

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



UNIVERSITY OF ILLINOIS EXTENSION

Ways to Reduce Nitrogen Loads from Drained Cropland in the Midwest

1. Improved Nitrogen Management Practices that Reduce Nitrate in the Plant Root Zone



Figure 9: Fertilizer application rate, timing, form, and other factors can affect drainage nitrate loads.

What is improved nitrogen management?
The four most widely known improved nitrogen (N) management practices are termed the "4R" practices and aim to identify if the Right nitrogen source was applied at the Right rate, at the Right time, and in the Right place. These and other N management factors have complex agronomic and environmental impacts, thus only rate of N applied, time of N application, and use of a nitrification inhibitor are covered here. These improved N management strategies work together in different ways to reduce loss of nitrate in drainage water.

Rate of N application: Applying the proper rate of N has a greater influence on drainage water nitrate losses than any other N management factor including application timing.

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Ways to Reduce Nitrogen Loads from Drained Cropland in the Midwest

2. Winter Cover Crops Practices that Reduce Nitrate in the Plant Root Zone



Figure 11: Cover crops take up nitrate during the season when no annual crop is in the field (photo: Dan Isgrig).

What are cover crops in the Midwest?
Cover crops, sometimes called "catch crops," are crops that fall and grow until the soil freezes. Some cover crops can be overwinter and need to be killed using herbicides or tillage prior to planting the main crop in the spring. Others do not survive the winter, and therefore have the advantage of not needing to be killed in the spring. Others types of cover crops often do not produce as much growth, resulting in less overall water quality benefit. Possible cover crops in the Midwest include small grains (oat, winter wheat, barley, triticale, and winter rye), legumes (alfalfa, hairy vetch, and clover), grasses (annual ryegrass), and brassicas (oilseed radish, oriental mustard, and winter canola).

How do cover crops improve water quality?
Cover crops can significantly reduce nitrate losses by taking up water and nitrate from the soil after the main crop is harvested in the fall, and before the main crop starts

to use significant amount of water and spring. At those times when nitrate l drains can be very high, the reduction is considerable. By extending the season of nutrient uptake beyond that of annual gr: losses to drains can be reduced.

How effective are cover crops?
Research shows the reduction in nitrate loss crop has ranged from 13% in Minnesota to 20% in Iowa. While the effect of nitrate to cover crops are likely greater for high org in poorly drained soils. In general, cover crop i water quality depends on growth and establ crop establishment and growth can be limite rainfall, poor soil conditions at planting, or la the cover due to delays in harvesting the gra

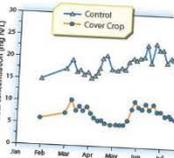


Figure 12: Cover crops can significantly reduce nitrate drainage (from Kasper et al., 2007).

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

6. Recycling Drainage Practices that Reduce Delivery of Nitrate to the Field's Edge

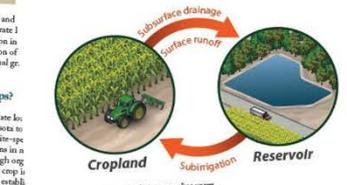


Figure 20: Schematic of a drainage recycling system.

What is drainage water recycling?
Drainage water recycling is the practice of storing drainage water in a pond or reservoir, and then returning it to the drainage situation during dry periods. In conventional drainage water is routed to a channel to move it off site as quickly as possible, which means the water is no longer available to meet future crop needs. Although excess soil water is prevalent during the late winter and spring period in midwestern agriculture, soil water deficits during the late summer often limit grain production. During these times, having access to the drainage water that was routed away earlier in the season would be advantageous.

Drainage water recycling requires an initial construction and infrastructure investment. On-site storage of drainage water requires construction of a pond or reservoir, which may require pump-takes some land out of production, and may require pumping facilities to move the drainage water to the reservoir and back to the soil. Pumping needs depend mainly on the type of irrigation practice chosen for applying the water

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

7. Bioreactors Practices that Remove Nitrate at the Edge of the Field or Downstream

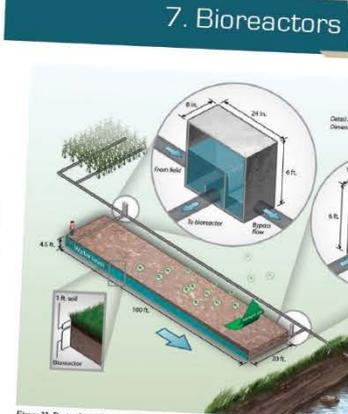


Figure 22: Denitrification bioreactors are an edge-of-field water quality improvement system that enhances the denitrification of nitrate in the stream and would likely be placed in a row match a green strip and drainage system.

