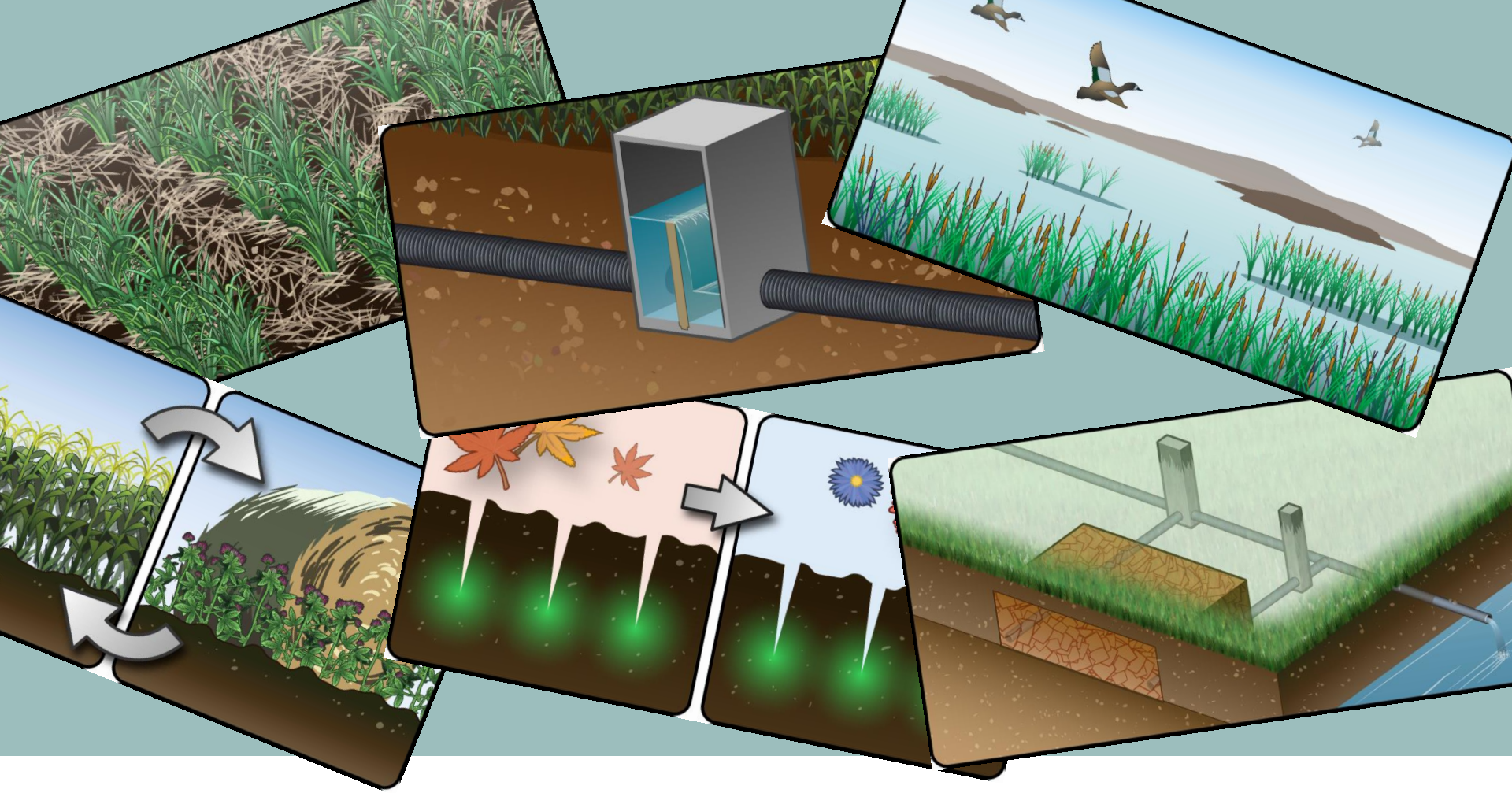

CHOOSE YOUR OWN ADVENTURE:
TEN WAYS TO REDUCE NITRATE IN DRAINAGE

Dr. Laura Christianson
University of Illinois at
Urbana-Champaign

ARTIFICIAL DRAINAGE IS INTEGRAL TO CROP PRODUCTIVITY.

The Midwest has a long history of drainage because it improves crop growth and trafficability.

http://www.nejohnston.org/wej/120%20Years%20of%20Johnston%20Farming/120%20years%20of%20Johnston%20Farming.html; http://mrbdc.mnsu.edu/sites/mrbdc.mnsu.edu/files/public/major/midminn/subshed/sevenmi/vtour/images/trench_crew_l.jpg

ARTIFICIAL DRAINAGE IS INTEGRAL TO CROP PRODUCTIVITY.

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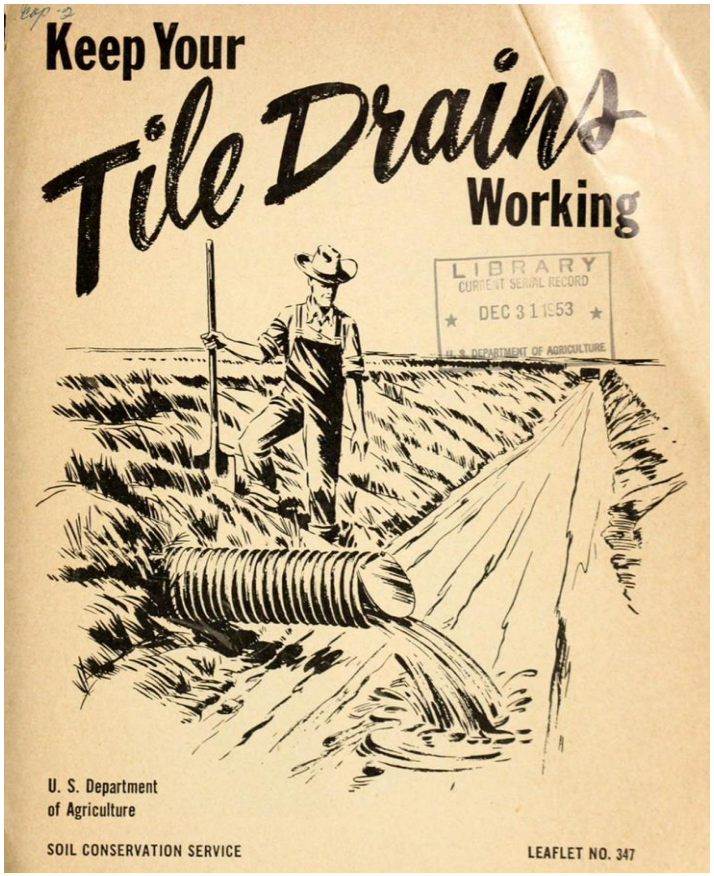
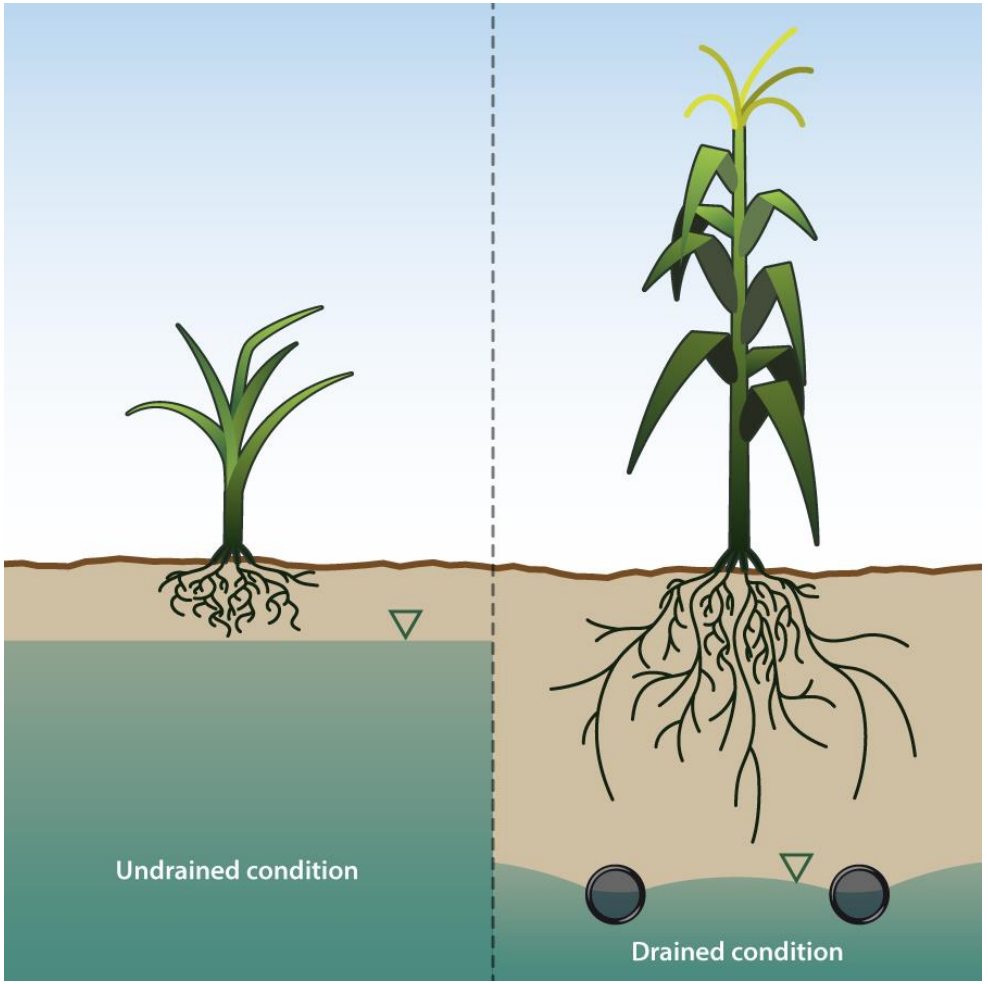


ARTIFICIAL DRAINAGE IS INTEGRAL TO NEW CHALLENGES.

The Midwest has a long history of drainage because it improves crop growth and trafficability.

Tile drainage changes the natural hydrology and is a pathway for nutrients to move from our fields.



Not to scale

DRAINAGE NITRATE LOAD = NITRATE CONCENTRATION X VOLUME OF WATER

$$\textbf{Pounds of nitrate leaving field} \text{ (every year)} = \frac{\textbf{milligrams of nitrate}}{\textbf{per liter}} \text{ (sampled over time)} \times \textbf{drainage water volume} \text{ (from the whole year)}$$

(PLUS UNIT CONVERSIONS)

Mass load:

- Amount of a chemical discharged during a defined period of time
- Comparison with agronomic practices
- Iowa Nutrient Reduction Strategy

IOWA NUTRIENT REDUCTION STRATEGY

A science and technology-based framework to assess and reduce nutrients to Iowa waters and the Gulf of Mexico

Prepared by:
Iowa Department of Agriculture and Land Stewardship
Iowa Department of Natural Resources
Iowa State University College of Agriculture and Life Sciences

Updated September 2014

Adapted from Iowa Nutrient Reduction Strategy

DRAINAGE NITRATE LOAD =
NITRATE CONCENTRATION X VOLUME OF WATER

$$\textbf{Pounds of nitrate leaving field}_{\text{every year}} = \frac{\textbf{milligrams of nitrate}}{\textbf{per liter}}_{\text{sampled over time}} \times \textbf{drainage water volume}_{\text{from the whole year}}$$

(PLUS UNIT CONVERSIONS)

Mass load:

- Amount of a chemical discharged during a defined period of time

Concentration:

- Amount of a chemical in a defined volume of water
- Something we can measure in the lab
- Important for numeric criteria (drinking water standard) and toxicity (acute, chronic)

