-years** of data from historic and current drainage practices.



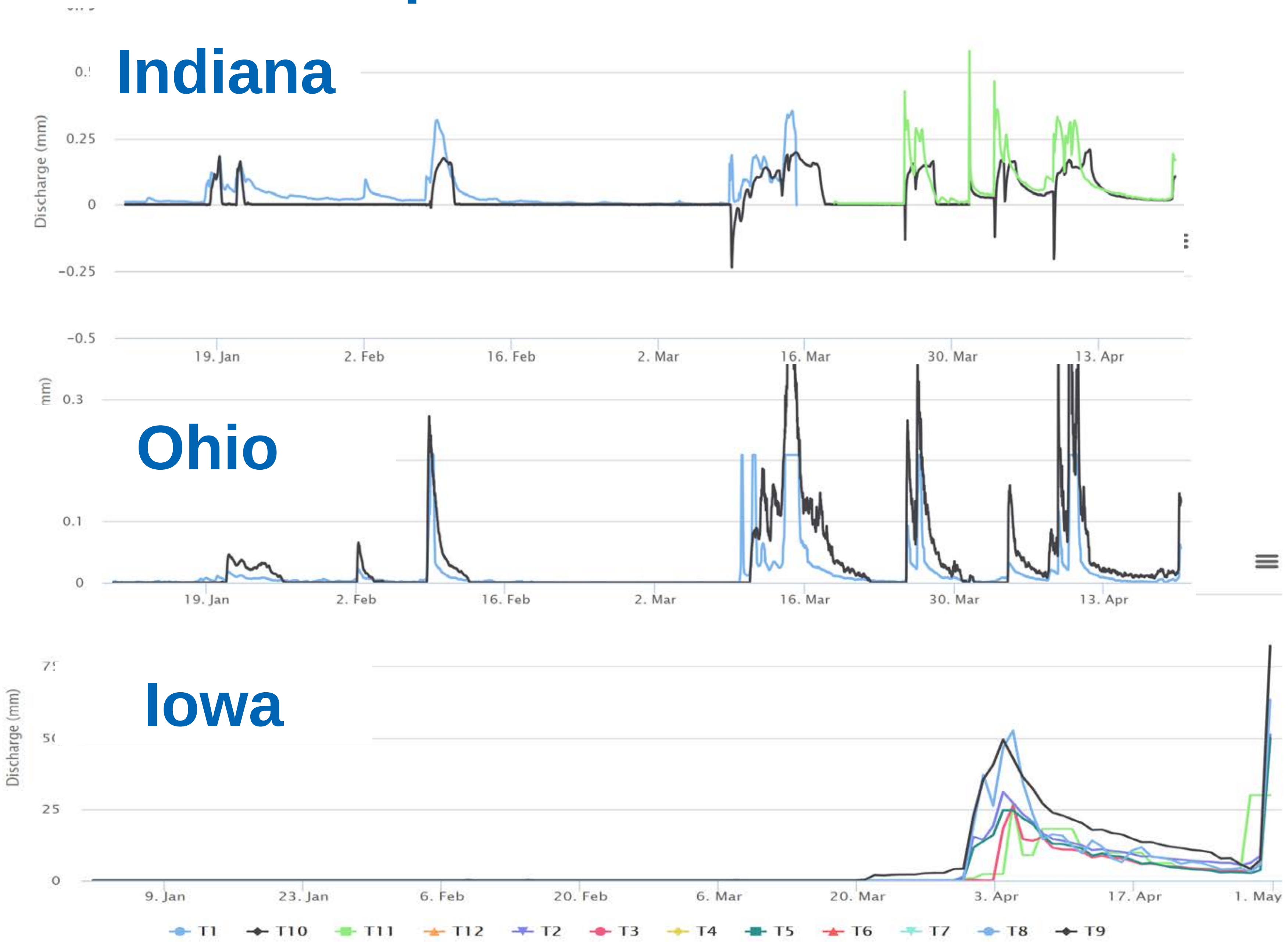




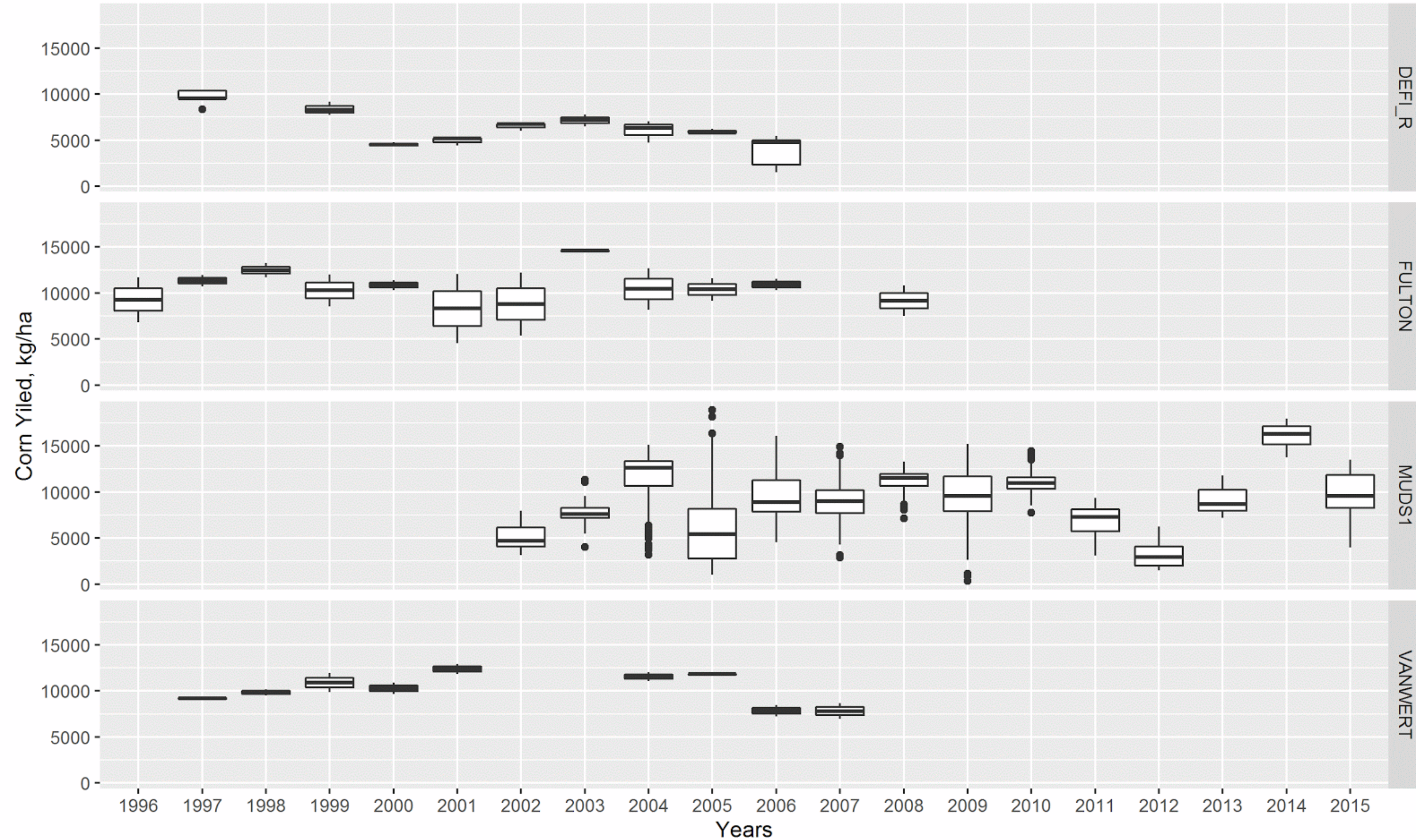
Controlled drainage significant effects:

- **Nitrate**: **Decrease** of 2.3 and 4.0 lbs/acre
- **Soluble Reactive Phosphorus**: **Slight increase** of 0.08 and 0.09 lbs/acre.
- **Total Phosphorus**: **Slight increase** of 0.07 and 0.06 lbs/acre.)