TEN WAYS TO REDUCE NITROGEN LOADS FROM DRAINED CROPLAND IN THE MIDWEST

THIS WORK BROUGHT TO YOU BY

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**NORTH CENTRAL REGION
WATER NETWORK**

USDA NIFA (Agreement
No. 2008-51130-04751),

East Dakota Water
Development District



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Association

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IOWA STATE UNIVERSITY
Extension and Outreach



UNIVERSITY OF MINNESOTA
EXTENSION

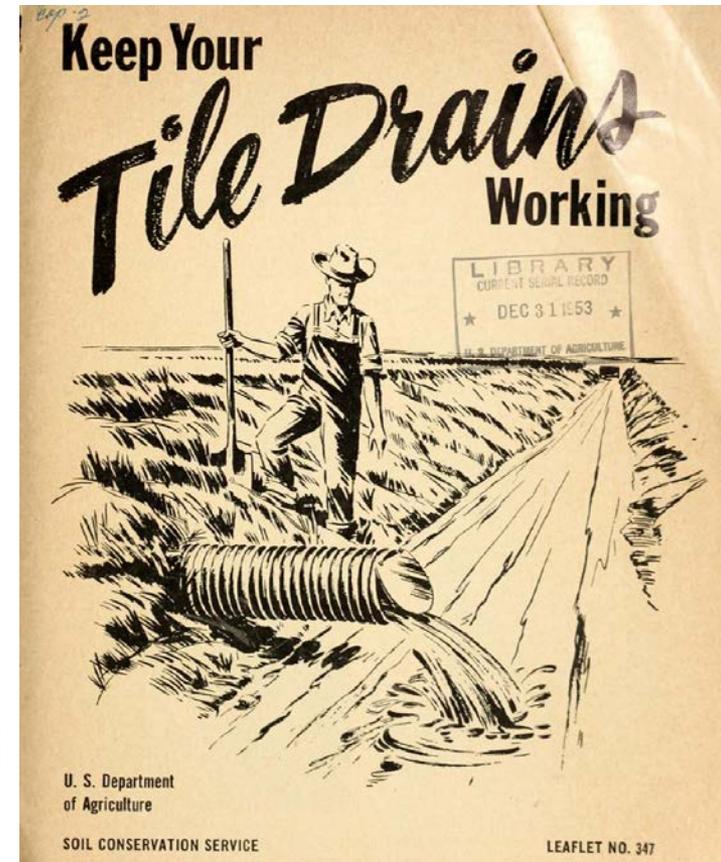
ARTIFICIAL DRAINAGE IS INTEGRAL TO CROP PRODUCTIVITY.

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



ARTIFICIAL DRAINAGE IS INTEGRAL TO CROP PRODUCTIVITY.