1 grain of sand (1 mg)
+
1 liter bottle
=
one milligram of sand per liter

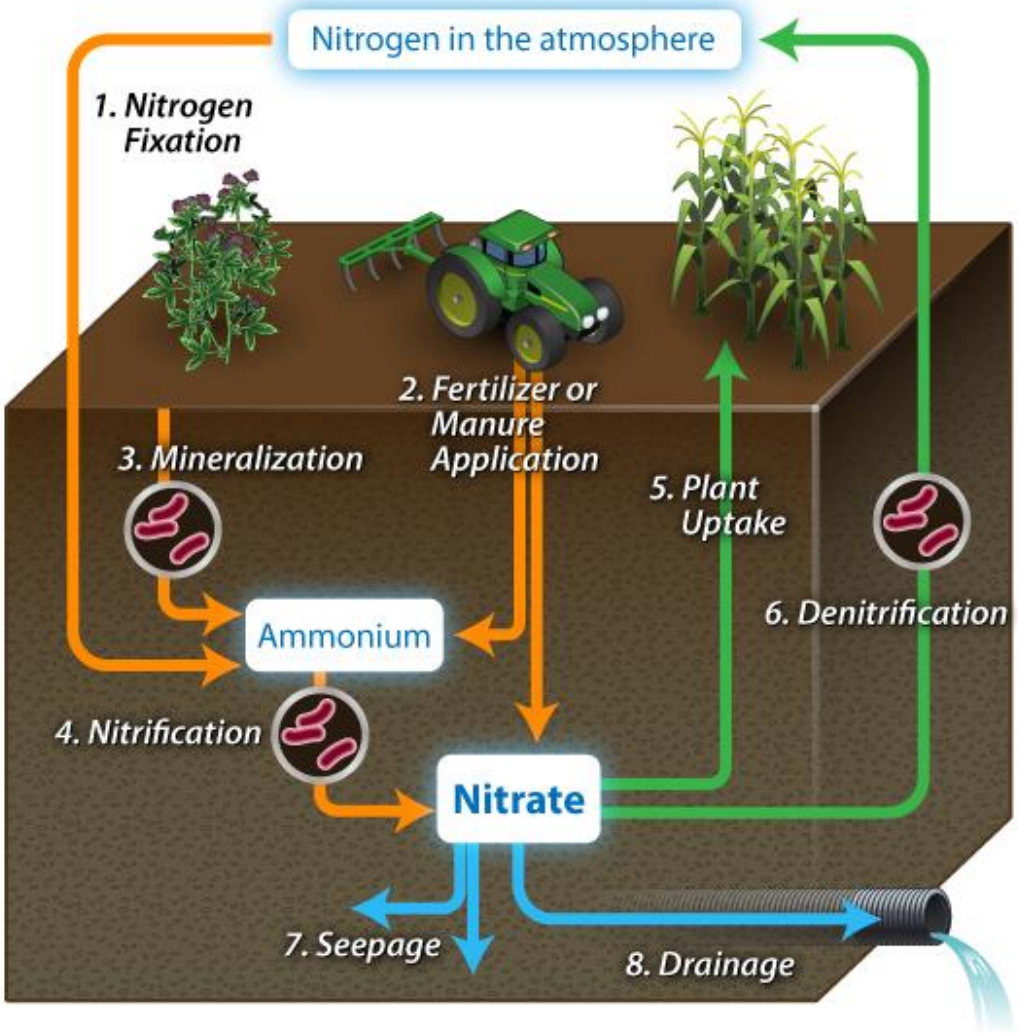
THE NITROGEN CYCLE

Processes that impact the concentration of nitrate in the soil (and in drainage)

Processes that increase nitrate

Outputs to plants and air

Outputs to water



From Christianson et al. (In preparation)

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(PLUS UNIT CONVERSIONS)

Mass load:

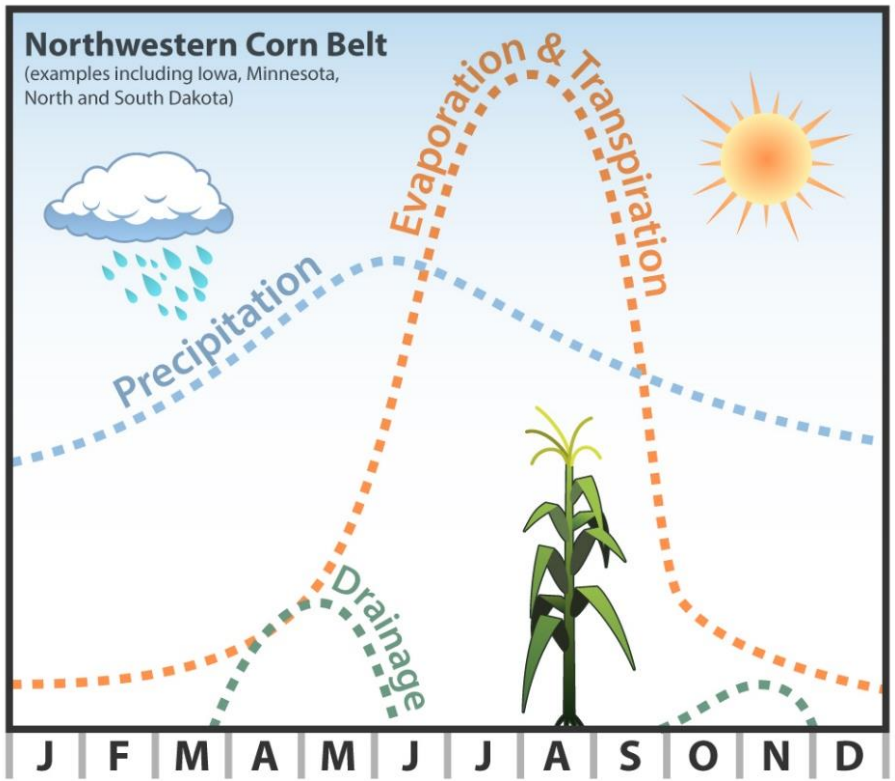
- Amount of a chemical discharged during a defined period of time

Concentration:

- Amount of a chemical in a defined volume of water

Flow:

- volume or rate (aka, discharge)



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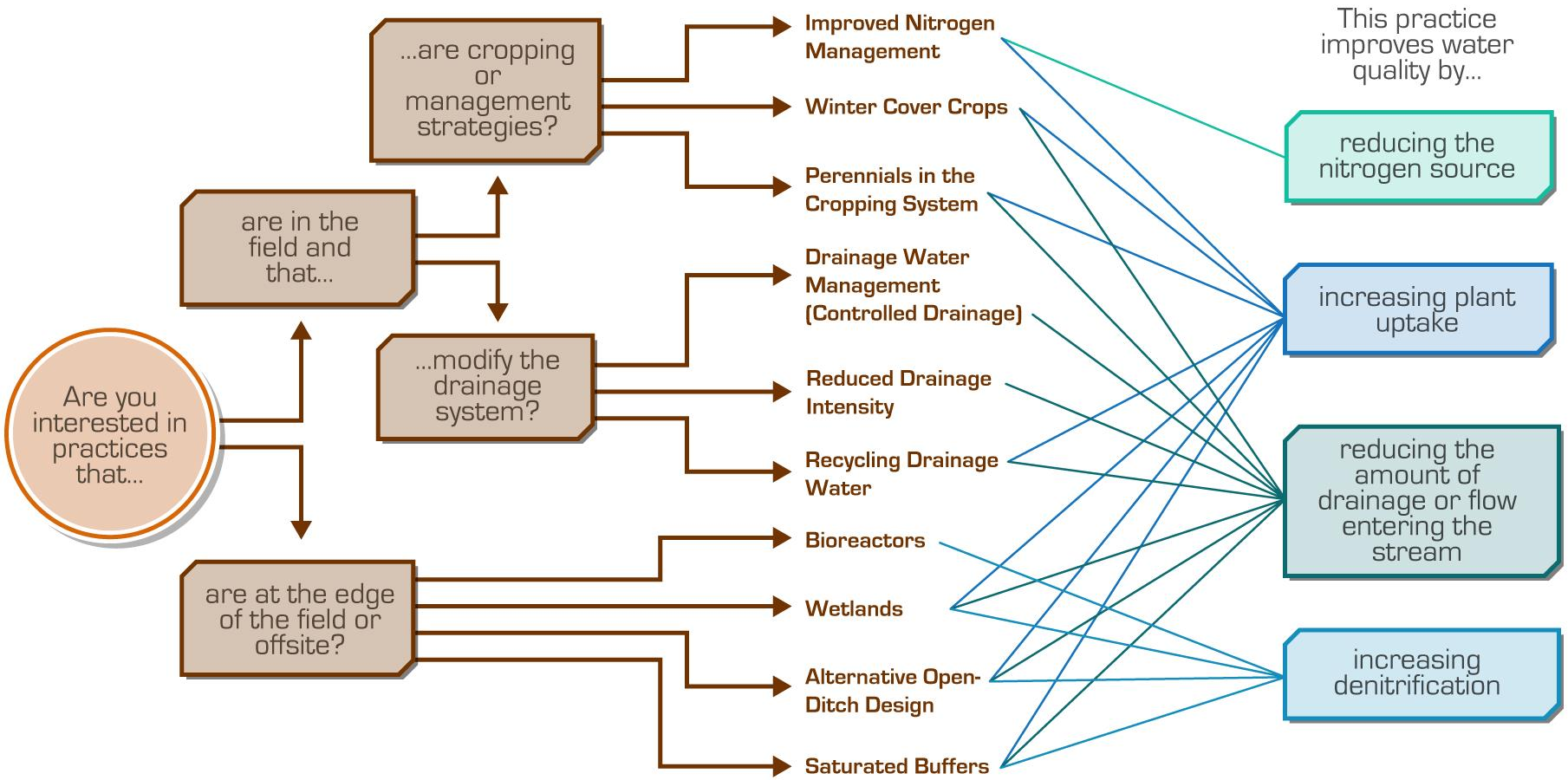


Start over to learn about more practices

IN-FIELD MANAGEMENT PRACTICE:

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."

http://www.nutrientstewardship.com/what-are-4rs

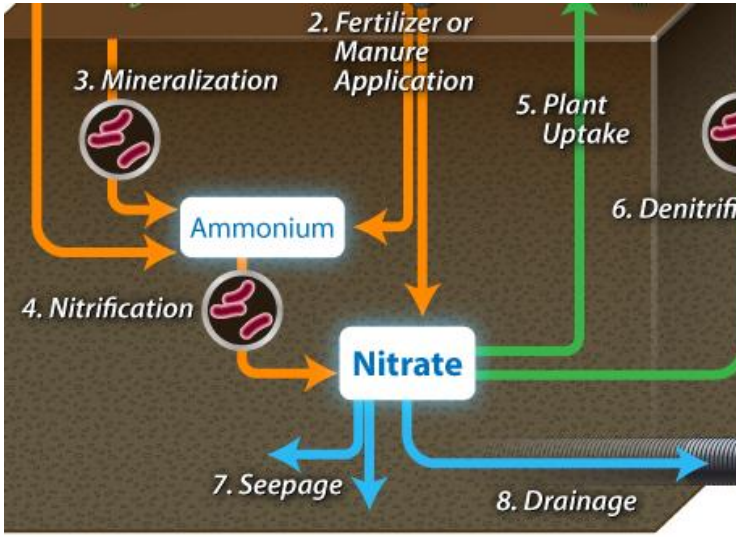
IN-FIELD MANAGEMENT PRACTICE:

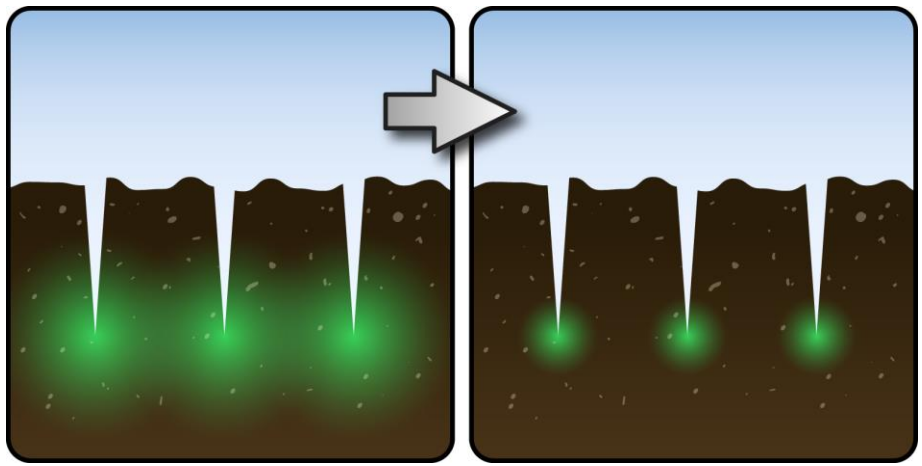
IMPROVED N MANAGEMENT (4RS)

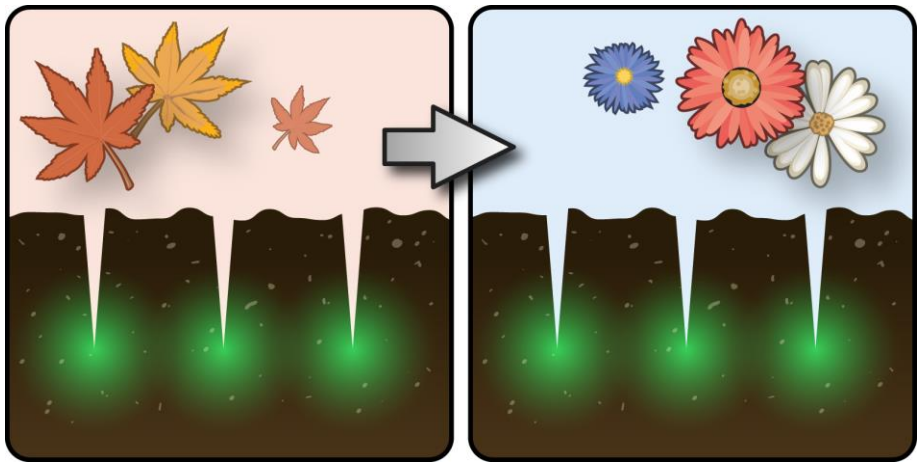
What is it? Applying "the right source of nutrient, at the right **rate**, at the right **time**, and in the right **place**."