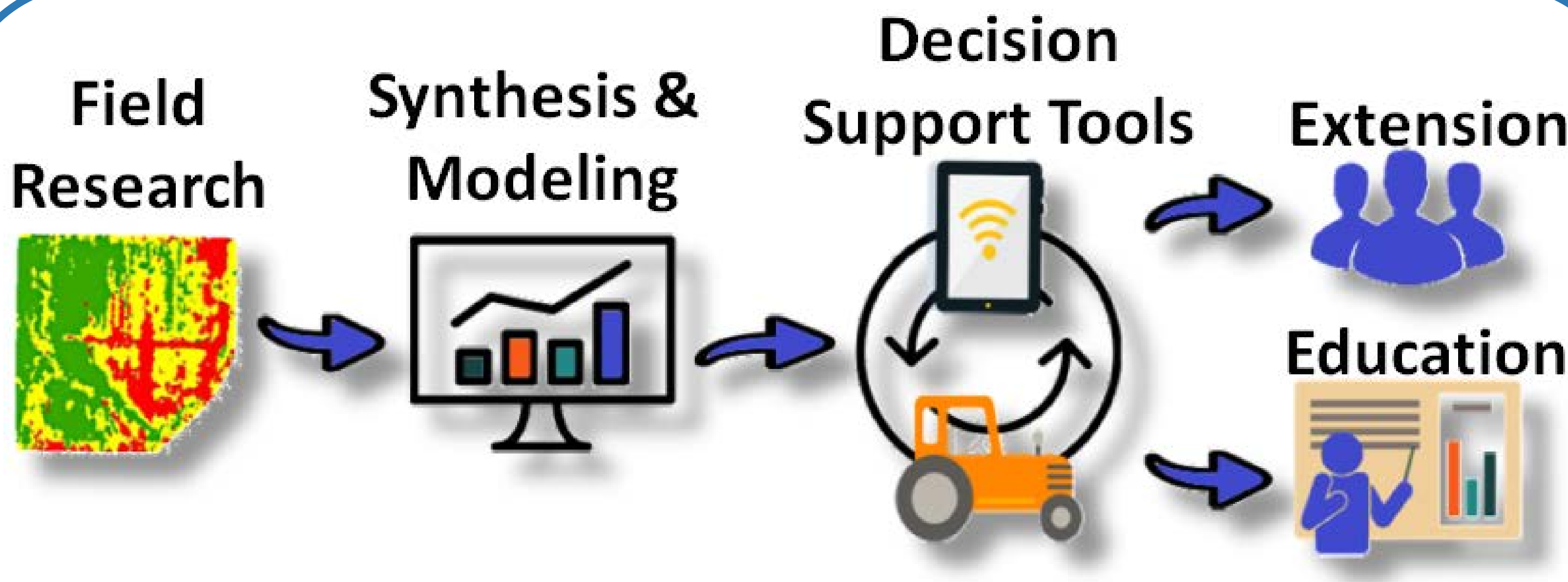
Example: Tile Flow for 3 Sites



Example: Corn Yield Data for 3 Drainage Water Recycling Sites



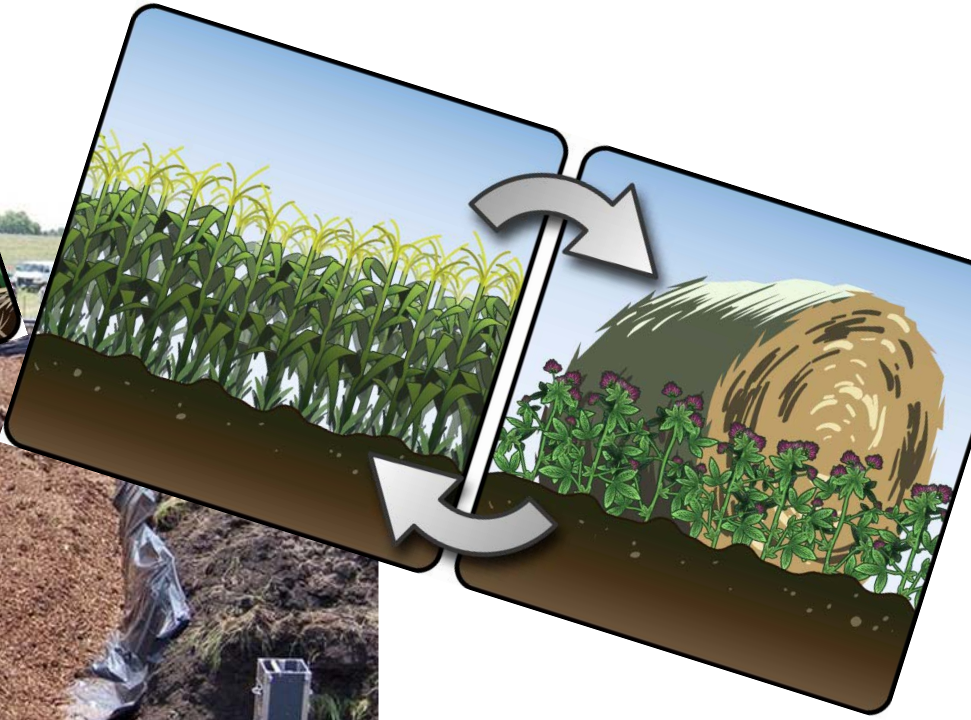
An integrated project to transform drainage



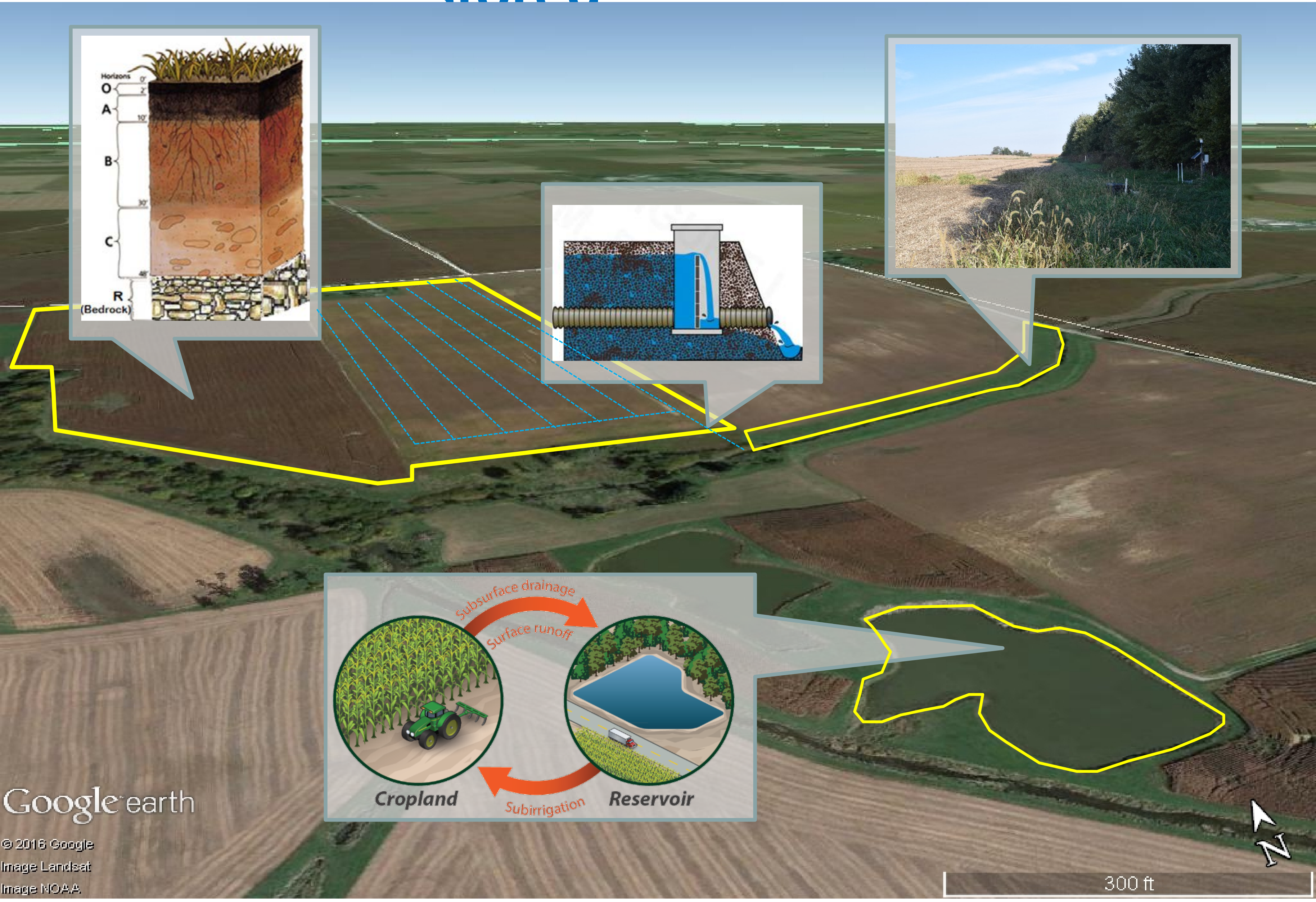
Strengthen and Broaden the Network
(Researchers, Industry, Contractors, Agencies)

Network of diverse stakeholders, should include CCAs

Storing water is not the only way to reduce nitrate losses from drained land.



Drainage water storage can be stored:



New publication:

10 Ways to Reduce Nitrogen Loads from Drained Cropland in the Midwest

10 Ways to Reduce Nitrogen Loads

1. Improved Nitrogen Management
2. Cover Crops
3. Perennials in the Cropping System
4. Drainage Water Management
5. Reduced Drainage Intensity
6. Recycling Drainage Water
7. Bioreactors
8. Wetlands
9. Alternative Open Ditch Design
10. Saturated Buffers

10 Ways to Reduce Nitrogen Loads

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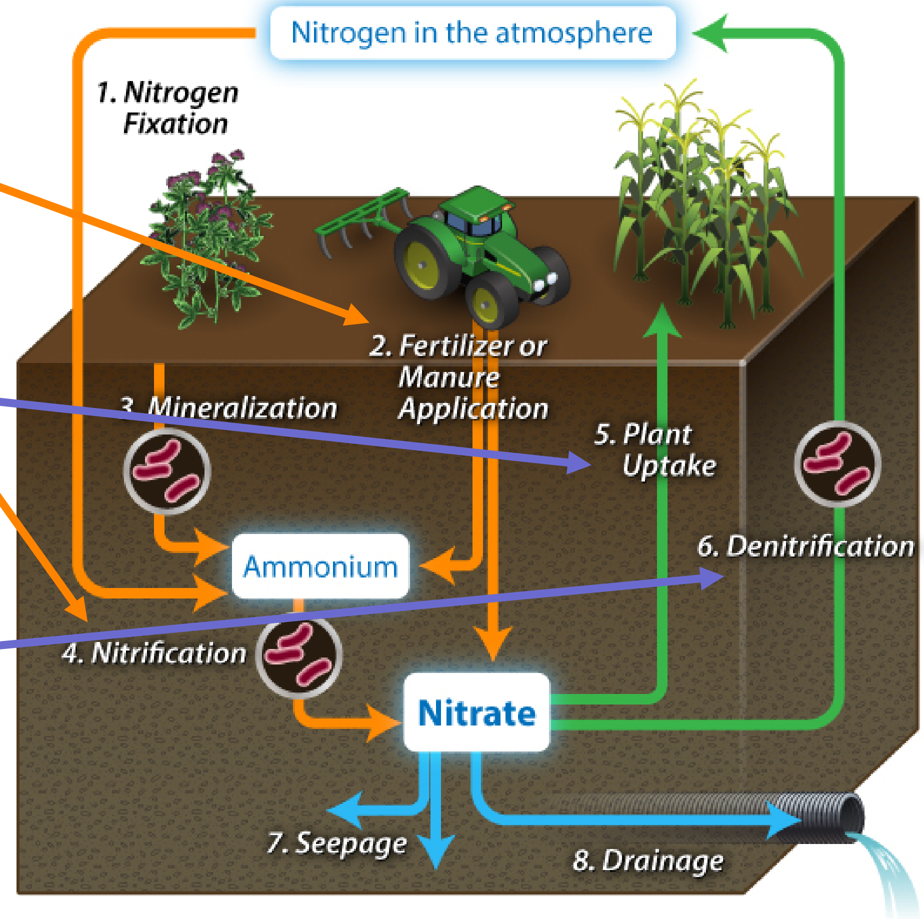
6. Recycling Drainage Water