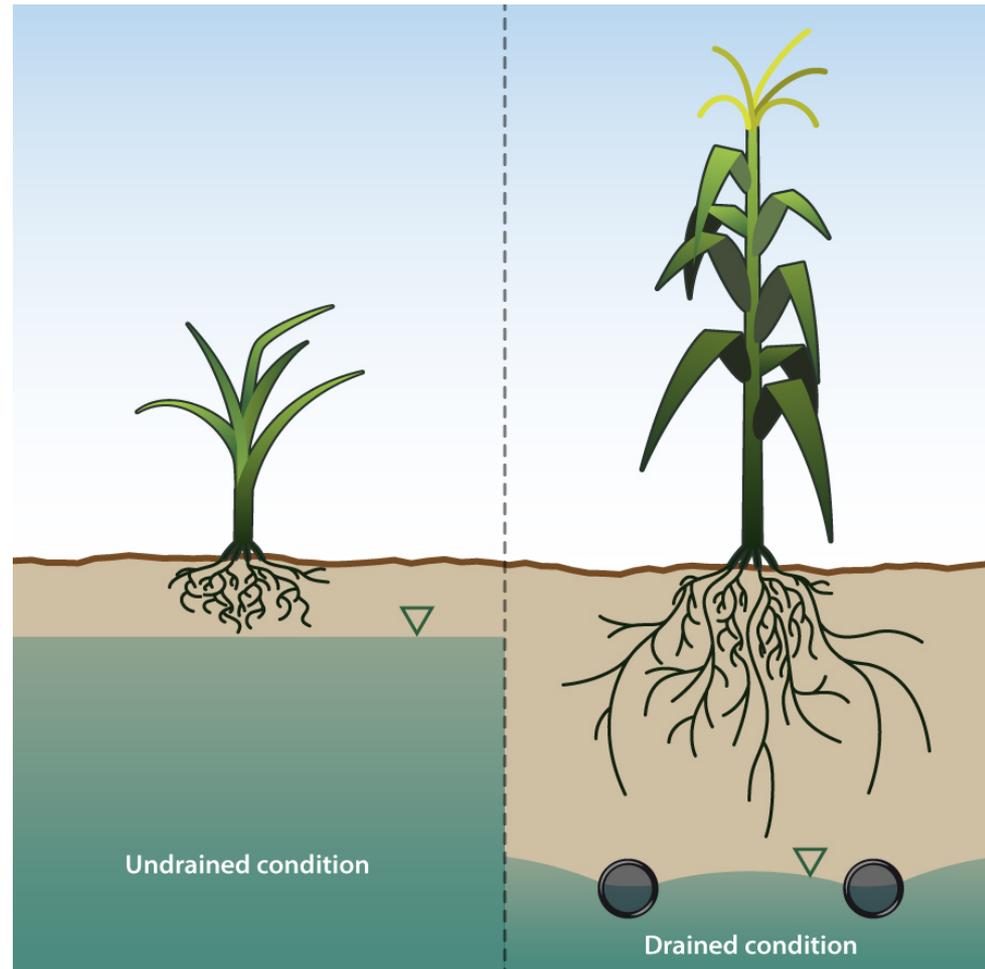
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ARTIFICIAL DRAINAGE IS INTEGRAL TO NEW CHALLENGES.

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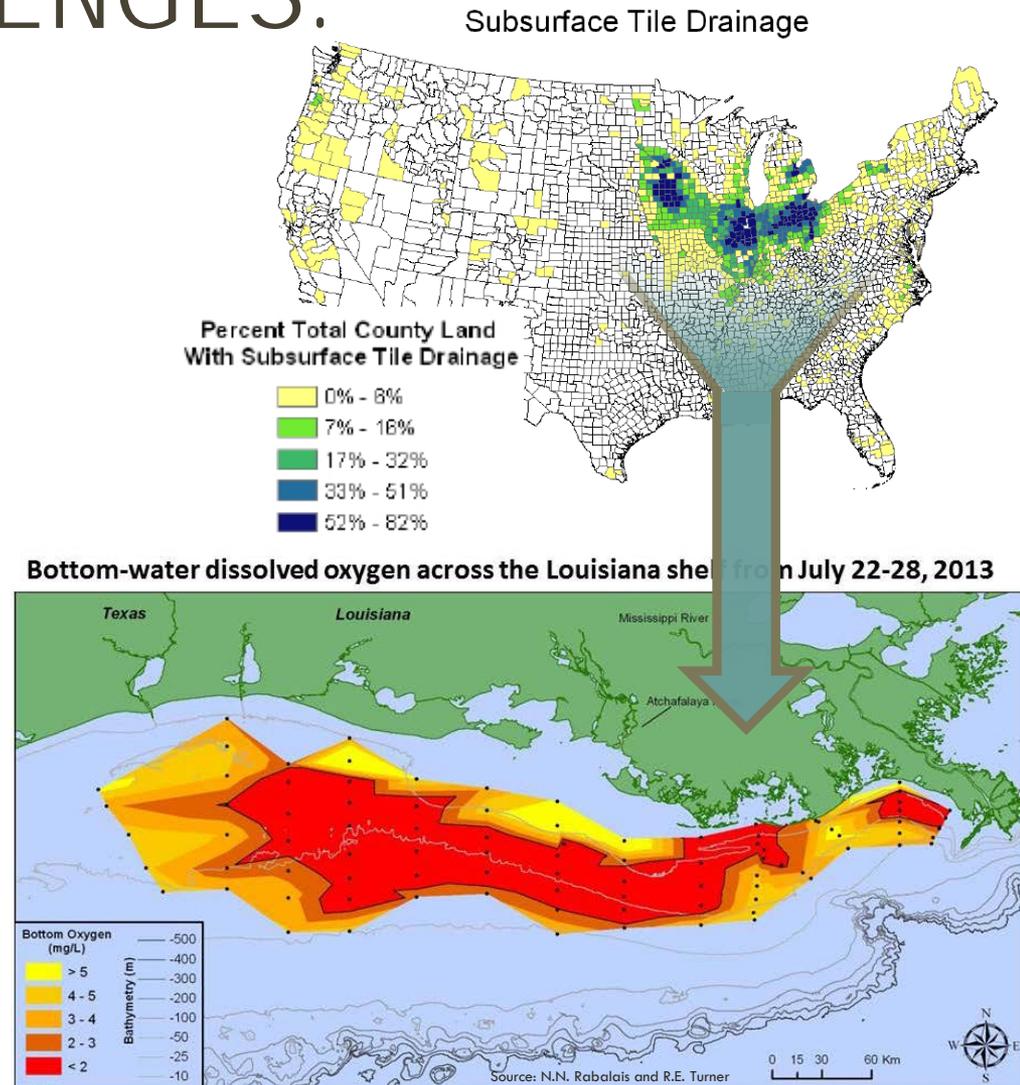
Tile drainage changes the natural hydrology and is a pathway for nutrients to move from our fields.