How does it reduce N loss in drainage?

Reduces the source of N (rate) or increasing plant uptake (timing, inhibitor)







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

IN-FIELD MANAGEMENT PRACTICE:

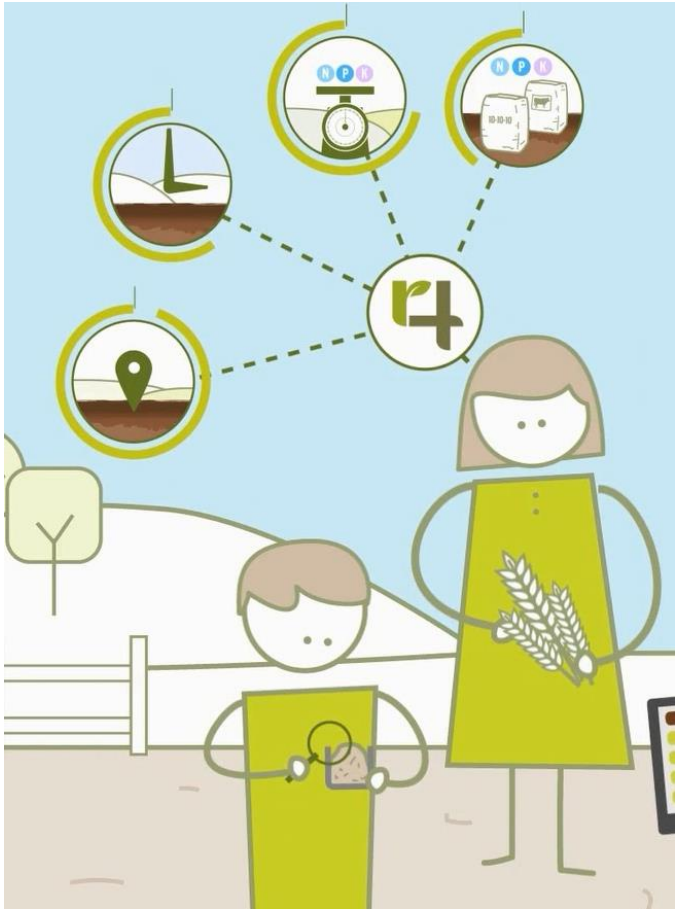
IMPROVED N MANAGEMENT (4RS)

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 (rate) or increasing plant uptake (timing, inhibitor)

How effective is it? 4-10% N loss reduction in the Iowa Strategy

Where does it work? Everywhere N is applied



https://www.youtube.com/watch?v=3Qja938T5e0

Start over to learn about more practices

IN-FIELD MANAGEMENT PRACTICE:

WINTER COVER CROPS

What is it? A crop planted in late fall to cover the soil over the winter.

Winter wheat drilled into soybeans following harvest.

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

Photo: http://www.covercrops.msu.edu/general/general.html

IN-FIELD MANAGEMENT PRACTICE:

WINTER COVER CROPS

What is it? A crop planted in late fall to cover the soil over the winter

How does it reduce N loss in drainage? Takes up water and nitrate from the so… winter

How effective is it? 28-31% N loss reduction in the Iowa Strategy

Where does it work? Robust establis… is the most important for water quality benefits

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

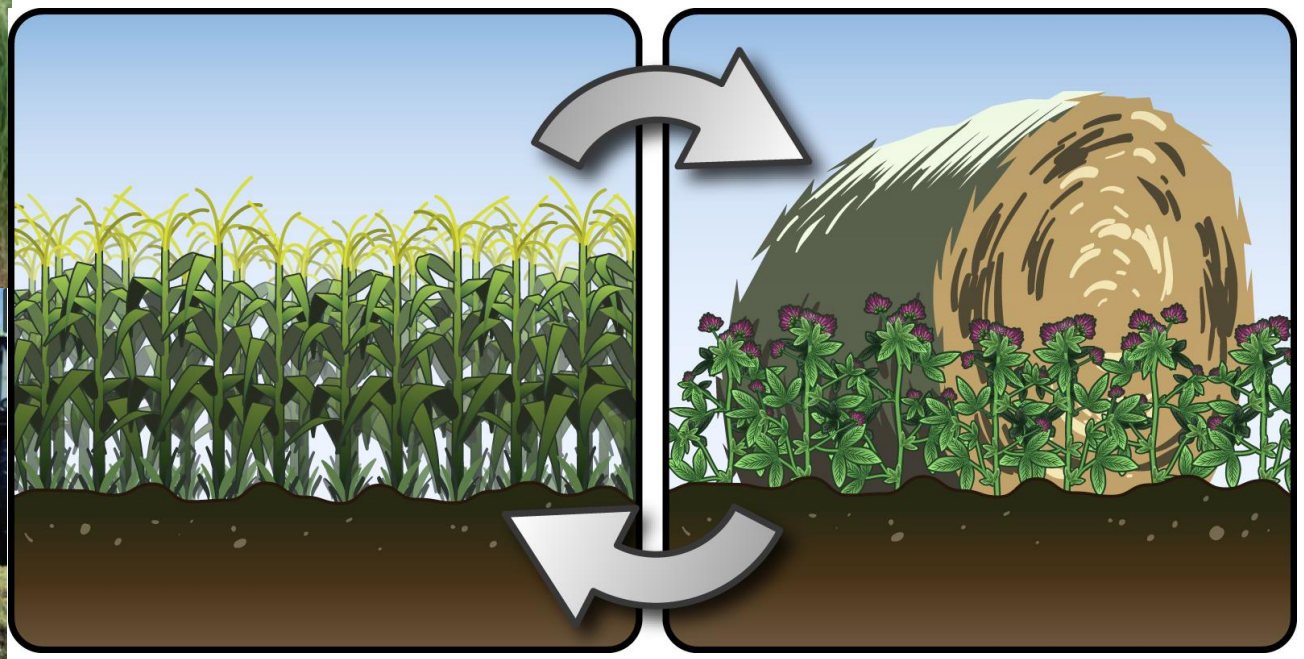
Start over to learn about more practices

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

IN-FIELD MANAGEMENT PRACTICE:

PERENNIALS IN THE ROTATION

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



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

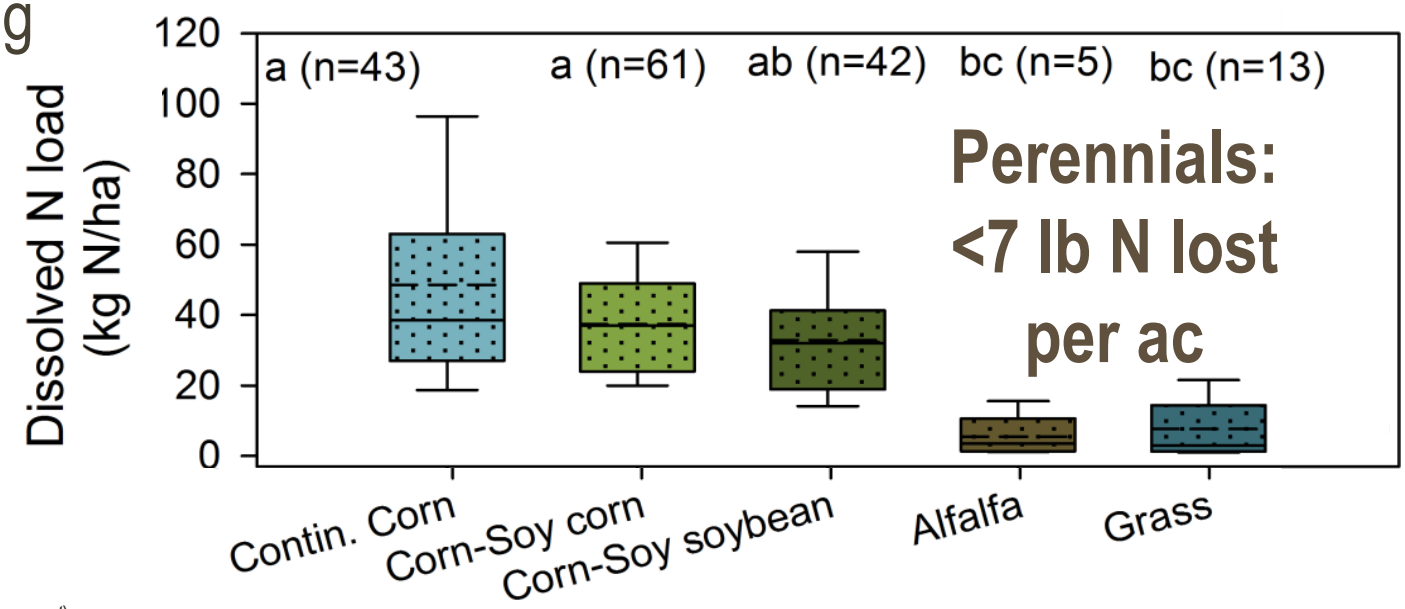
IN-FIELD MANAGEMENT PRACTICE:

PERENNIALS IN THE ROTATION

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

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

Annual Crop Rotations: >28 lb N lost per ac



Source: Christianson and Harmel, 2015 (*Ag. Water Management*)

IN-FIELD MANAGEMENT PRACTICE:

PERENNIALS IN THE ROTATION

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

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

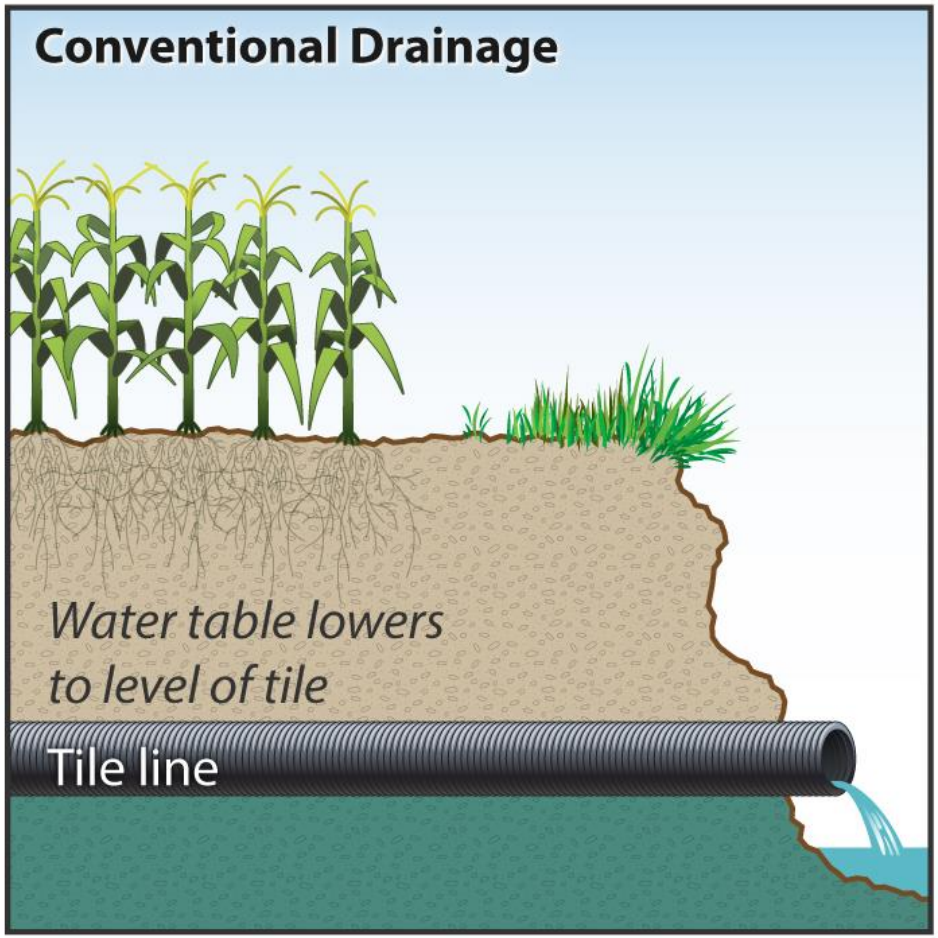
How effective is it? 72-85% N loss reduction in the Iowa Strategy