4 ways practices can improve water quality

reducing the nitrogen source

increasing plant uptake

increasing denitrification



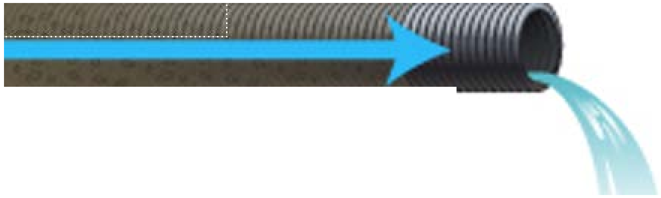
4 ways the practices improve water quality

reducing the nitrogen source

increasing plant uptake

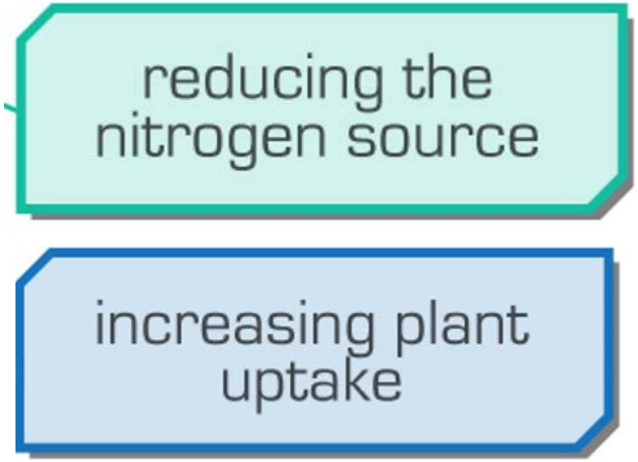
increasing denitrification

reducing the amount of drainage or flow entering the stream



In-field management practice:

1. Improved N management (4Rs)



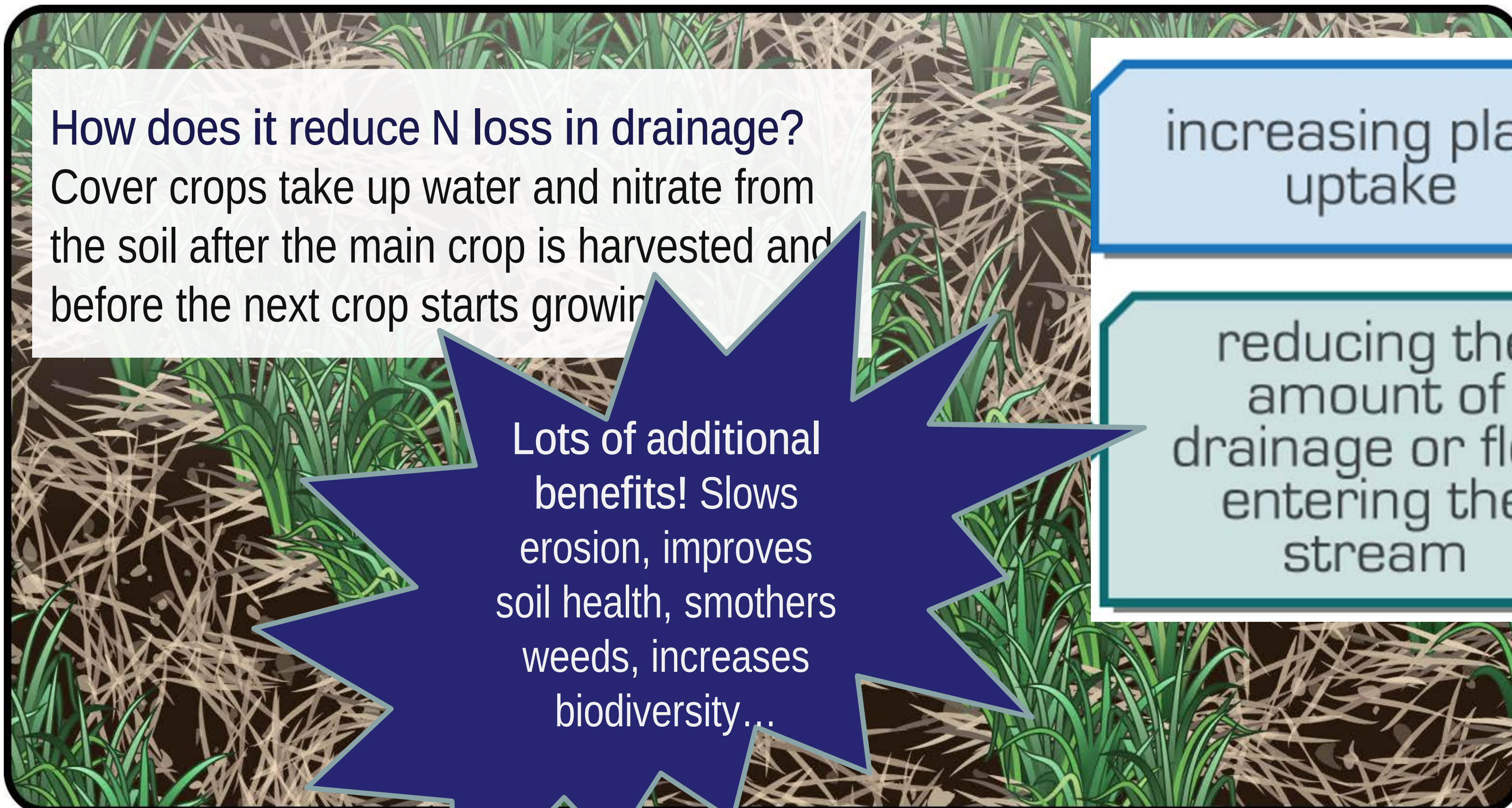
What is it? Applying “the right source of nutrient, at the right rate, at the right time, and in the right place.”

How does it reduce N loss in drainage?

- Reduces the source of N
- May increase plant uptake (timing)

In-field management practice:

2. Winter cover crops



How does it reduce N loss in drainage?

Cover crops take up water and nitrate from the soil after the main crop is harvested and before the next crop starts growin

Lots of additional benefits! Slows erosion, improves soil health, smothers weeds, increases biodiversity…

increasing plant uptake

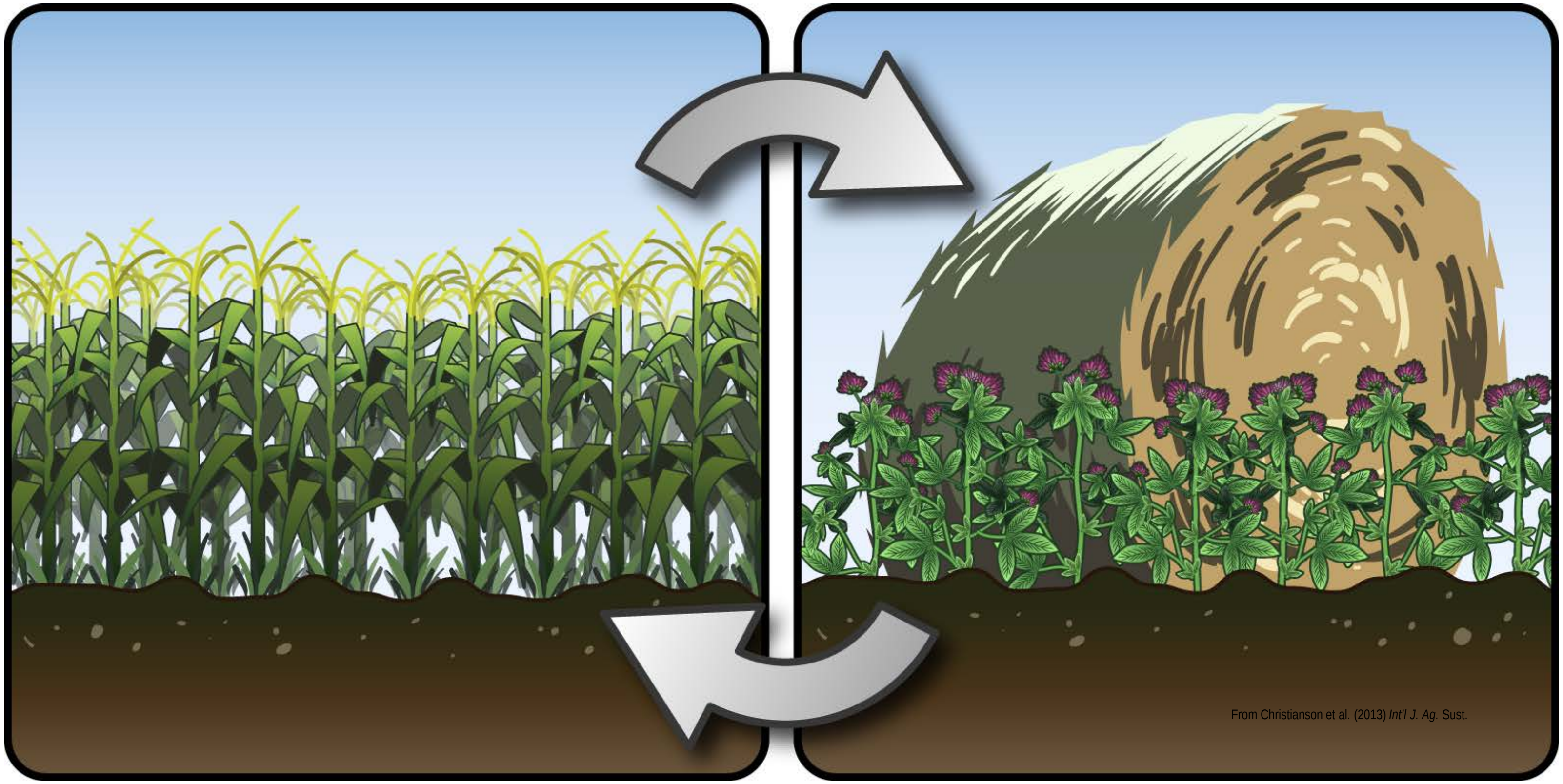
reducing the amount of drainage or flow entering the stream

From Christianson et al. (2013) *Int'l J. Ag.* Sust.