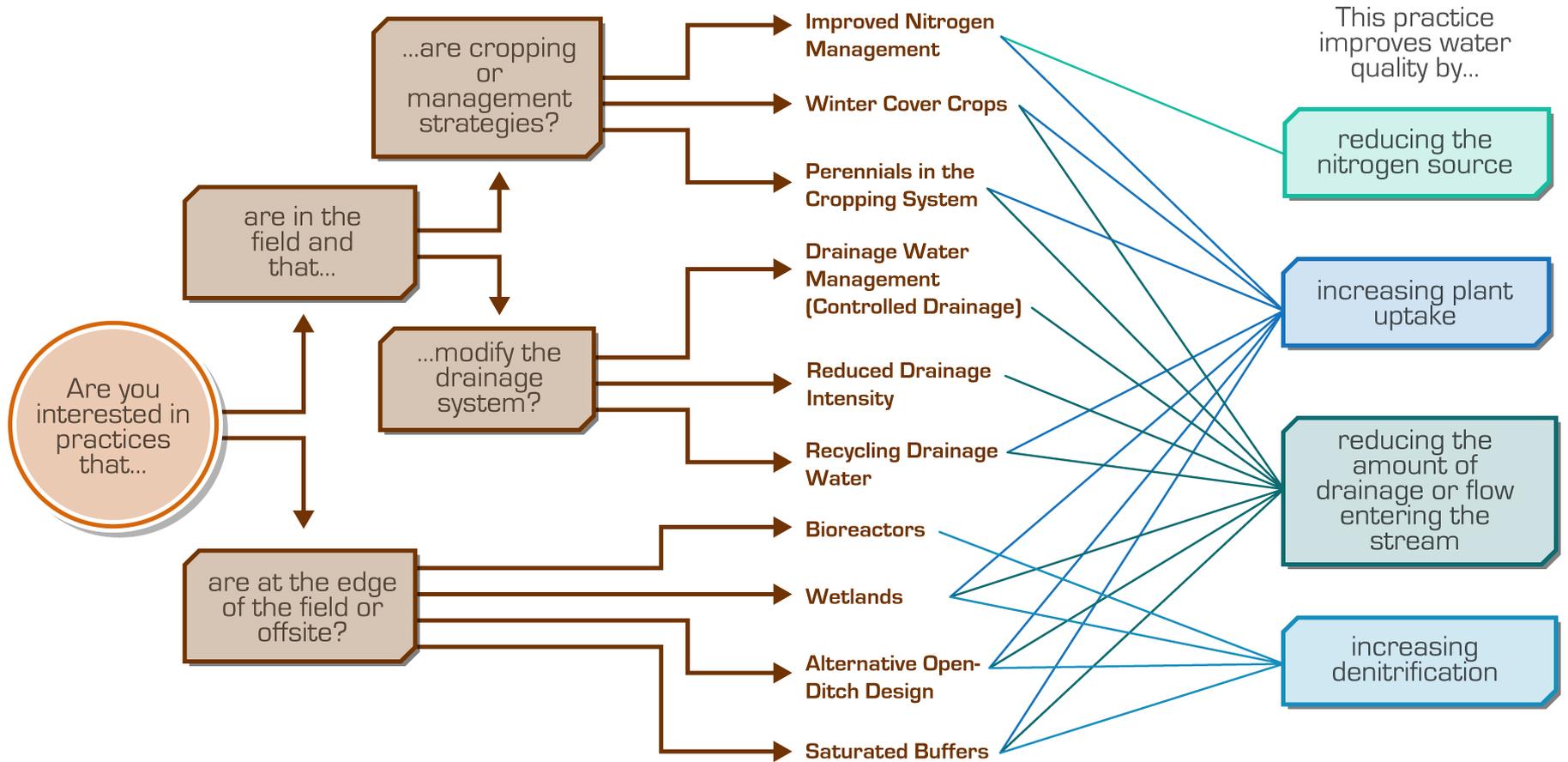


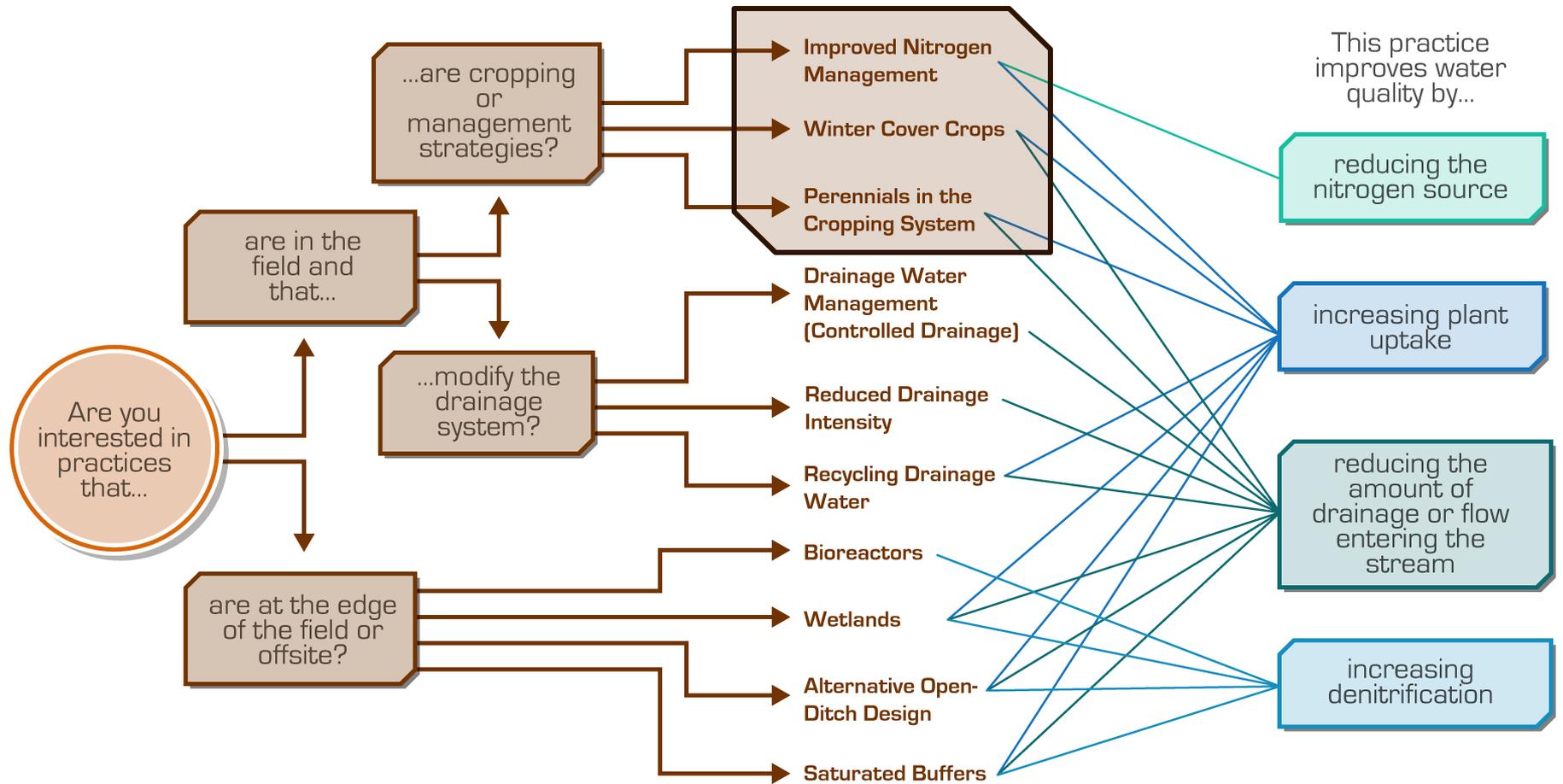