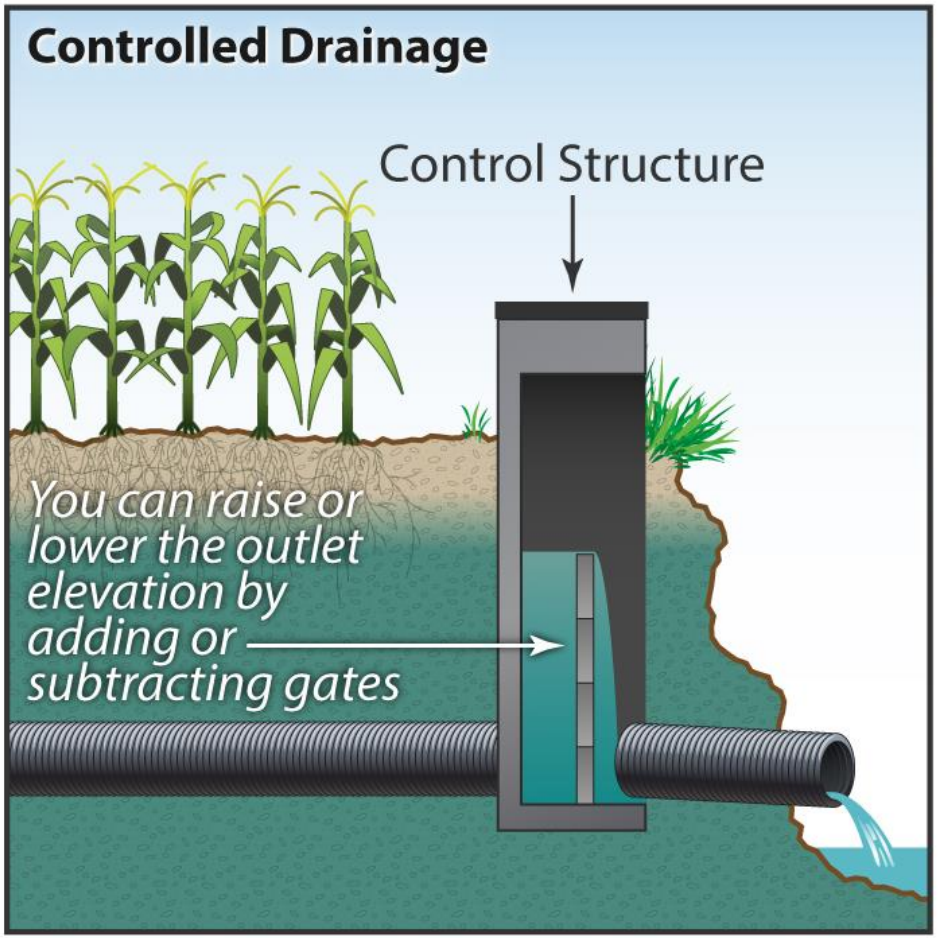
Where does it work? Most perennial crops can be widely grown, but their adoption is limited by availability of on-farm utilization, markets, and infrastructure

Start over to learn about more practices

IN-FIELD DRAINAGE SYSTEM PRACTICE:

CONTROLLED DRAINAGE



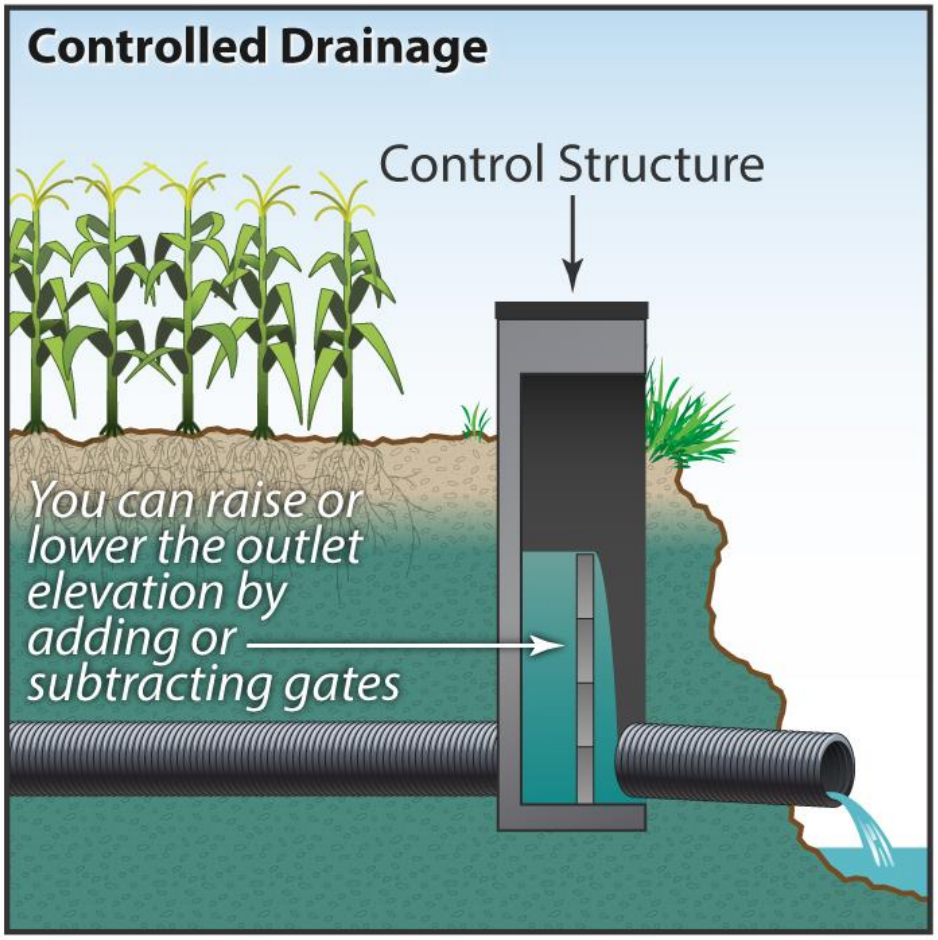


From Christianson et al. (In preparation)

IN-FIELD DRAINAGE SYSTEM PRACTICE:

CONTROLLED DRAINAGE

What is it? Adjustable structures to manage the level of the drainage outlet



IN-FIELD DRAINAGE SYSTEM PRACTICE:

CONTROLLED DRAINAGE

What is it? Adjustable structures

How does it reduce N loss in drainage? Holds back water and nitrate in the water during periods when drainage isn't critical

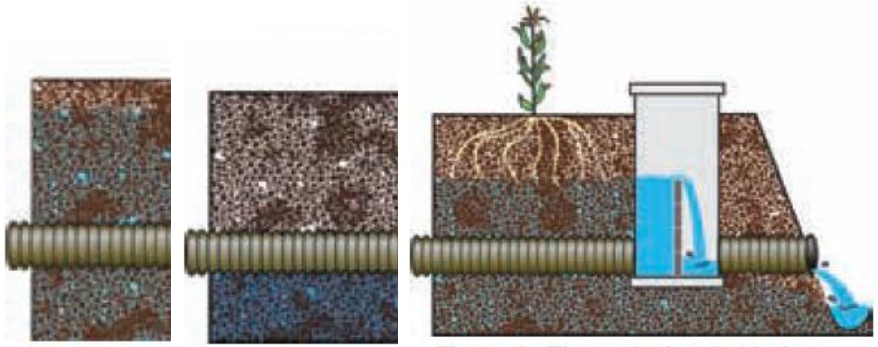
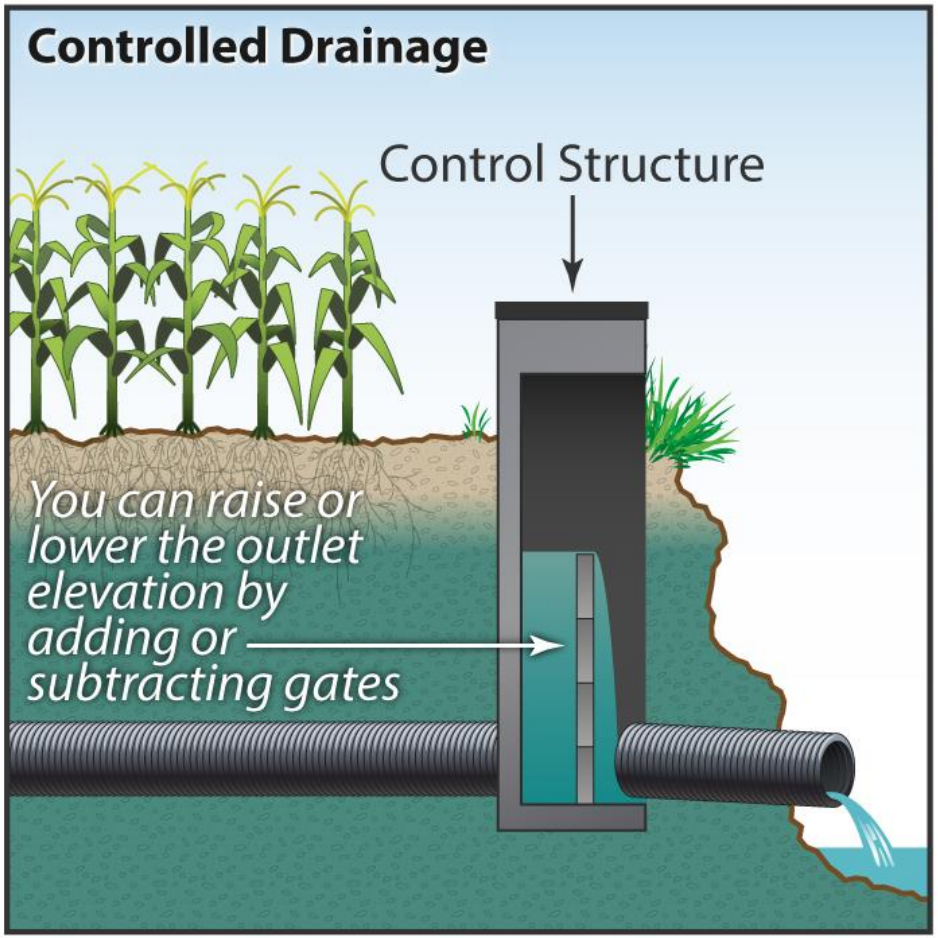


Figure 1. *T harvest to*

Figure 2. *The c weeks before p allow the field t*

Figure 3. *The outlet is raised after planting to potentially store water for crops.*



Source: Frankenberger et al. (Purdue Extension publication WQ-44)

IN-FIELD DRAINAGE SYSTEM PRACTICE:

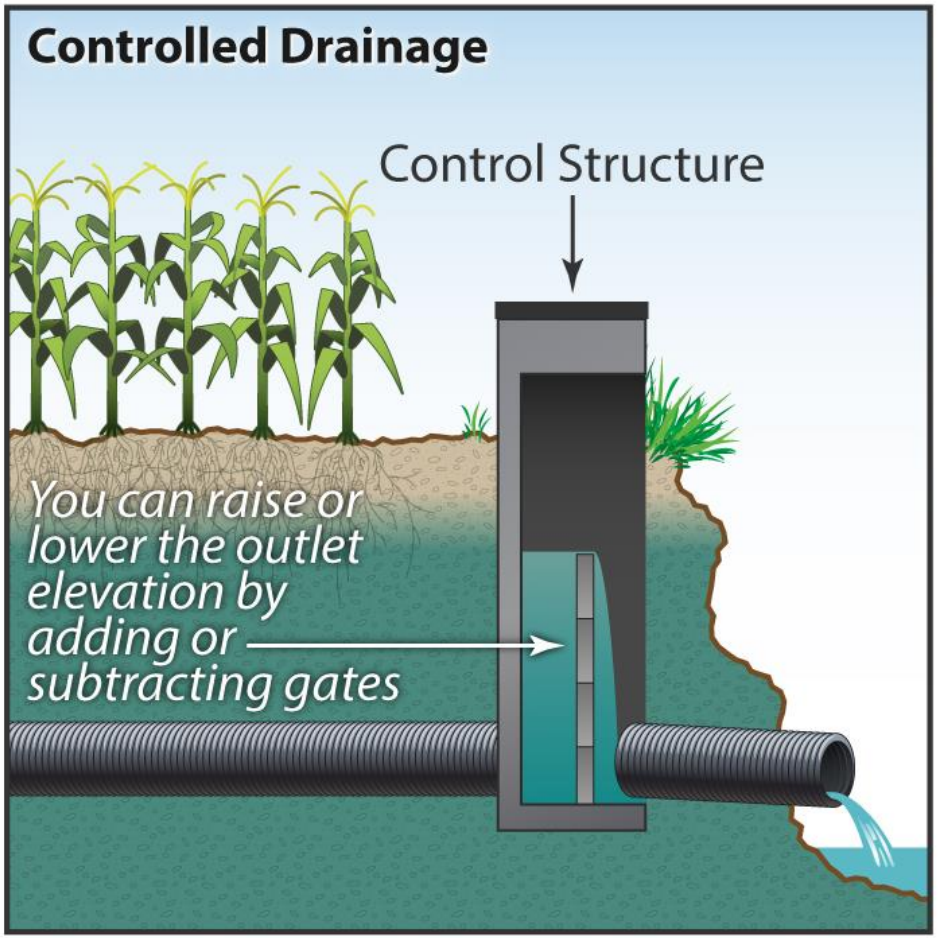
CONTROLLED DRAINAGE

What is it? Adjustable structures

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

How effective is it? 33% N reduction (15-75%) in the Iowa Strategy

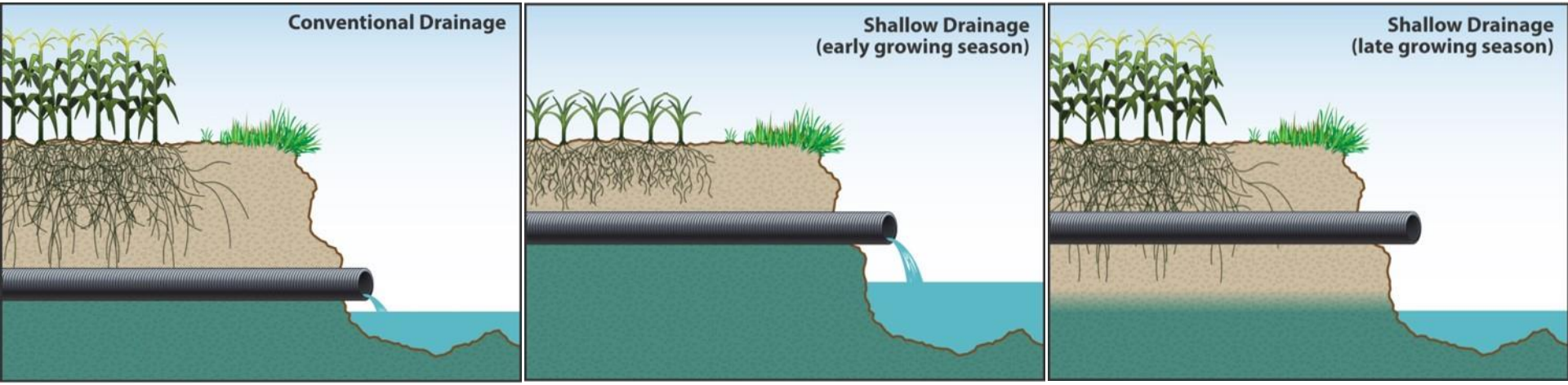
Where does it work? Most practical on slopes of <0.5% because more structure are needed with steeper slopes.