In-field management practice:

3. Perennials in the rotation

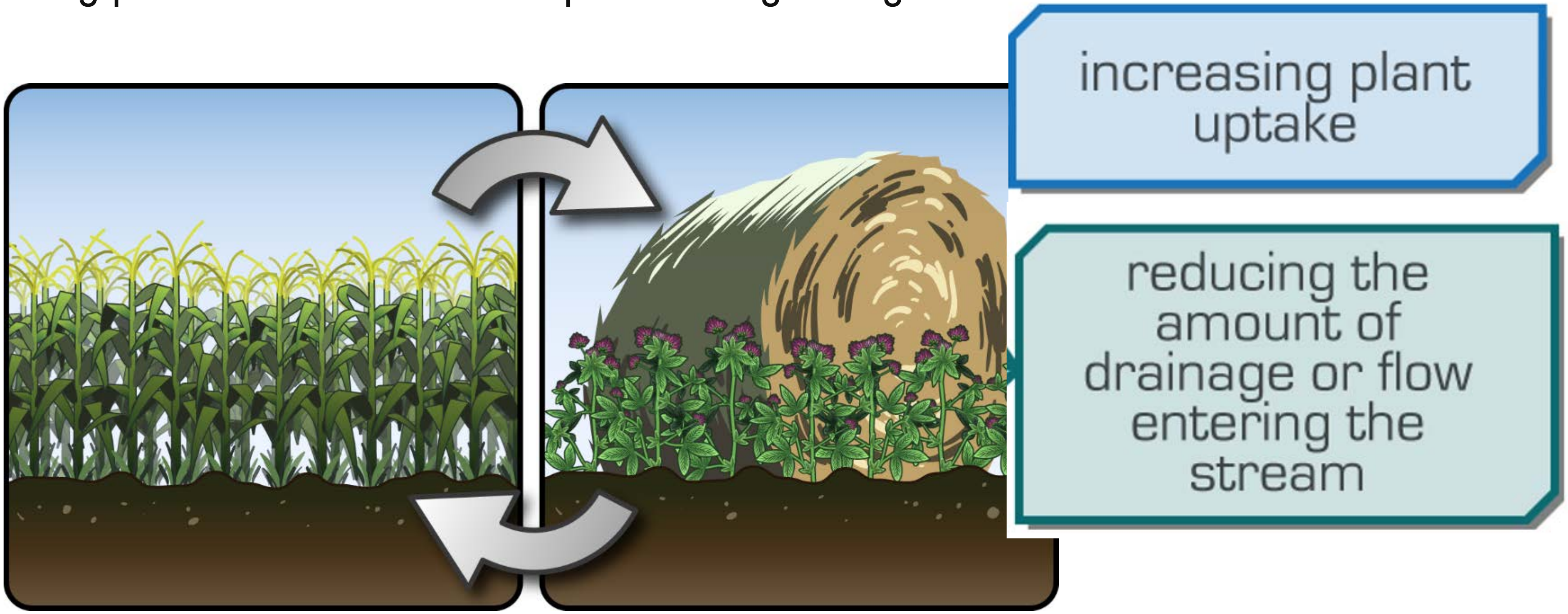
What is it? Inclusion of perennials within an extended rotation or at critical locations within a field



In-field management practice:

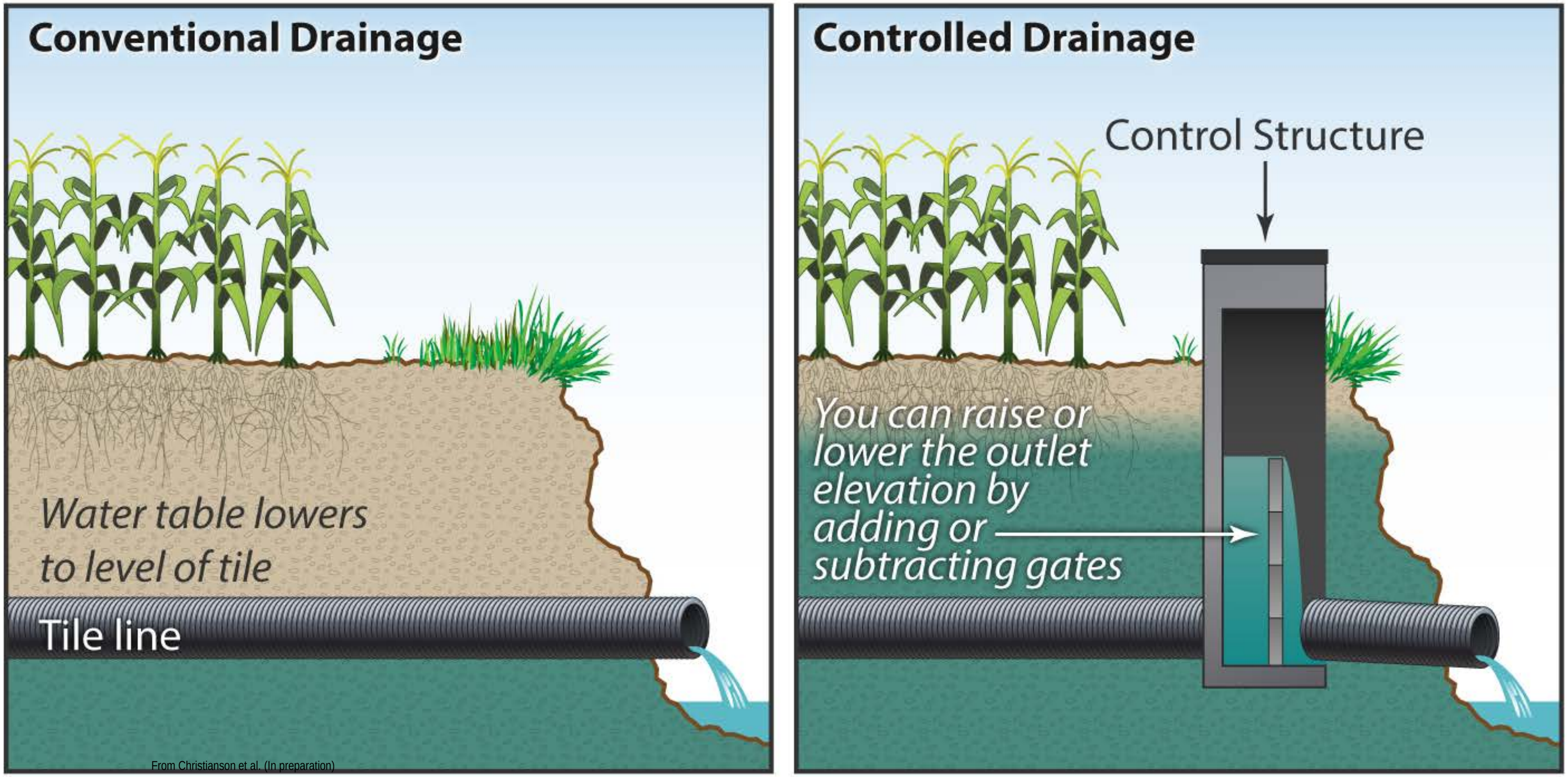
3. Perennials in the rotation

How does it reduce N loss in drainage? Takes up water and nitrate from the soil during periods when annual crops are not growing



In-field Drainage system practice:

4. Drainage water management
(a.k.a. controlled drainage)



From Christianson et al. (In preparation)

In-field Drainage system practice:

Drainage water management

What is it? Adjustable structures

How does it reduce N loss in drainage? Holds back water and nitrate in the water

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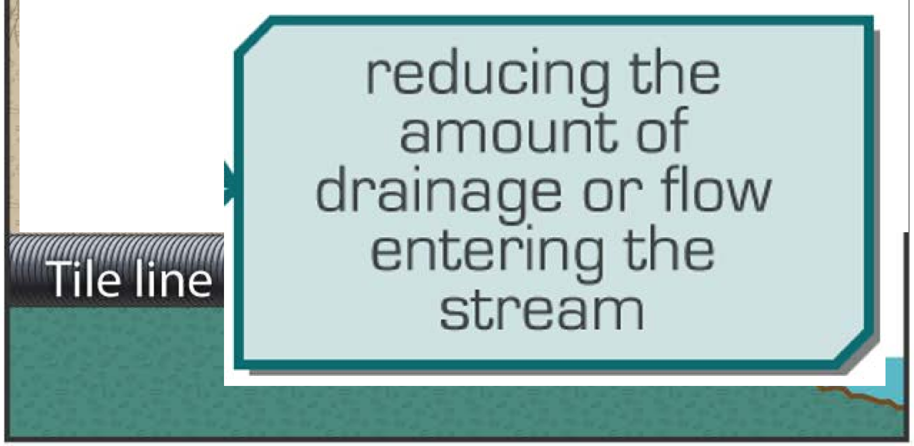
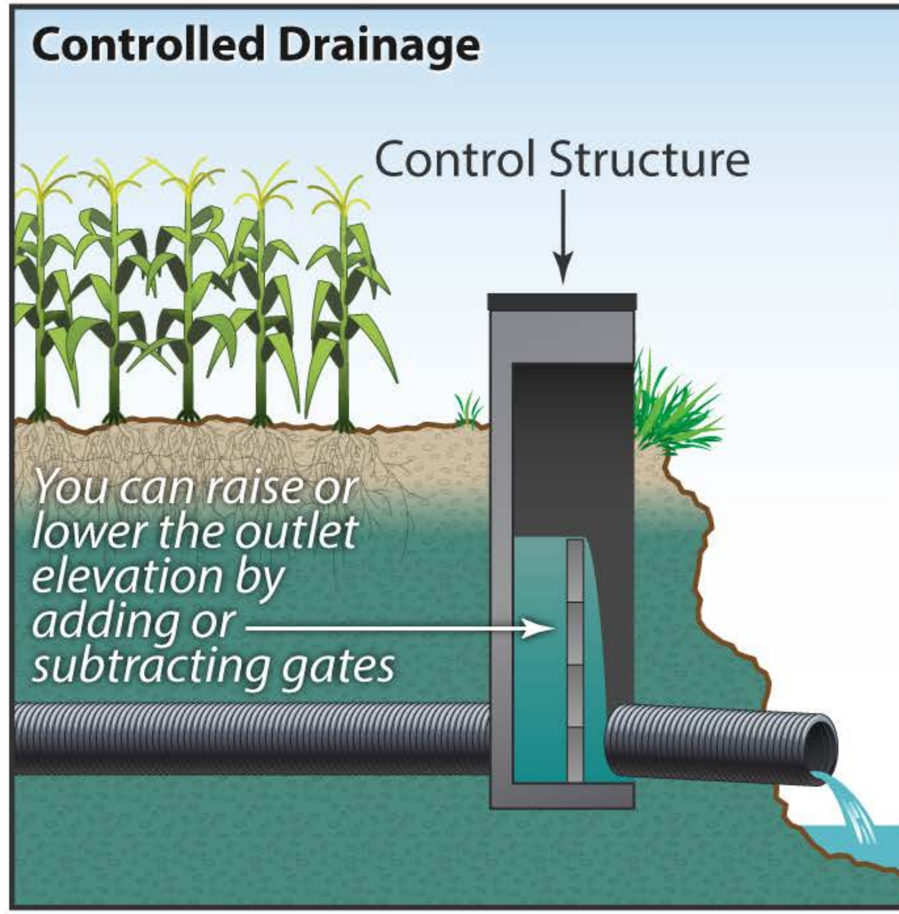
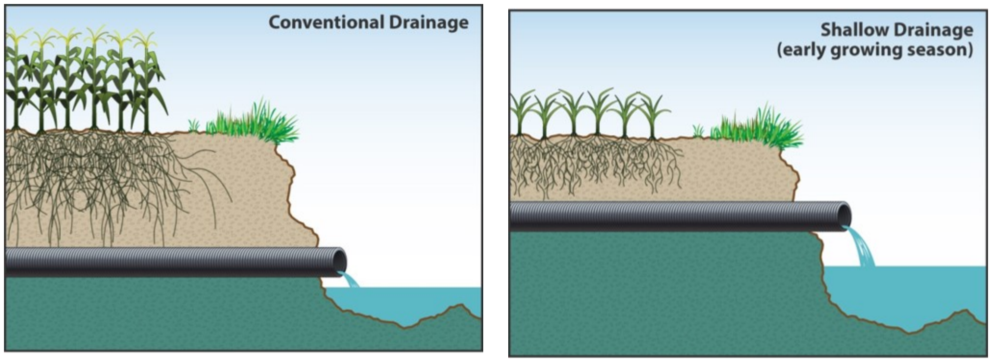
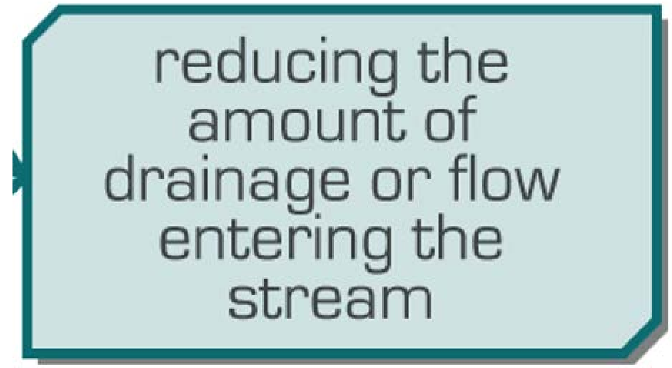