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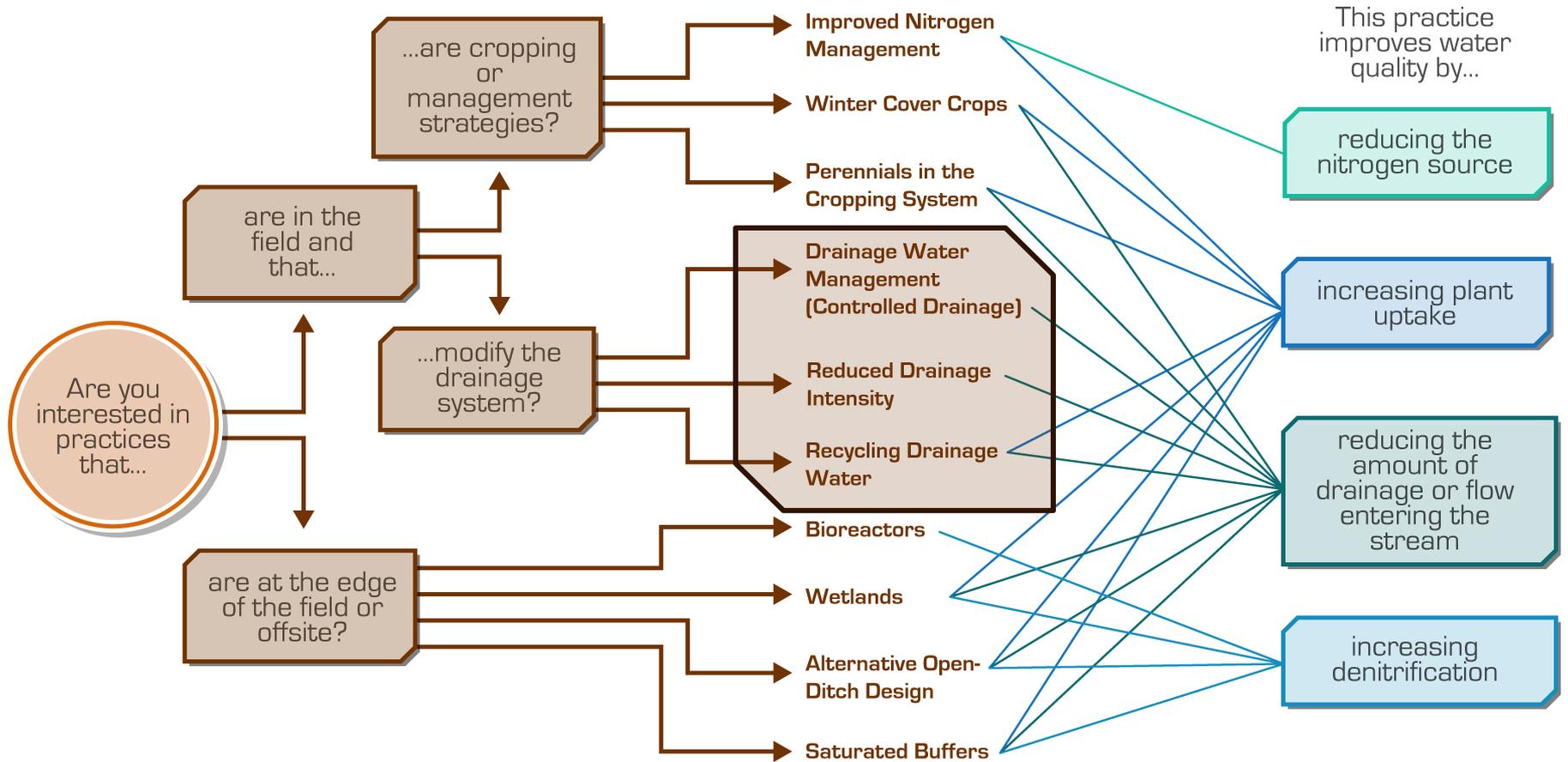