Start over to learn about more practices

IN-FIELD DRAINAGE SYSTEM PRACTICE:

REDUCED DRAINAGE INTENSITY

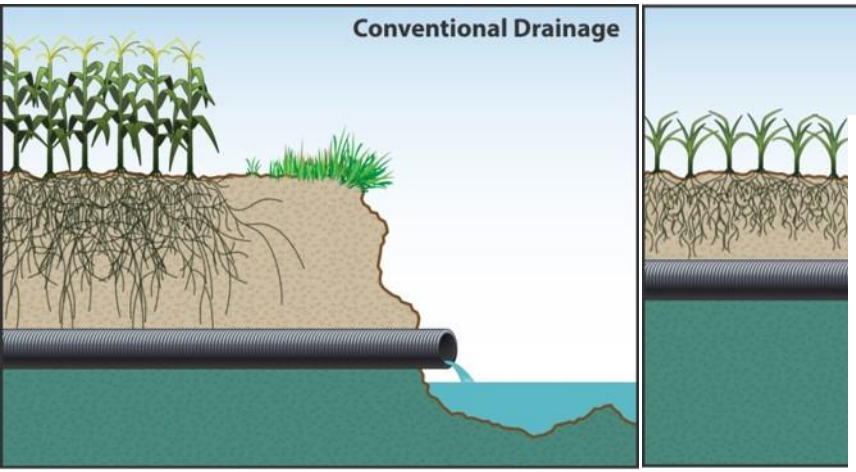


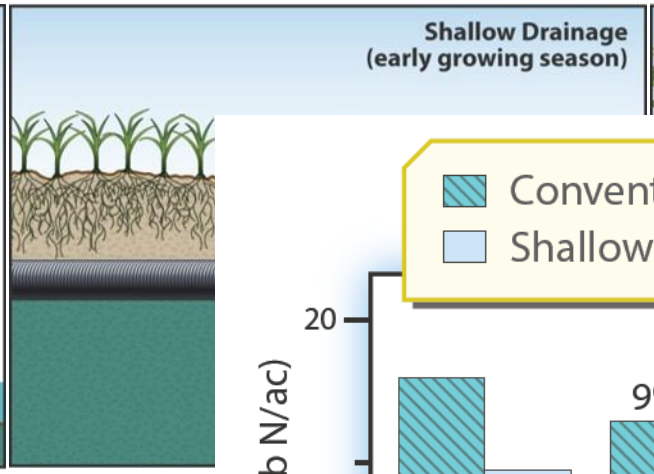
What is it? Installation of subsurface drains either closer to the surface or with wider spacing than conventionally done

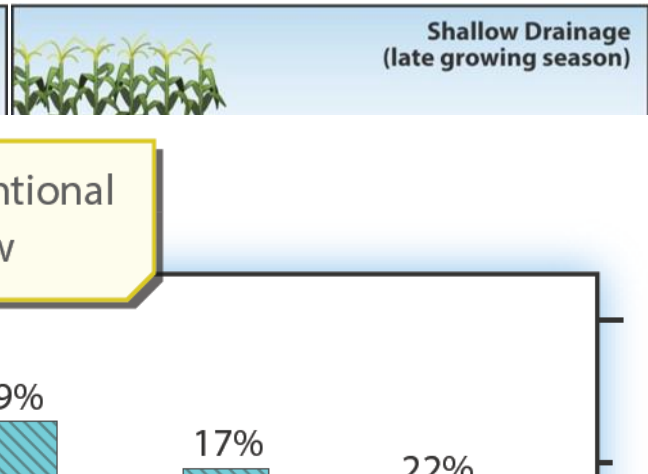
From Christianson et al. (In preparation)

IN-FIELD DRAINAGE SYSTEM PRACTICE:

REDUCED DRAINAGE INTENSITY







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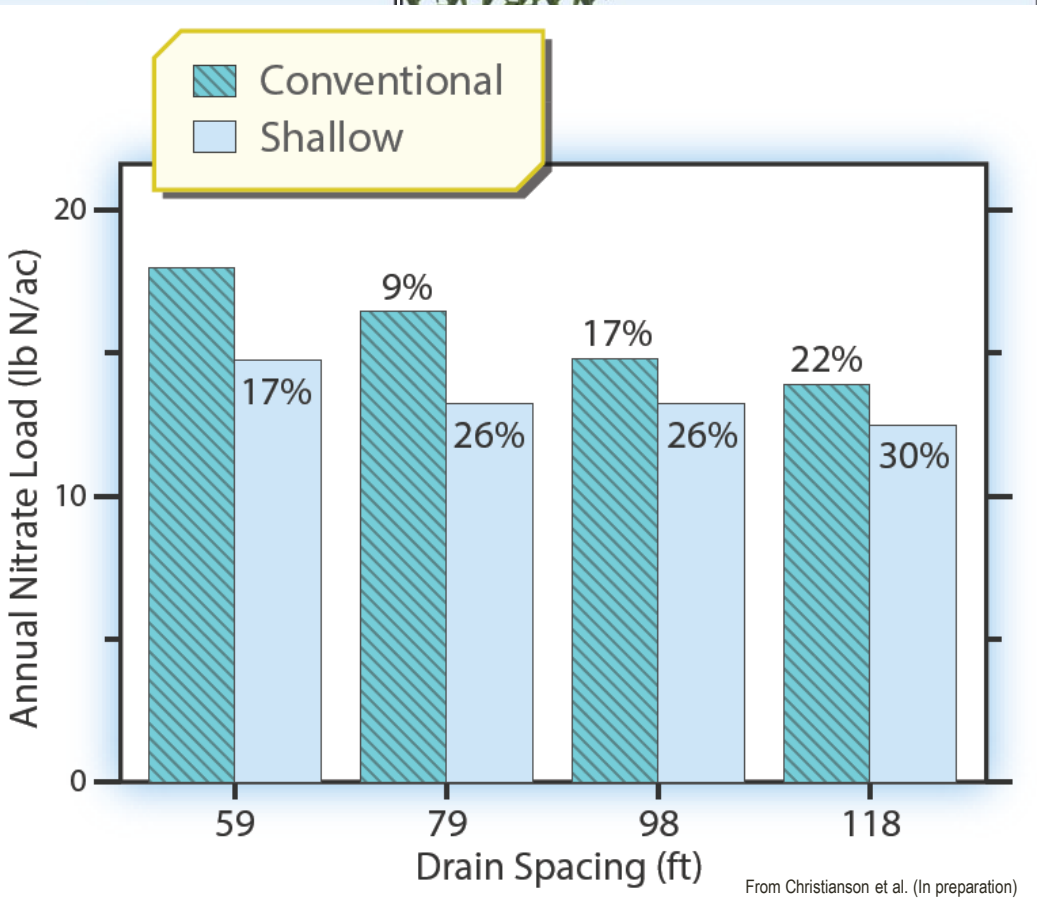
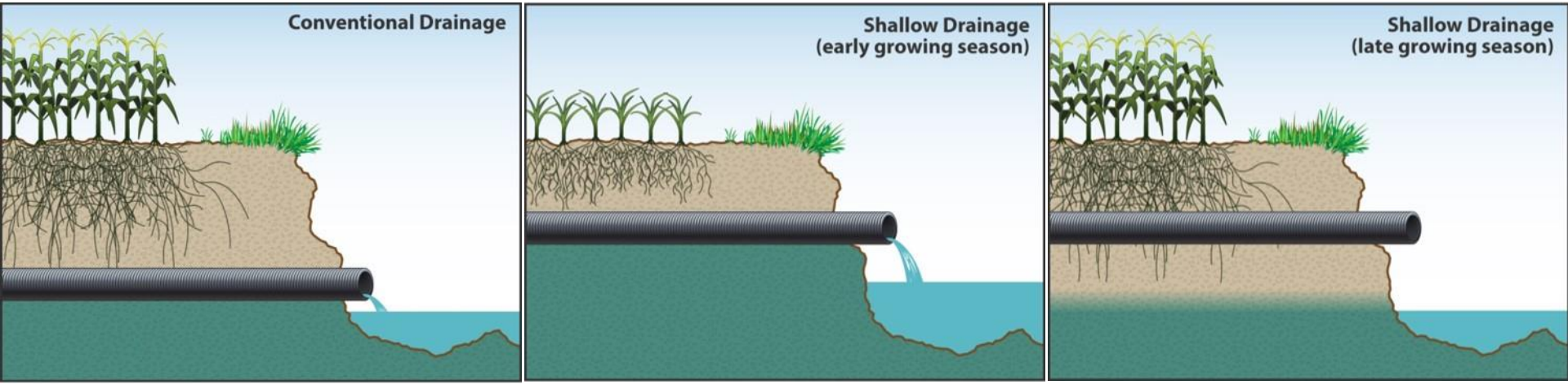


Source: Luo et al., 2010

From Christianson et al. (In preparation)

IN-FIELD DRAINAGE SYSTEM PRACTICE:

REDUCED DRAINAGE INTENSITY



What is it? Installation of either wider or shallower subsurface drains

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

How effective is it? 32% N reduction in the Iowa Strategy (shallow)

Where does it work? Anywhere subsurface drainage is installed

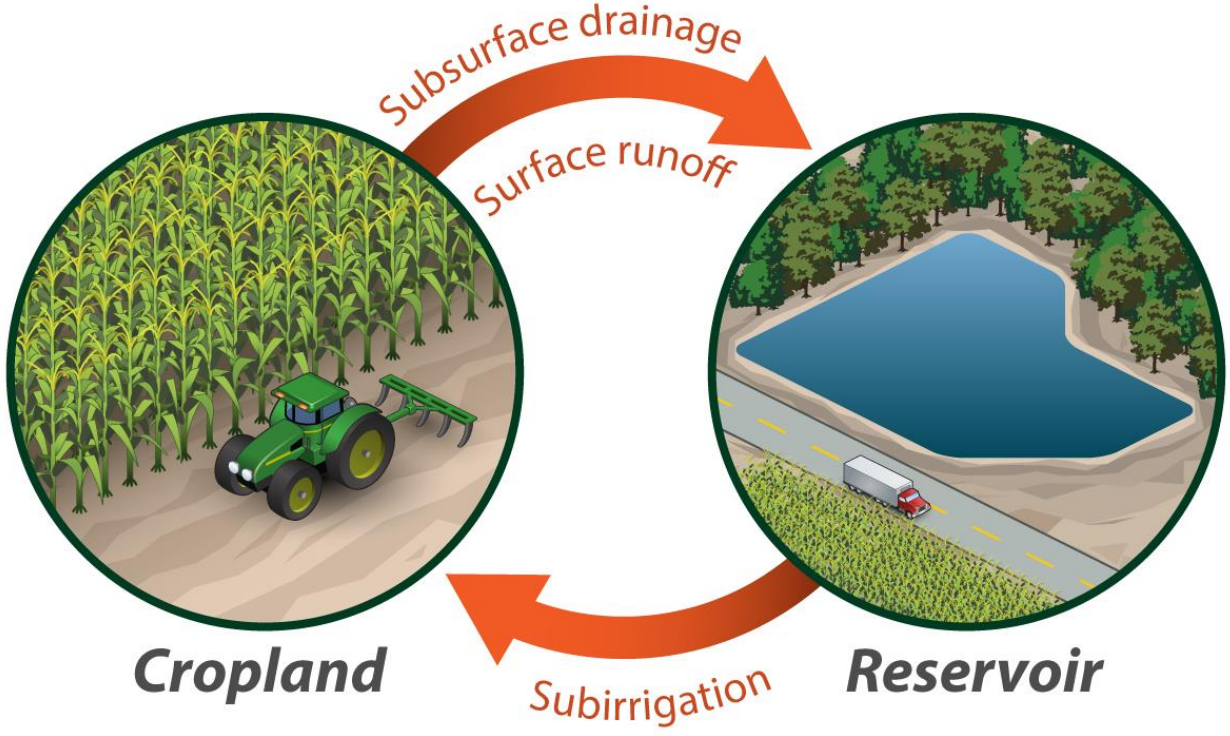
From Christianson et al. (In preparation)

Start over to learn about more practices

IN-FIELD DRAINAGE SYSTEM PRACTICE:

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 potentially eliminate nitrate loss by reducing or eliminating the water that leaves the site.