In-field Drainage system practice:

5. Reduced drainage intensity





What is it? Installation of subsurface drains either closer to the surface or with wider spacing than conventional

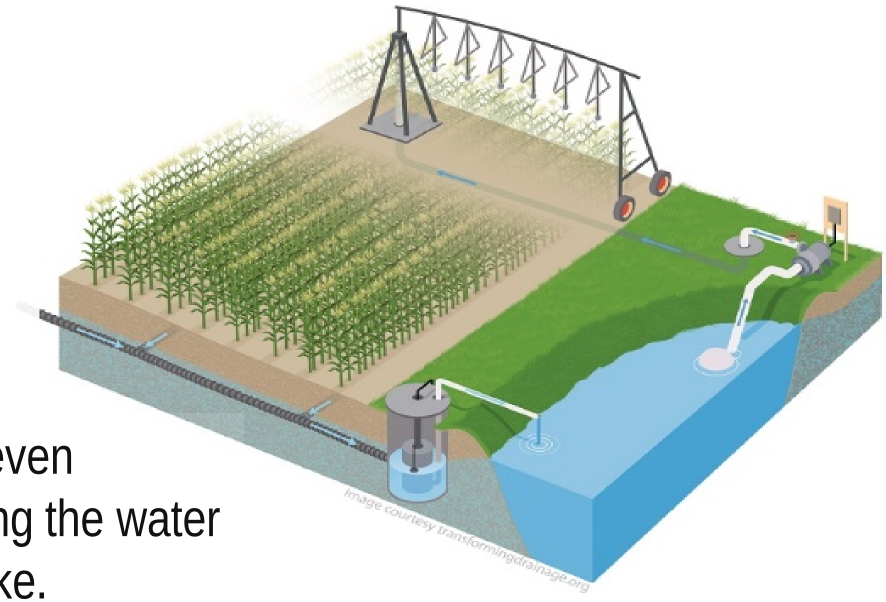
How does it reduce N loss in drainage?
Less water leaves the field as drainage, thus less N leaves the field.

Source: Luo et al., 2010

From Christianson et al. (In preparation)

In-field Drainage system practice:

6. Recycling drainage water



What is it? Drainage water is stored in a pond or reservoir and then returned it to the soil through irrigation during dry periods.

How does it reduce N loss in drainage?
Recycling the drainage water can reduce or even eliminate nitrate loss by reducing or eliminating the water that leaves the site and increasing plant uptake.

increasing plant uptake

reducing the amount of drainage or flow entering the stream

Edge-of-field or off-site practice:

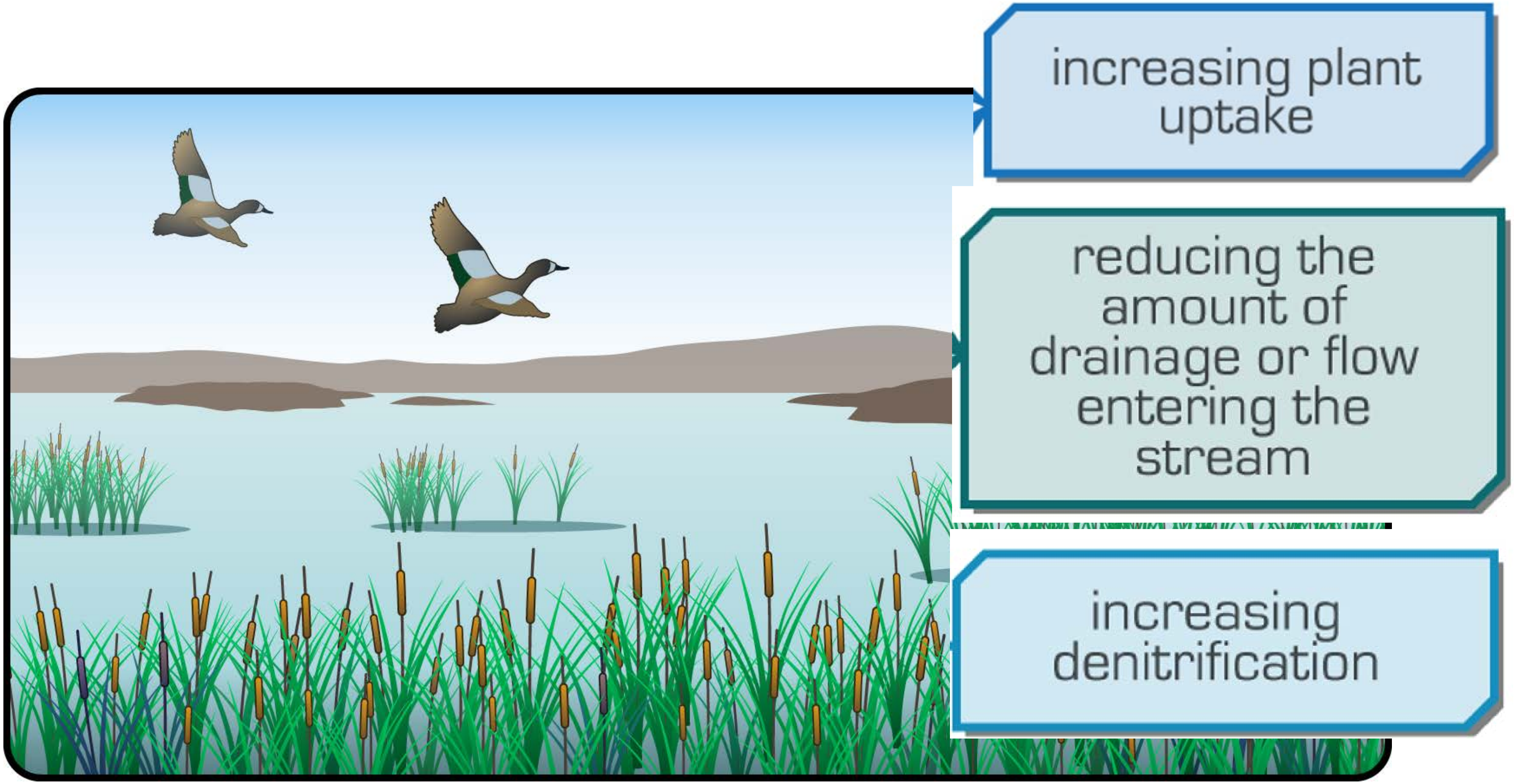
7. Woodchip bioreactors

How does it reduce N loss in drainage? Additional carbon "super-powers" the natural process of denitrification

increasing denitrification

Edge-of-field or off-site practice:

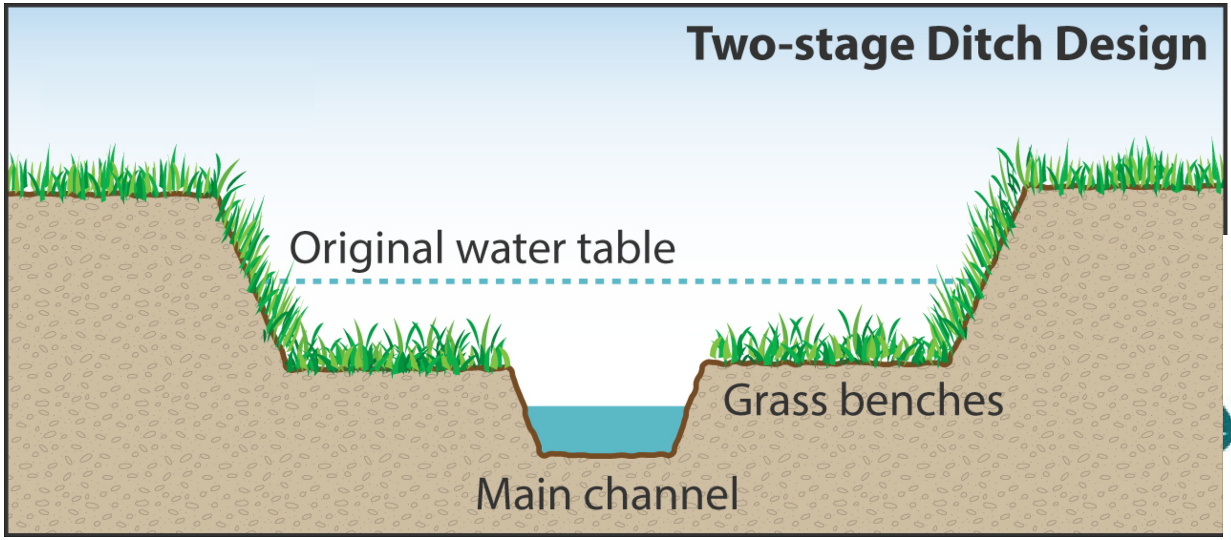
8. Wetlands



From Christianson et al. (2013) *Int'l J. Ag.* Sust.

Edge-of-field or off-site practice:

9. Alternative ditch design (Two-stage)



increasing plant uptake

reducing the amount of drainage or flow entering the stream

increasing denitrification

From Christianson et al. (In preparation)

Edge-of-field or off-site practice:

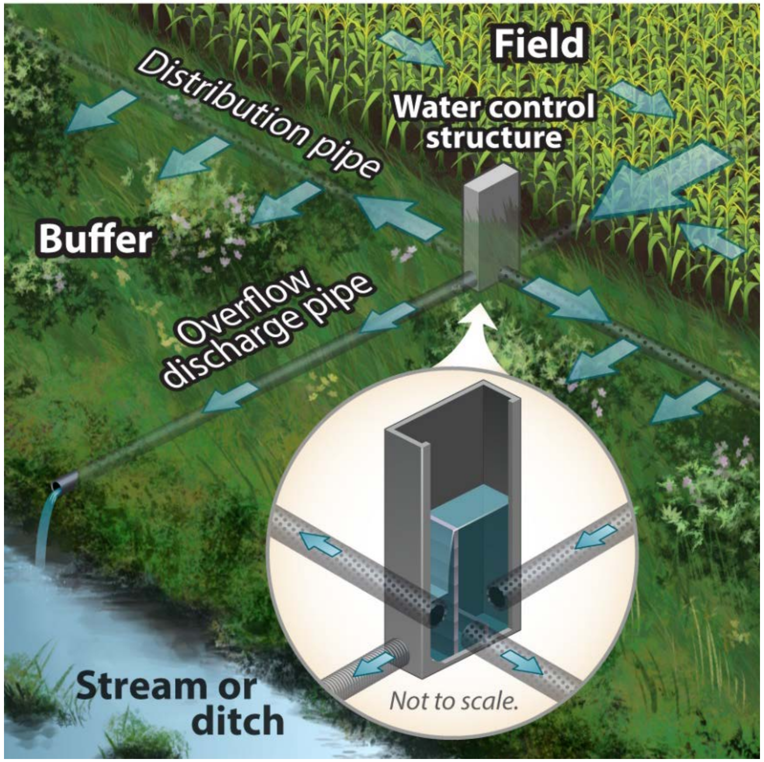
10. Saturated buffers

Wh ... edge-
of-f ... ws
dr
gr ... soil

H
dr ... h the
bu ... lants
up
re

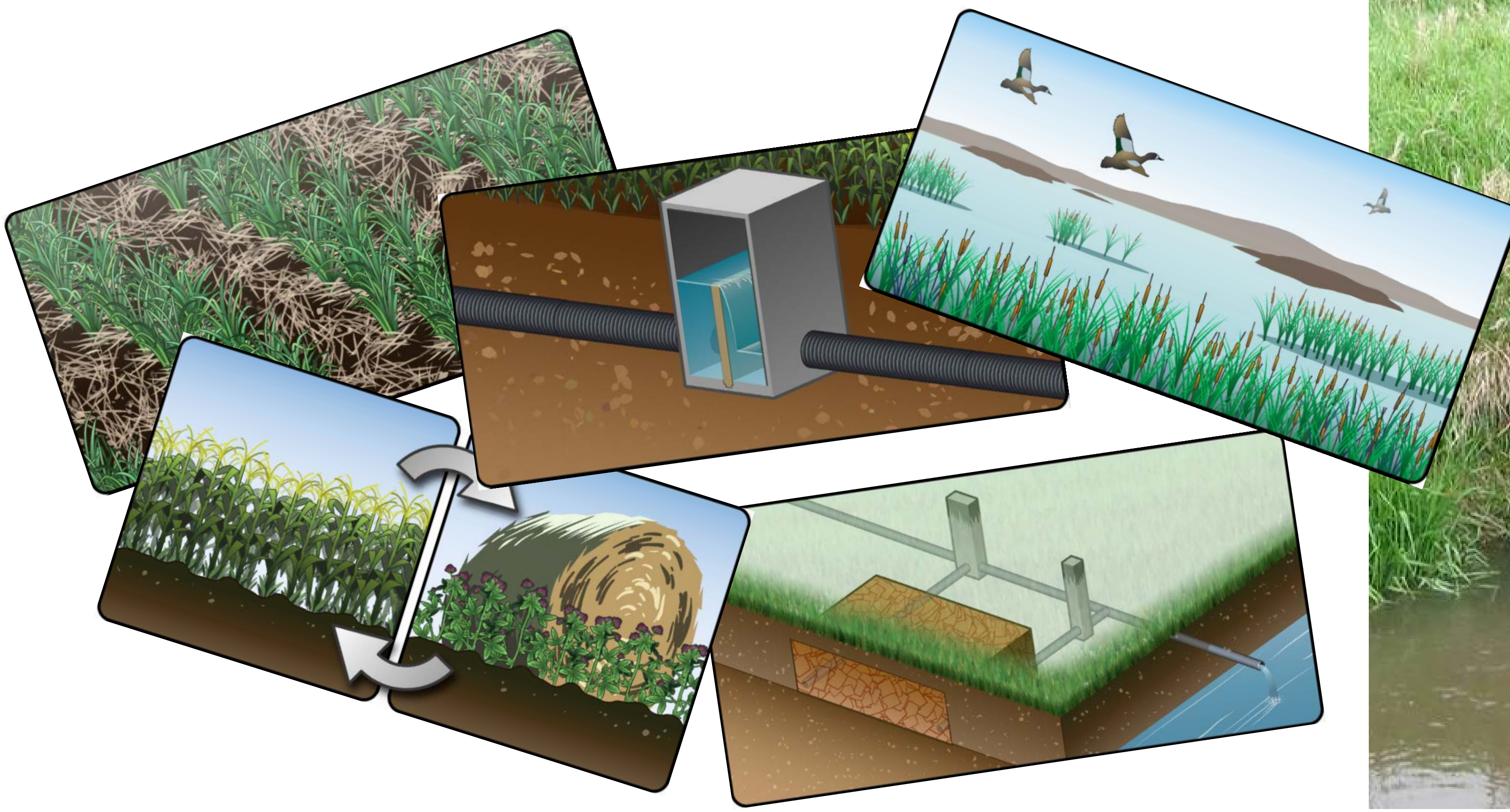
- increasing plant uptake
- reducing the amount of drainage or flow entering the stream
- increasing denitrification

Outlet with Saturated Buffer



From Christianson et al. (In preparation)

Annual crops like corn and soybeans are “leaky systems”; Drainage doesn’t cause this, but processes that could help are bypassed by drainage.



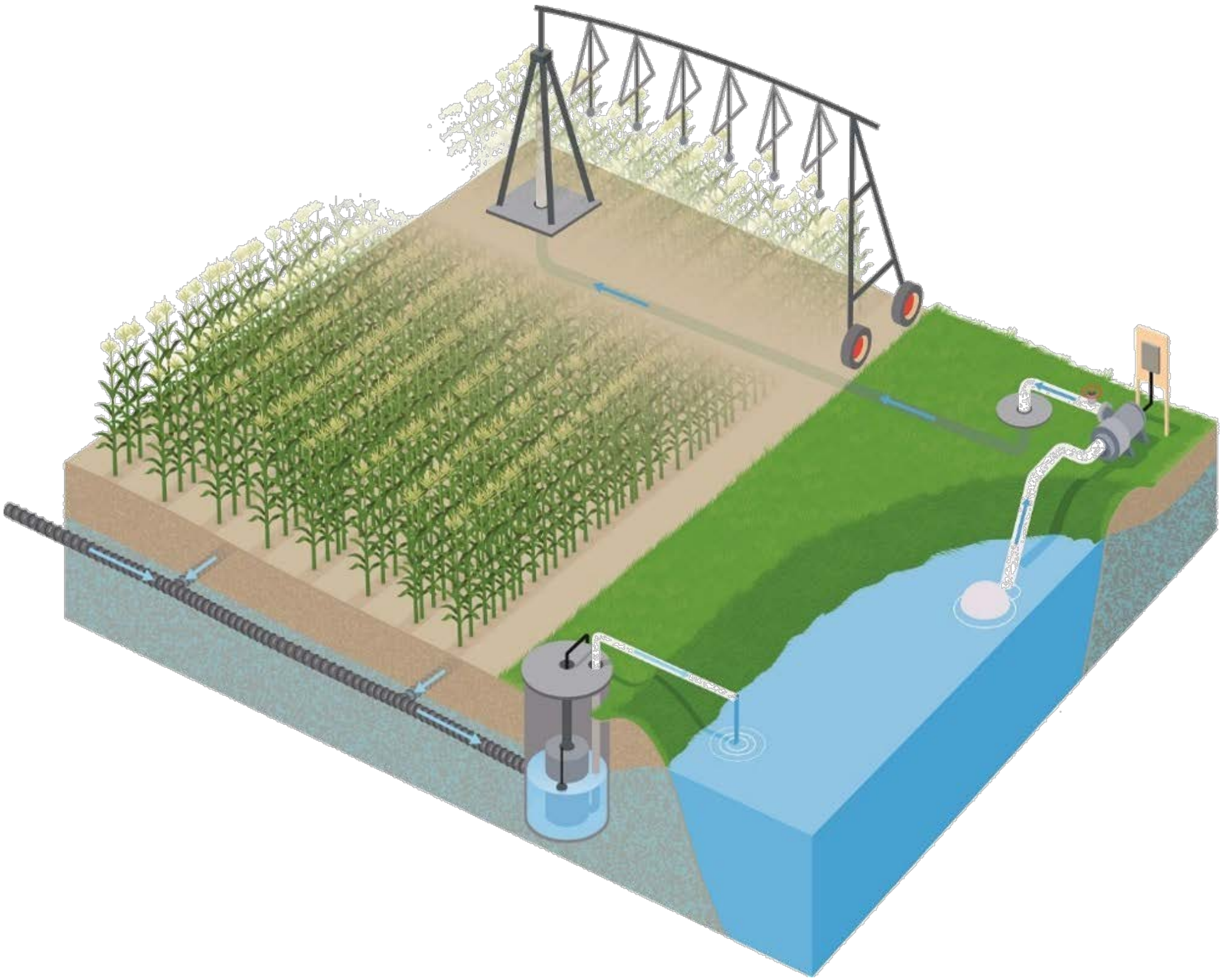
Ten Ways – Choose One

Ten Ways – Choose One

A reasonable goal: No one practice will be suitable on every acre, but every acre needs at least one practice.