From Christianson et al. (In preparation)

IN-FIELD DRAINAGE SYSTEM PRACTICE:

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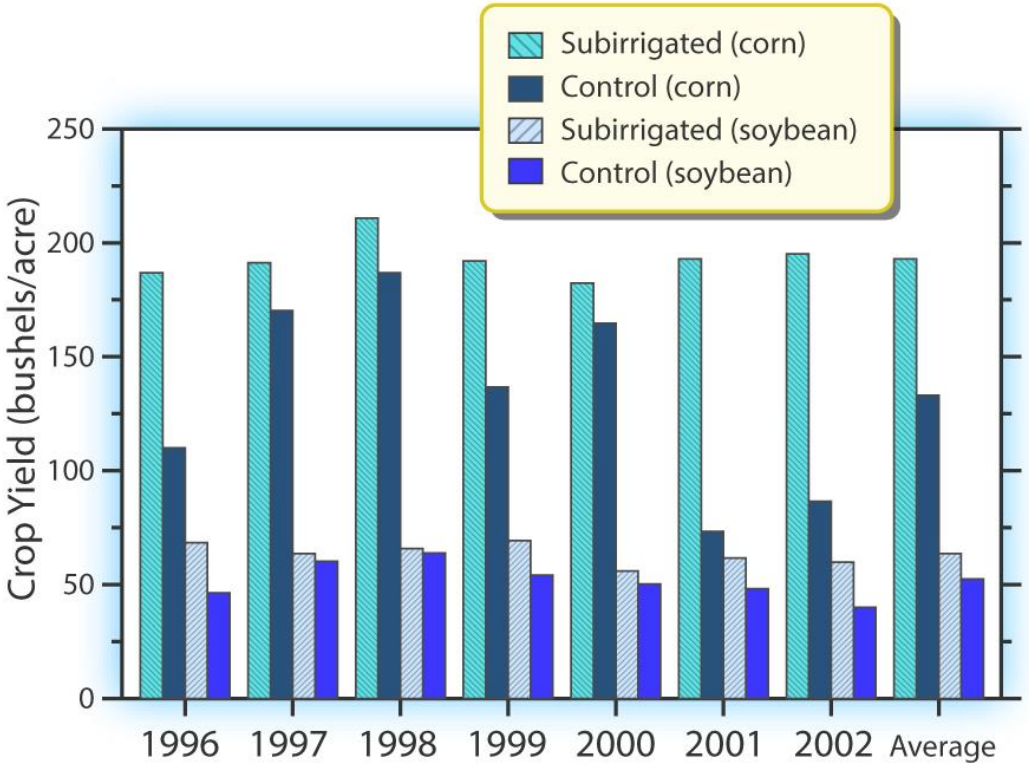


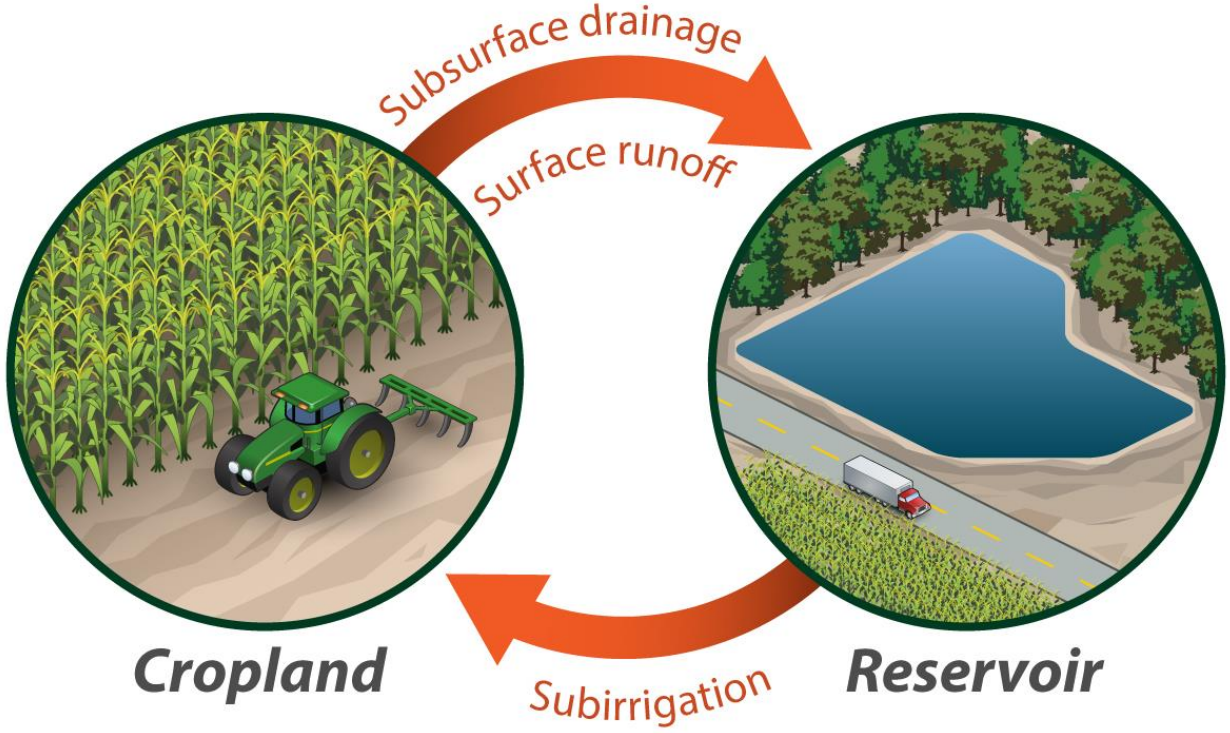
How does it reduce N loss in drainage?

Recycling the drainage water can reduce or even potentially eliminate nitrate loss by reducing or eliminating the water that leaves the site.

IN-FIELD DRAINAGE SYSTEM PRACTICE:

RECYCLING DRAINAGE WATER

What is it? Store drainage water for later crop application



How does it reduce N loss in drainage? Reduces drain flow leaving the site

How effective is it? Shows good potential, but is so new, it's not in the Iowa Strategy

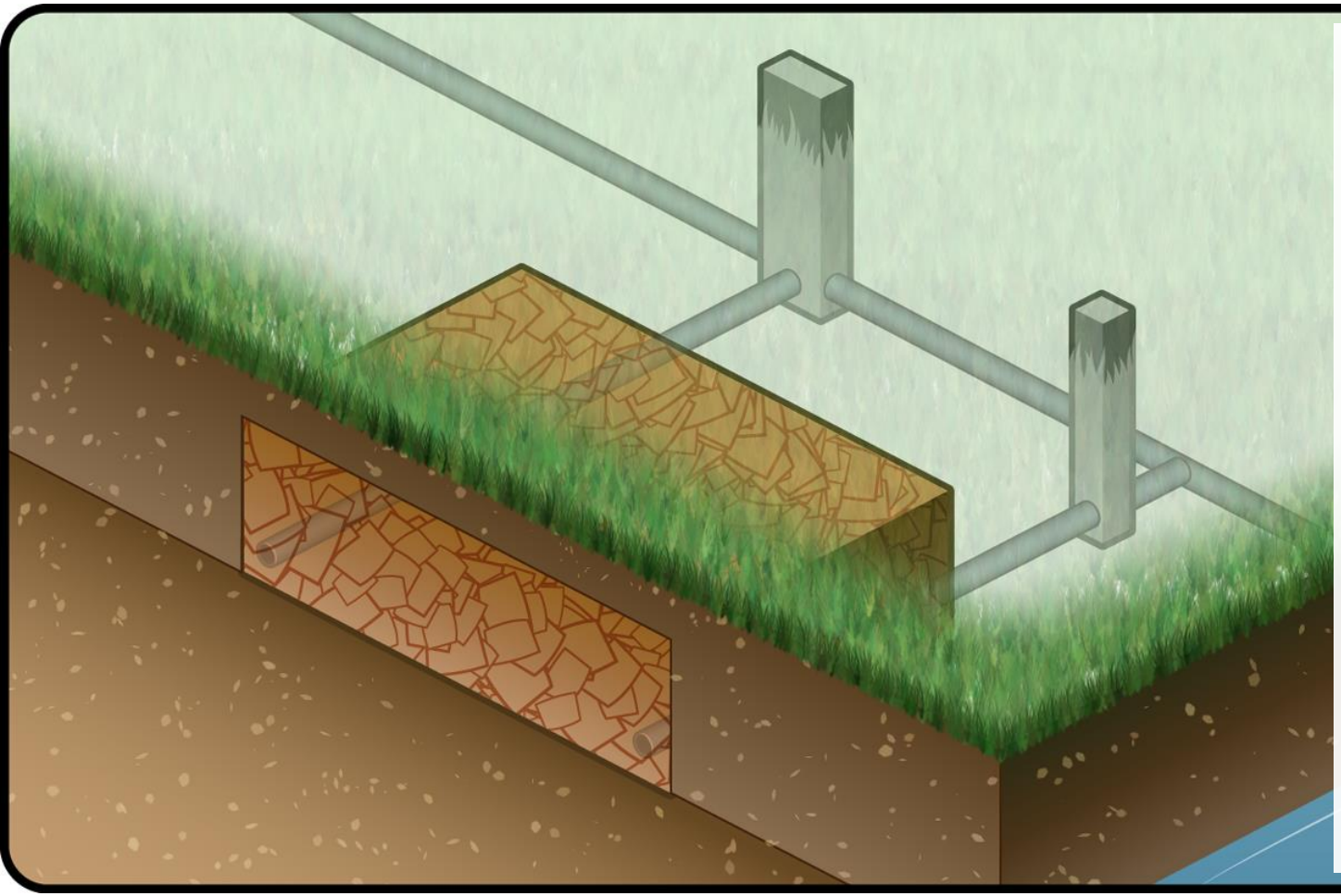
Where does it work? Wide applicability, but the available space for the pond and the cost are usually limiting factors.