For more information or to obtain the publication:
http://go.aces.illinois.edu/TenWays

Drainage water recycling

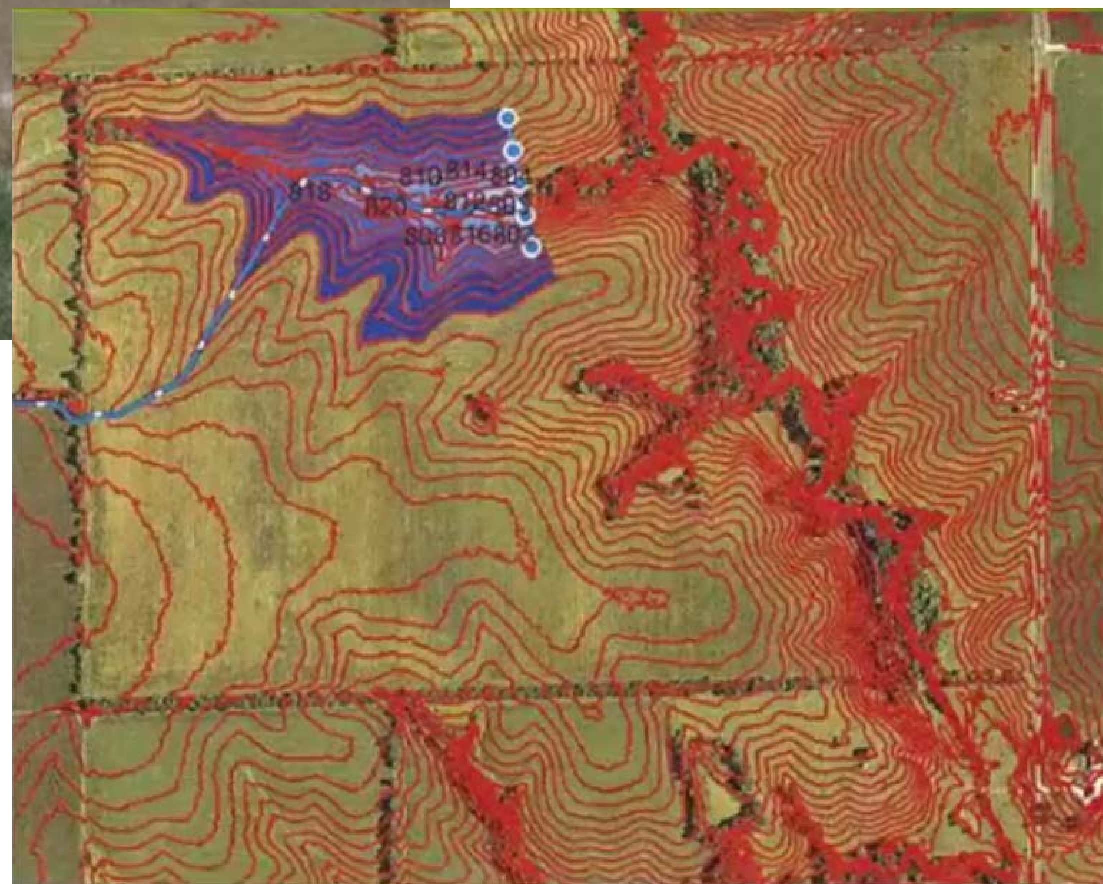


Drainage water recycling ponds likely need to be both large and deep to be economical

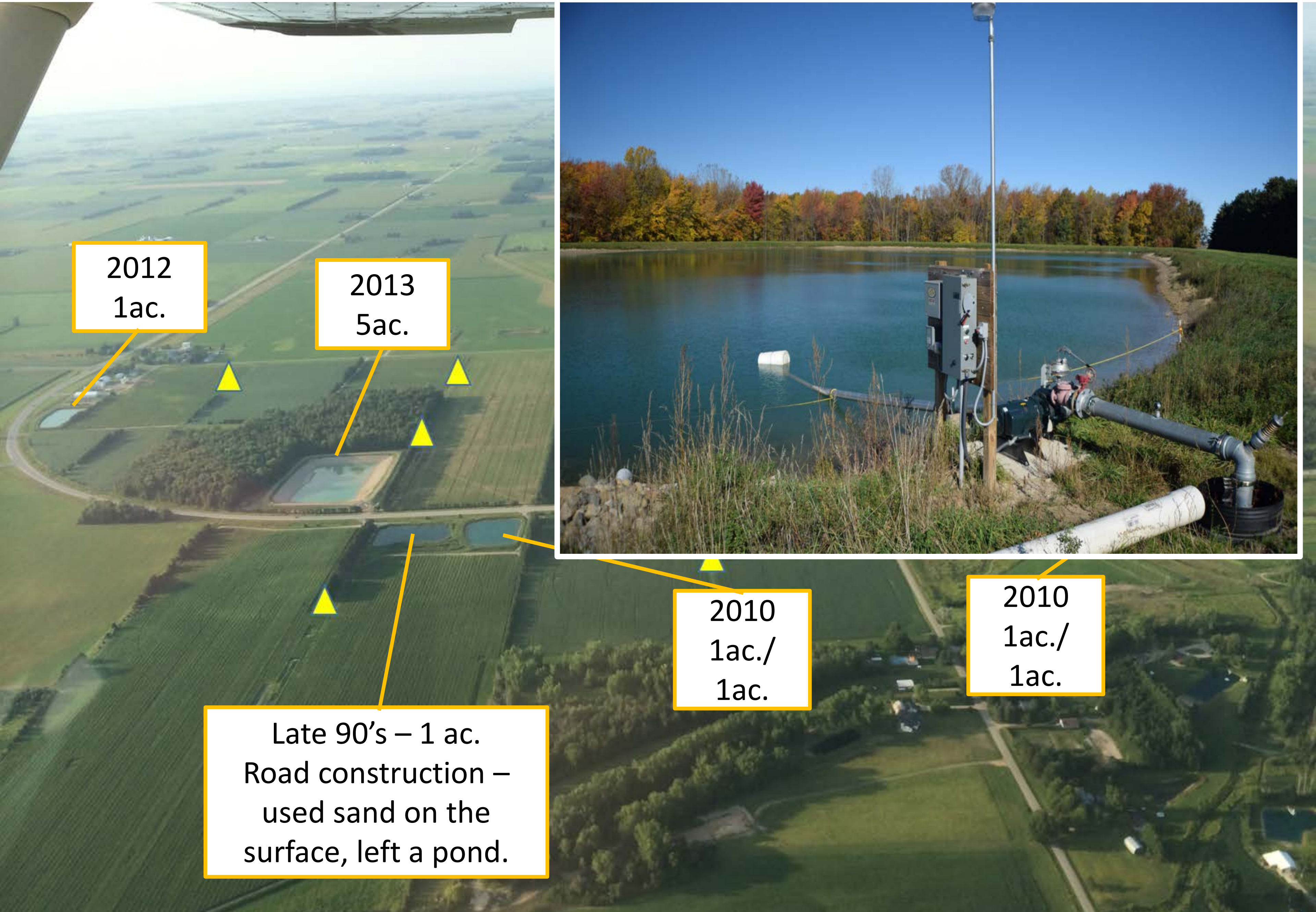
How big does the pond need to be?

- Depth of drainage: Example 3-13 inches (SEPAC)
- Depth of irrigation needed: 3-12 inches
  - More research needed on benefits of "deficit irrigation"
- For 80 acre field, Store 6 inches = 40 acre-feet
- Pond depth: 10 ft → Pond area 4+ acres

Embankment pond

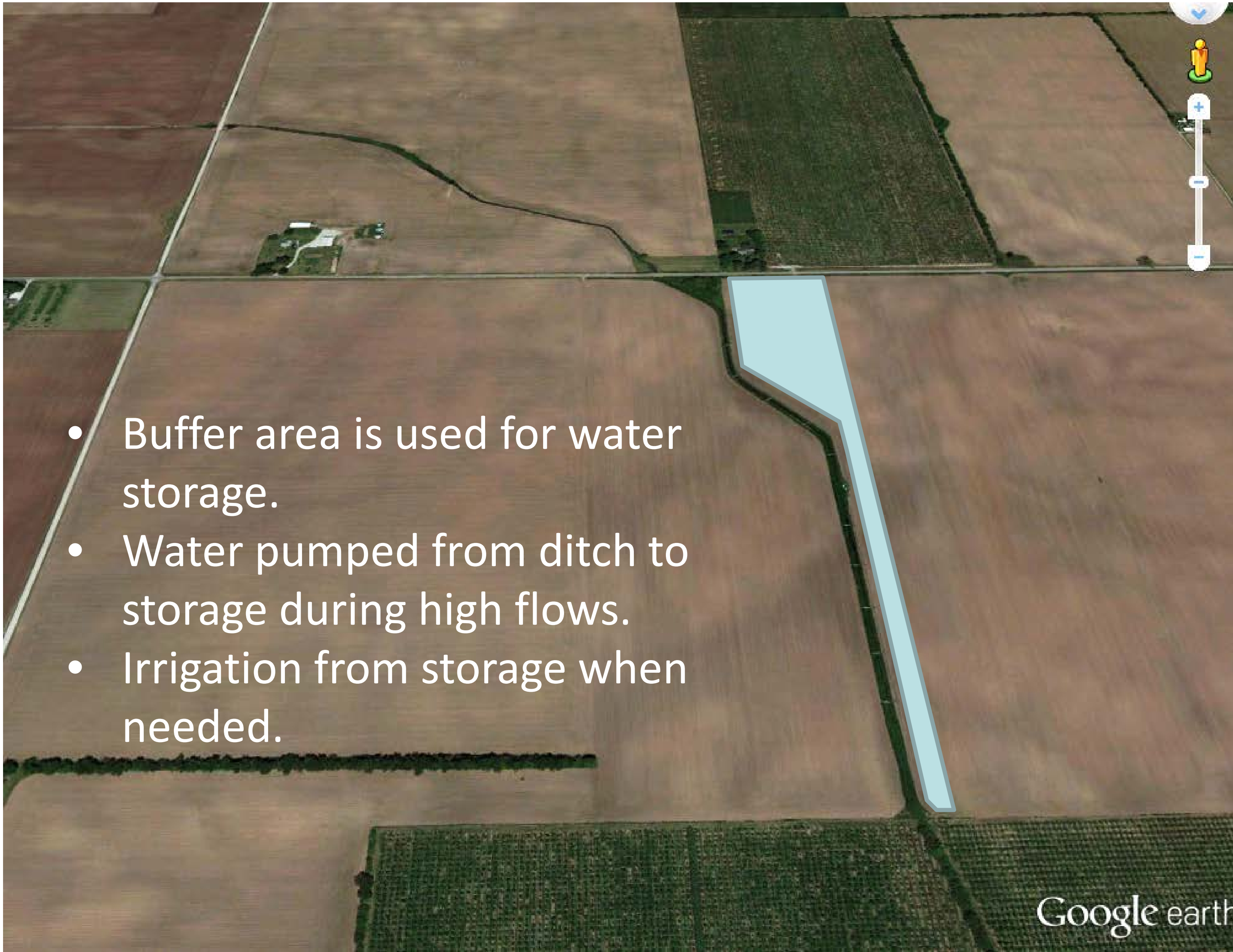


Drainage water recycling ponds on flat land in MI



Channel storage potential

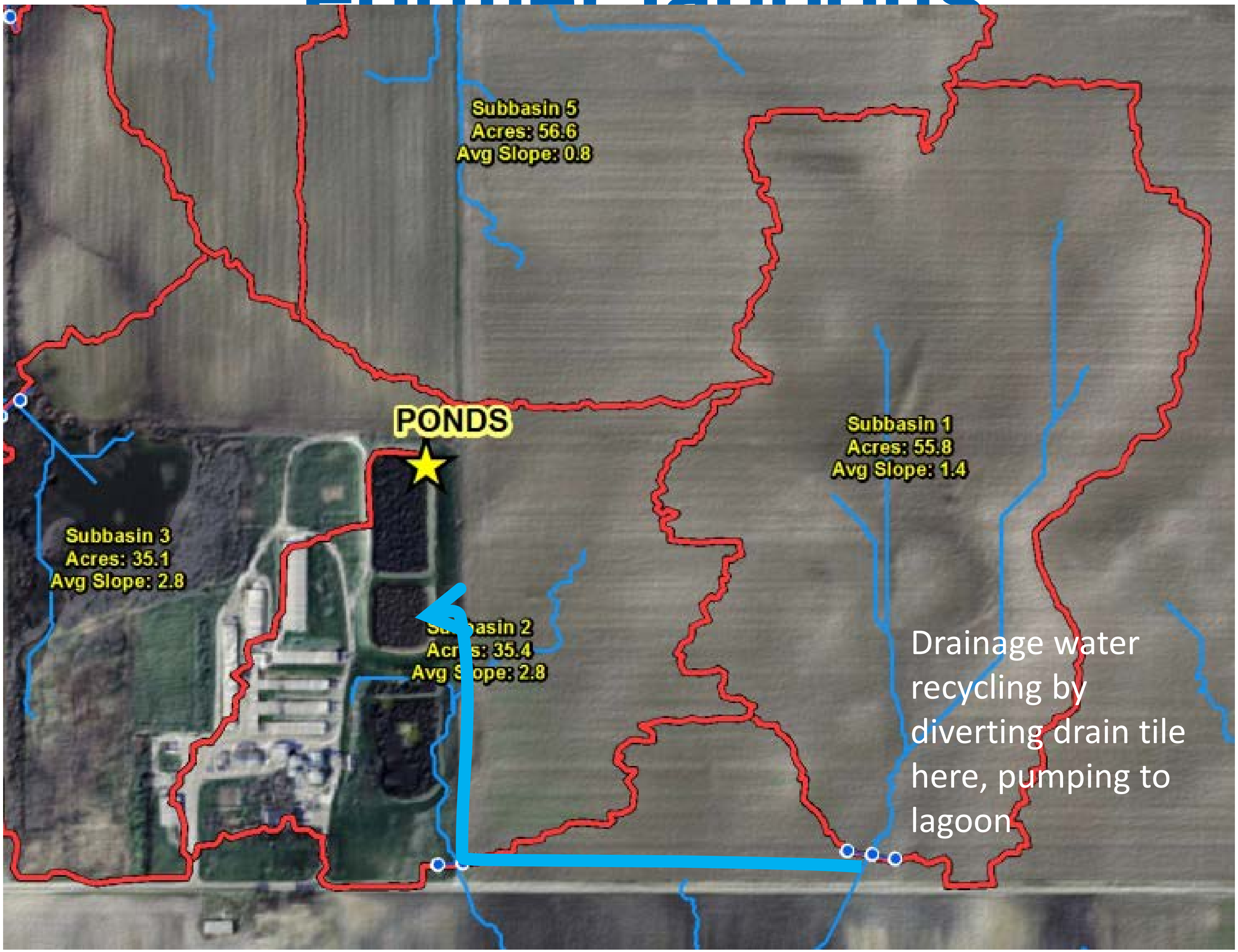
Long pond



- Buffer area is used for water storage.
- Water pumped from ditch to storage during high flows.
- Irrigation from storage when needed.

Former lagoons

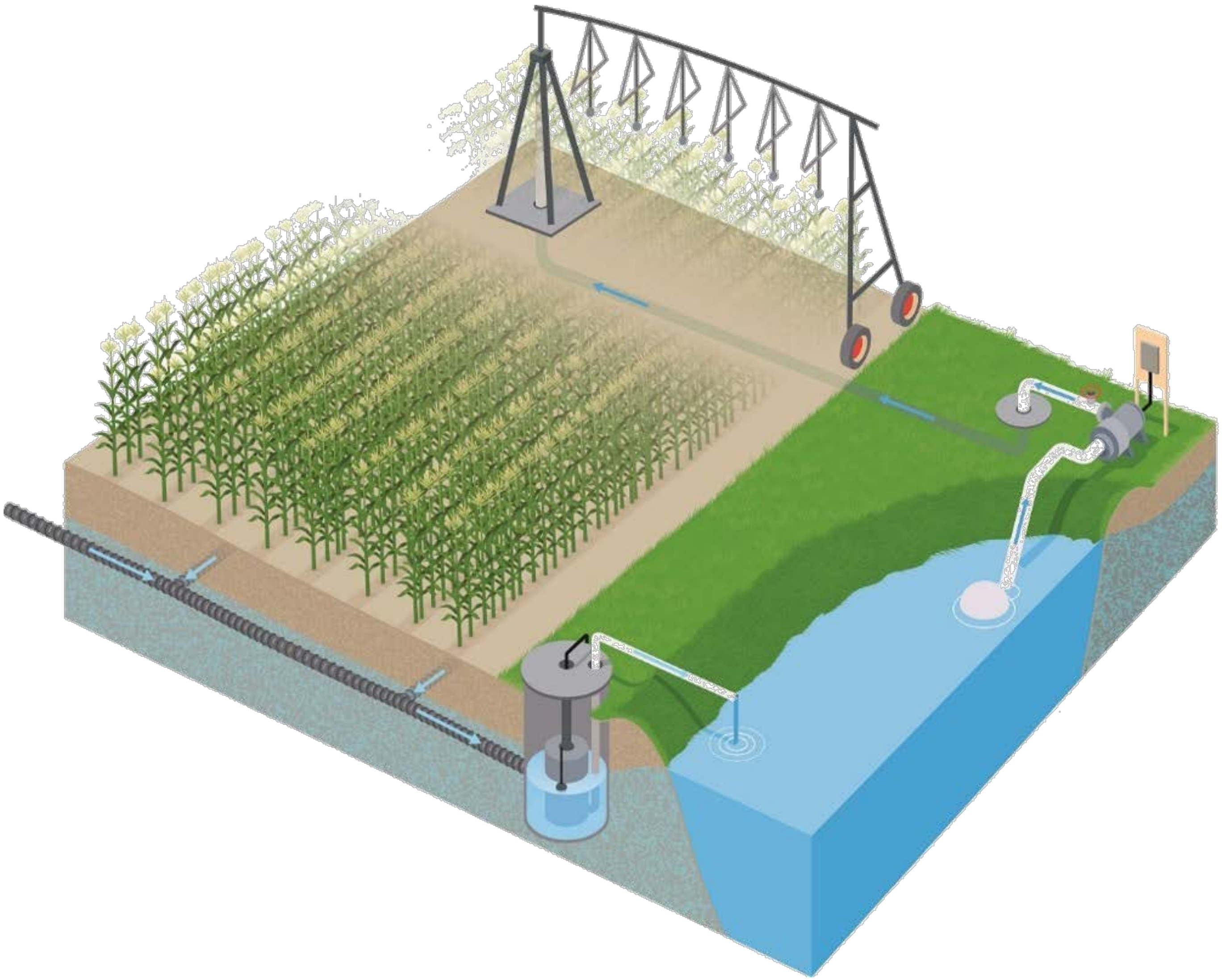
Former lagoons



Low yielding spots in the field

Drainage water recycling

How can you fit it in YOUR landscape?



Transforming Drainage

Long-term vision:

The process of designing and implementing agricultural drainage will be **transformed** to include practices that store water and reduce nutrient losses.

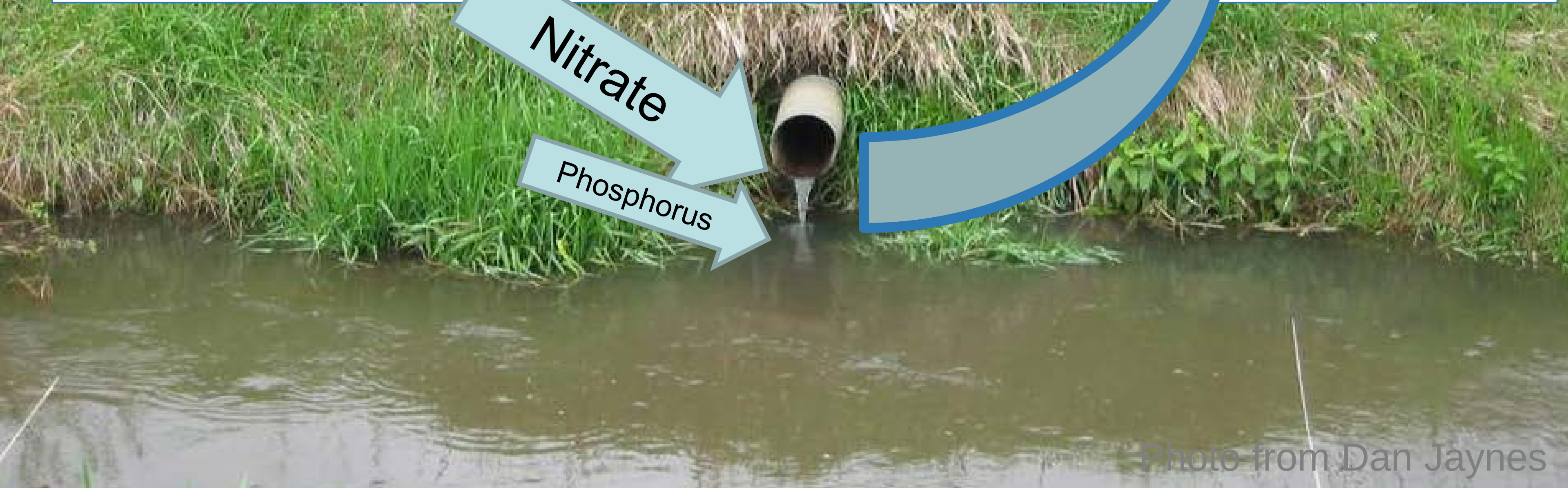


Photo from Dan Jaynes