Start over to learn about more practices

From Christianson et al. (In preparation)

EDGE-OF-FIELD OR OFF-SITE PRACTICE:

WOODCHIP BIOREACTORS



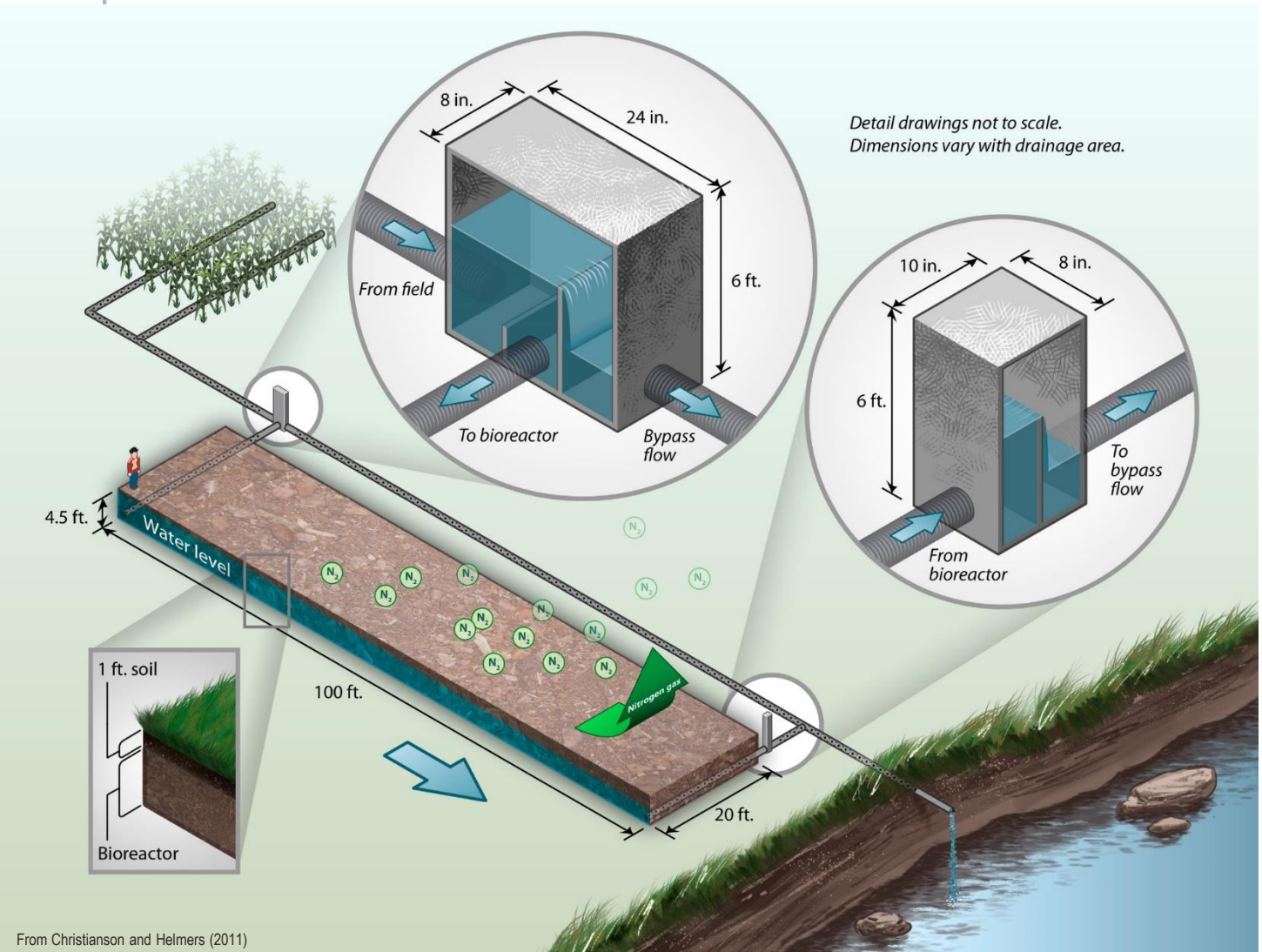
What is it?

Woodchip-filled trench where good microbes "eat" the carbon in the woodchips to fuel their work removing nitrate from the drainage water

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

EDGE-OF-FIELD OR OFF-SITE PRACTICE:

WOODCHIP BIOREACTORS



From Christianson and Helmers (2011)

What is it?

Woodchip-filled trench

How does it reduce N loss in drainage?

Additional carbon "super-powers" the natural process of denitrification

EDGE-OF-FIELD OR OFF-SITE PRACTICE:

WOODCHIP BIOREACTORS

What is it? Woodchip-filled trench

How does it reduce N loss in drainage? Enhances the natural process of denitrification

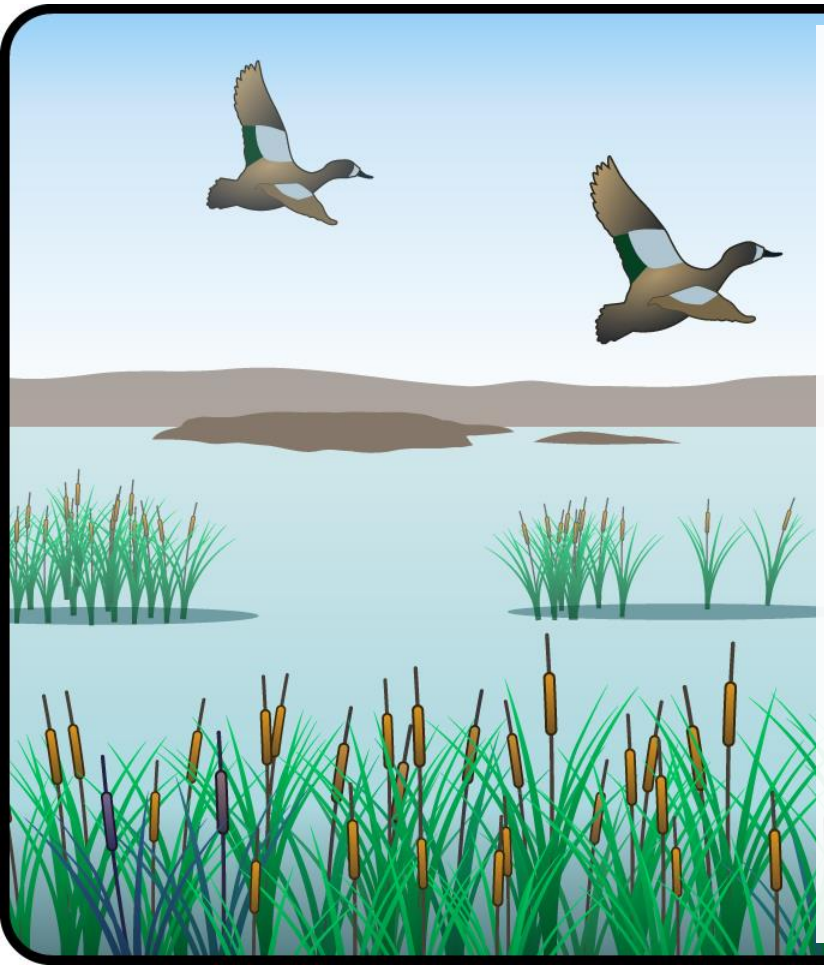
How effective is it? 43% N reduction in the Iowa Strategy

Where does it work? Anywhere subsurface drainage is installed and room is available for this narrow construction

Start over to learn about more practices

EDGE-OF-FIELD OR OFF-SITE PRACTICE:

WETLANDS



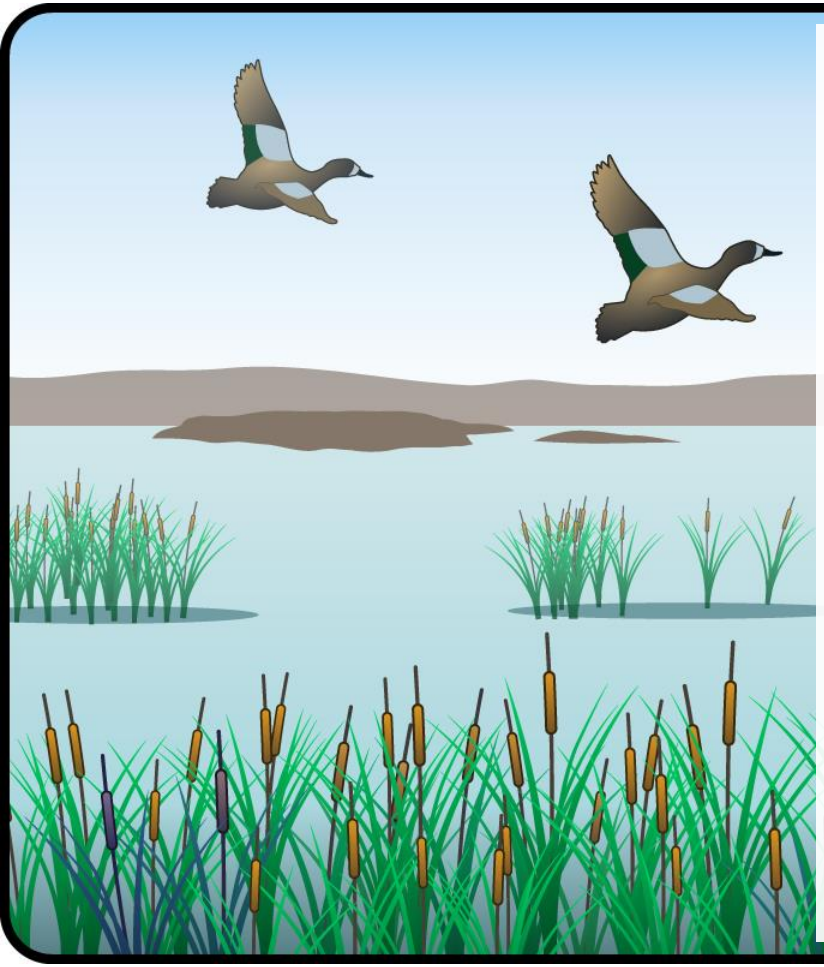
What is it? Constructed wetlands are dynamic ecosystems of plants, soil, bacteria, and water.

How does it reduce N loss in drainage? Wetlands primarily enhance the natural process of denitrification, but also provide some plant uptake of N and reduced downstream flow.

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

EDGE-OF-FIELD OR OFF-SITE PRACTICE:

WETLANDS



What is it? Constructed wetlands are dynamic ecosystems.

How does it reduce N loss in drainage? Denitrification, plant uptake, and reduced flow

How effective is it? 52% N reduction in the Iowa Strategy

Where does it work? Concerns about the cost of taking land out of production limits widespread implementation

Photo: https://iowalearningfarms.wordpress.com/2014/06/26/incredible-wetlands/

EDGE-OF-FIELD OR OFF-SITE PRACTICE:

WETLANDS

What is it? Constructed wetla s are
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do

Lots of additional benefits! Flood retention, wildlife habitat…

on in

about

the cost of tak out of production limits widespre implementation

Start over to learn about more practices

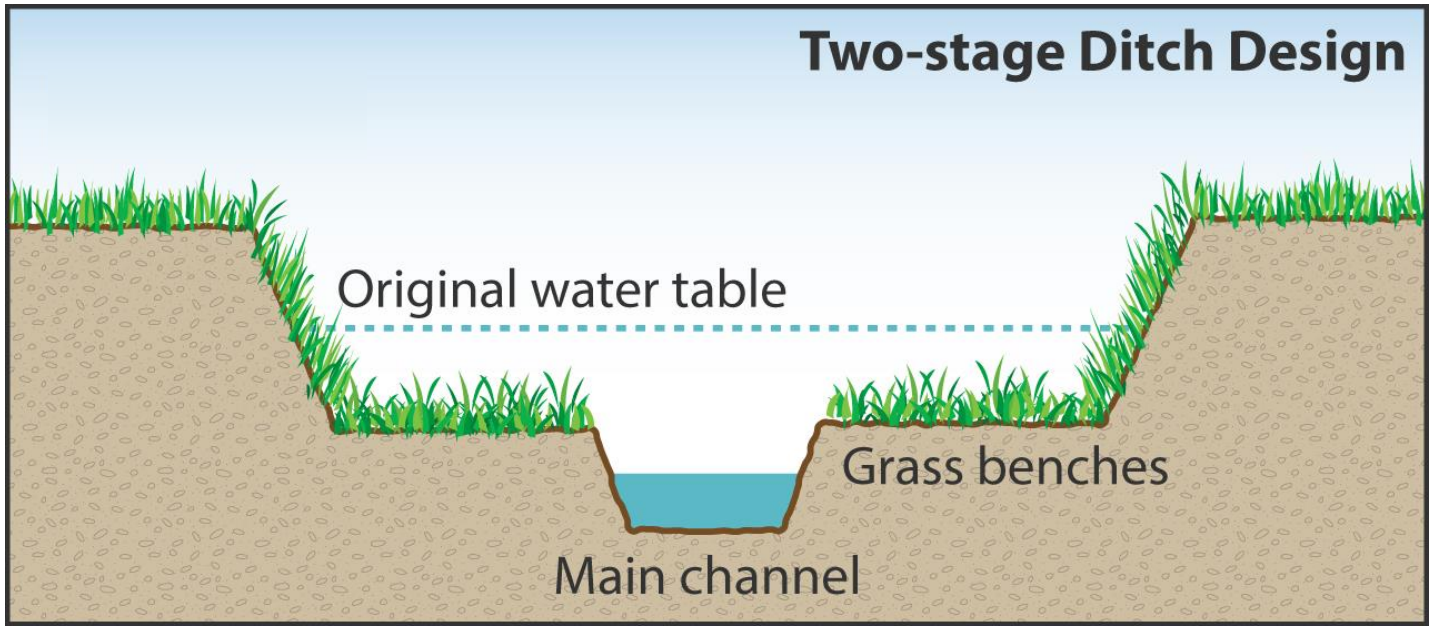
Photo: https://iowalearningfarms.wordpress.com/2014/06/26/incredible-wetlands/

EDGE-OF-FIELD OR OFF-SITE PRACTICE:

ALTERNATIVE DITCH DESIGN (TWO-STAGE)

What is it?

Retrofit an existing ditch to contain a small “main” channel and low, grassed floodplains



How does it reduce N loss in drainage?

Denitrification, plant uptake, and reduced flow via infiltration to the mini-floodplains

From Christianson et al. (In preparation)

EDGE-OF-FIELD OR OFF-SITE PRACTICE:

ALTERNATIVE DITCH DESIGN (TWO-STAGE)

What is it? Ditch retrofit into 2-stages

How does it reduce N loss in drainage? Denitrification, plant uptake, and reduced flow

How effective is it? Nitrate removal data is forthcoming (not in the Iowa Strategy)

Where does it work? Where there are existing ditches; ditch may need to be widened, but may reduce cleanout costs

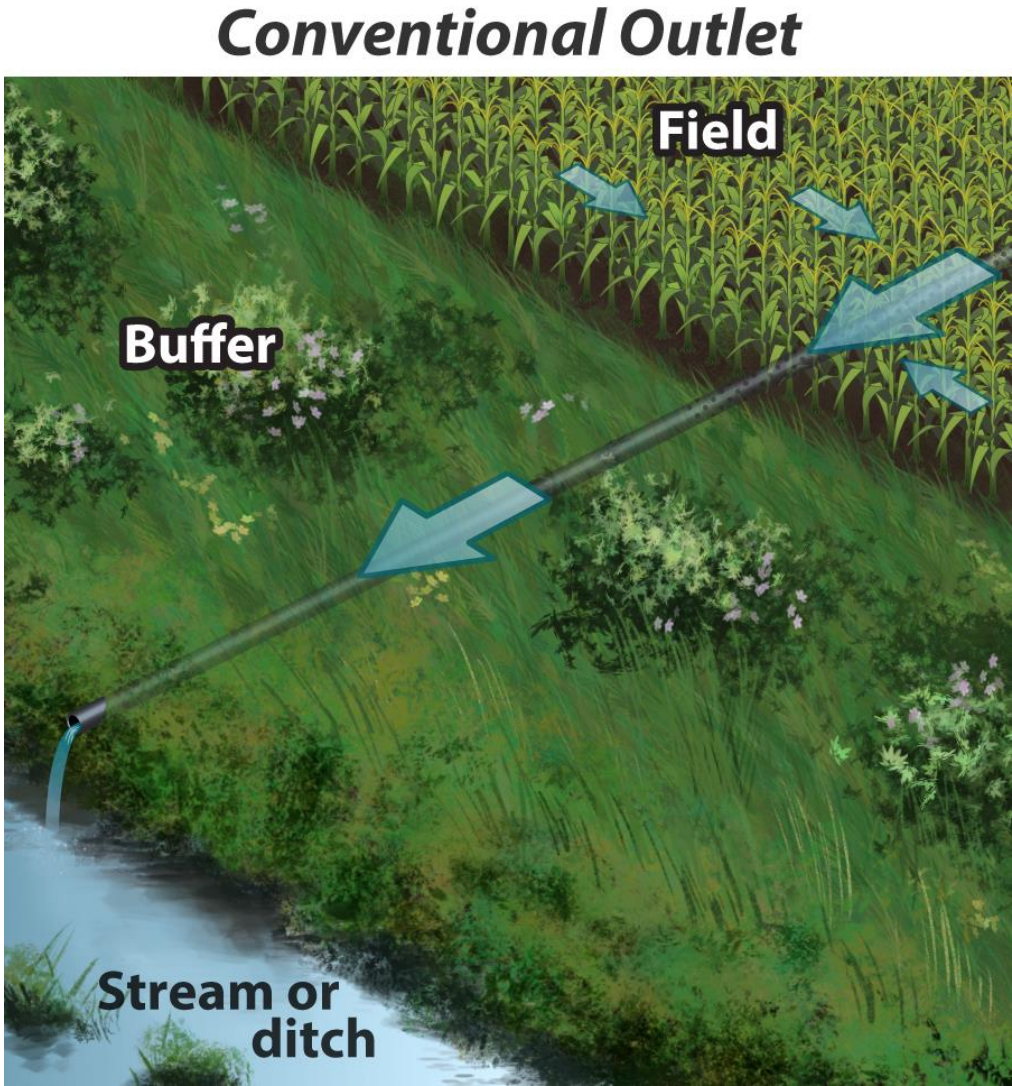
Start over to learn about more practices

http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/indiana/placesweprotect/two-stage-ditches-the-wabash.xml; http://www.nature.org/cs/groups/webcontent/@web/@indiana/documents/document/prd_034172.pdf

EDGE-OF-FIELD OR OFF-SITE PRACTICE:

SATURATED BUFFERS

What is it? A modification of the edge-of-field drainage system that allows drainage water to flow as shallow groundwater through the buffer's soil.



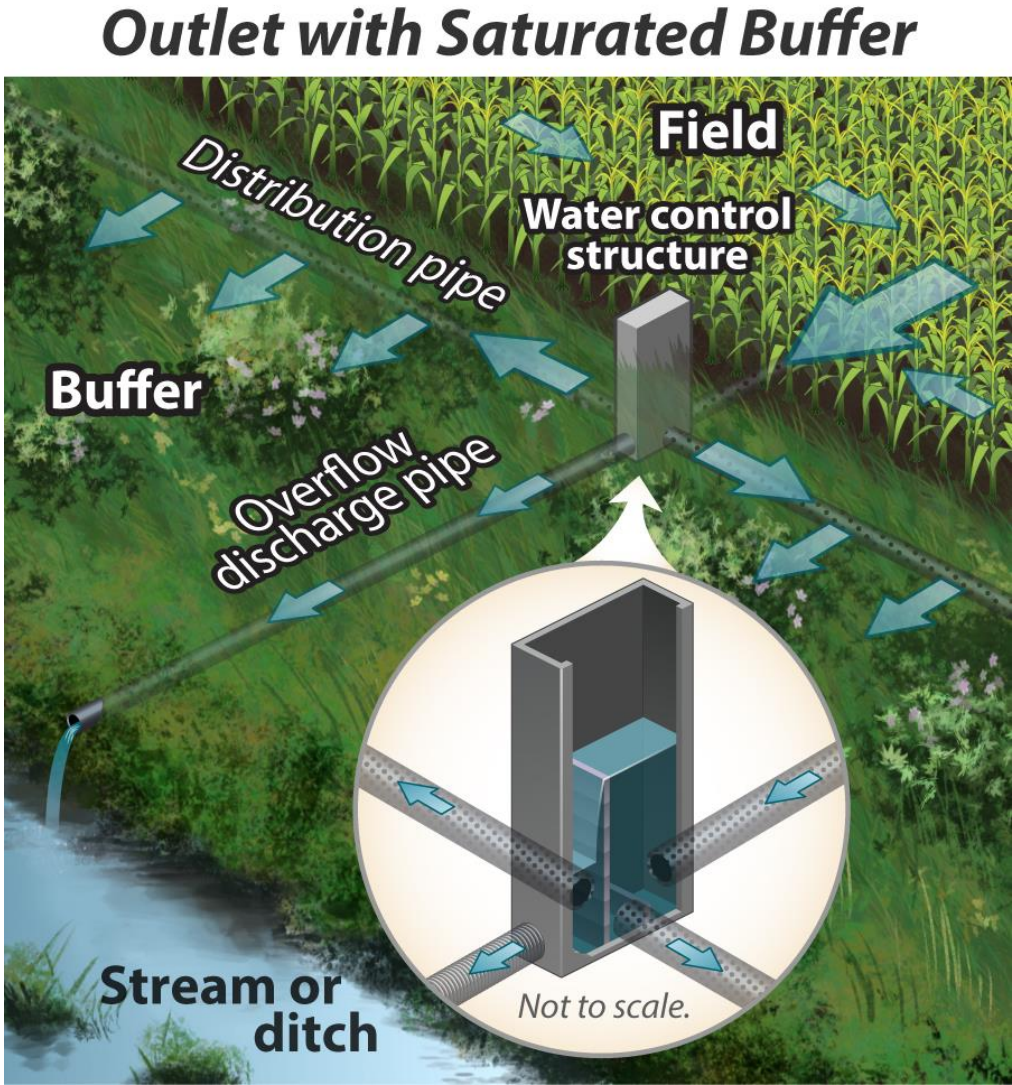
From Christianson et al. (In preparation)

EDGE-OF-FIELD OR OFF-SITE PRACTICE:

SATURATED BUFFERS

What is it? A modification of the edge-of-field drainage system that allows drainage water to flow as shallow groundwater through the buffer's soil

How does it reduce N loss in drainage? As water moves through the buffer's soil, nitrate is denitrified, plants uptake water and N, and flow is reduced.



From Christianson et al. (In preparation)

EDGE-OF-FIELD OR OFF-SITE PRACTICE:

SATURATED BUFFERS

What is it? Drainage treatment under a vegetated buffer

How does it reduce N loss in drainage? Denitrification, plant uptake, and flow reduction

How effective is it? 50% N reduction in the Iowa Strategy

Where does it work? Where there is a buffer or room for one

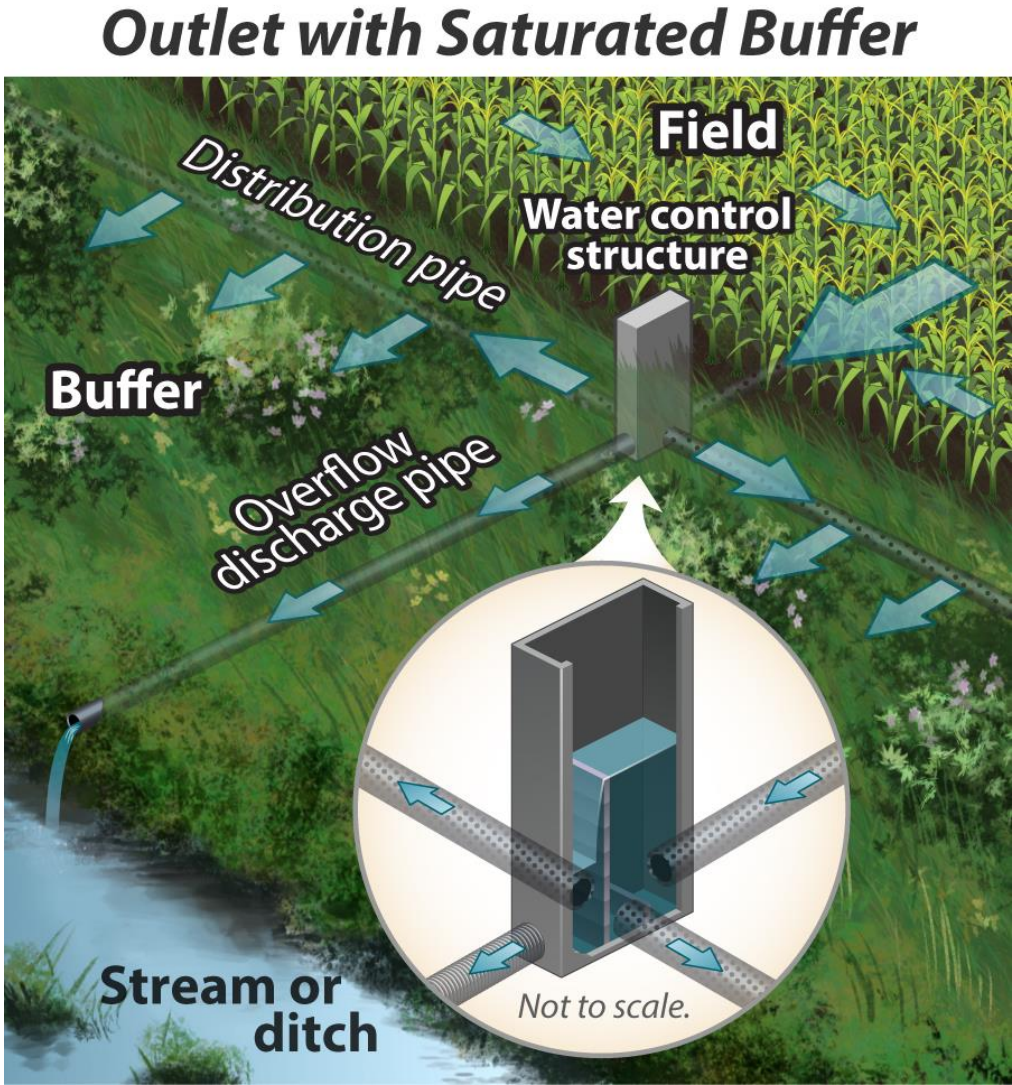


Photo: courtesy Dr. Dan Jaynes, USDA ARS

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Photo: courtesy Dr. Dan Jaynes, USDA ARS

Start over to learn about more practices

IOWA NUTRIENT REDUCTION STRATEGY

	In-field N management			In-field cropping management		Edge-of-field	
	Reducing N application rate to MRTN	Sidedress all spring N	Use of N Inhibitor	Cover crops	Perennial energy crops	Woodchip Bioreactors	Constructed Wetlands
Percent N reduction	10%	4%	9%	31%	72%	43%	52%
N reduced from baseline (in 1,000 short ton)*	28	12	2	79	54	55	69

*Relative to baseline load of 307 x 1,000 short ton

@IL_DrainDrop

SUMMARY

Practices to reduce N loads in drainage vary in:

- Effectiveness
- Cost
- Suitability
- Additional environmental and agronomic benefits

No one practice will be suitable on every acre, but every acre needs at least one new practice!

Golden Rule of Drainage: Drain only what is necessary for good trafficability and crop growth – and not a drop more.

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