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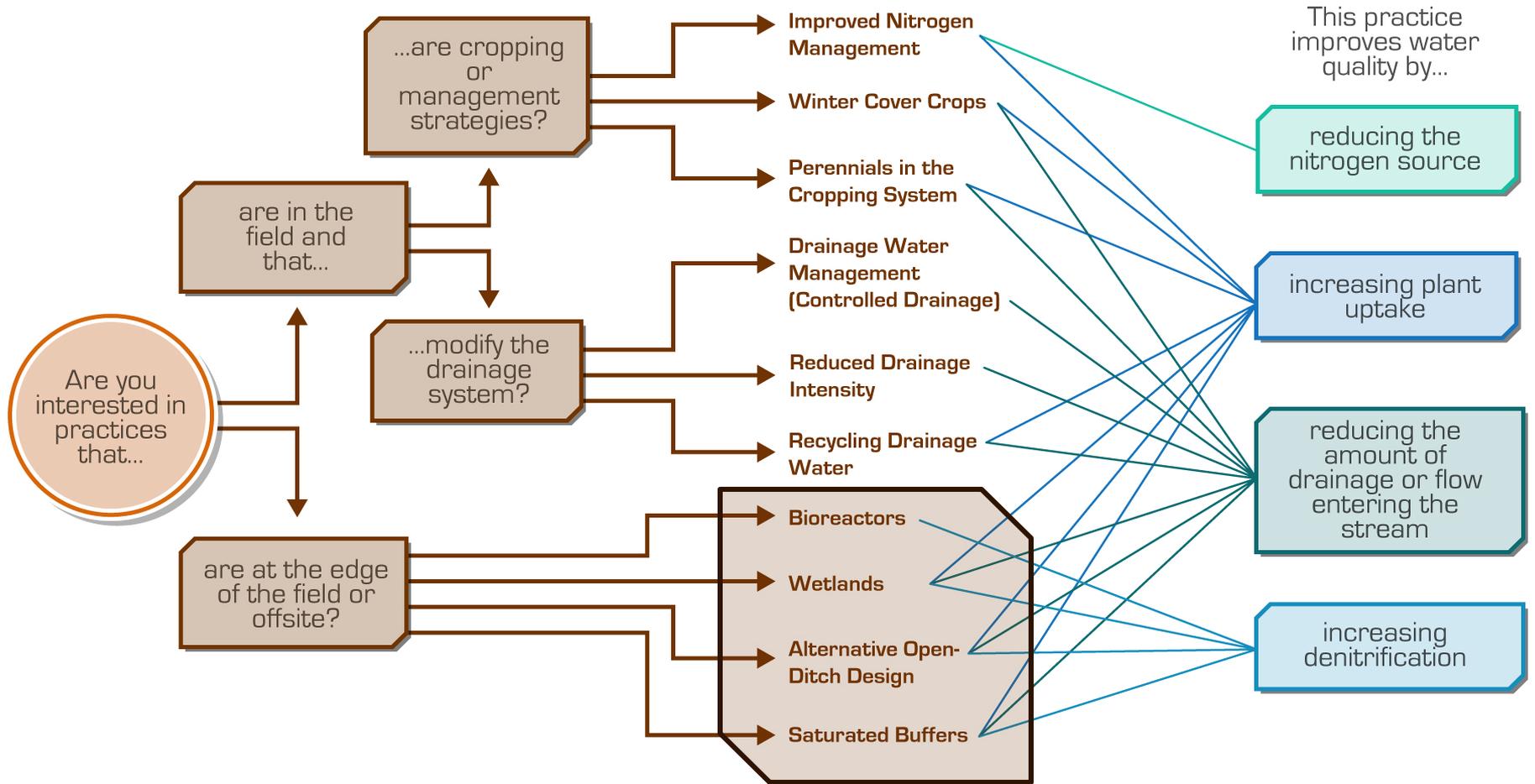
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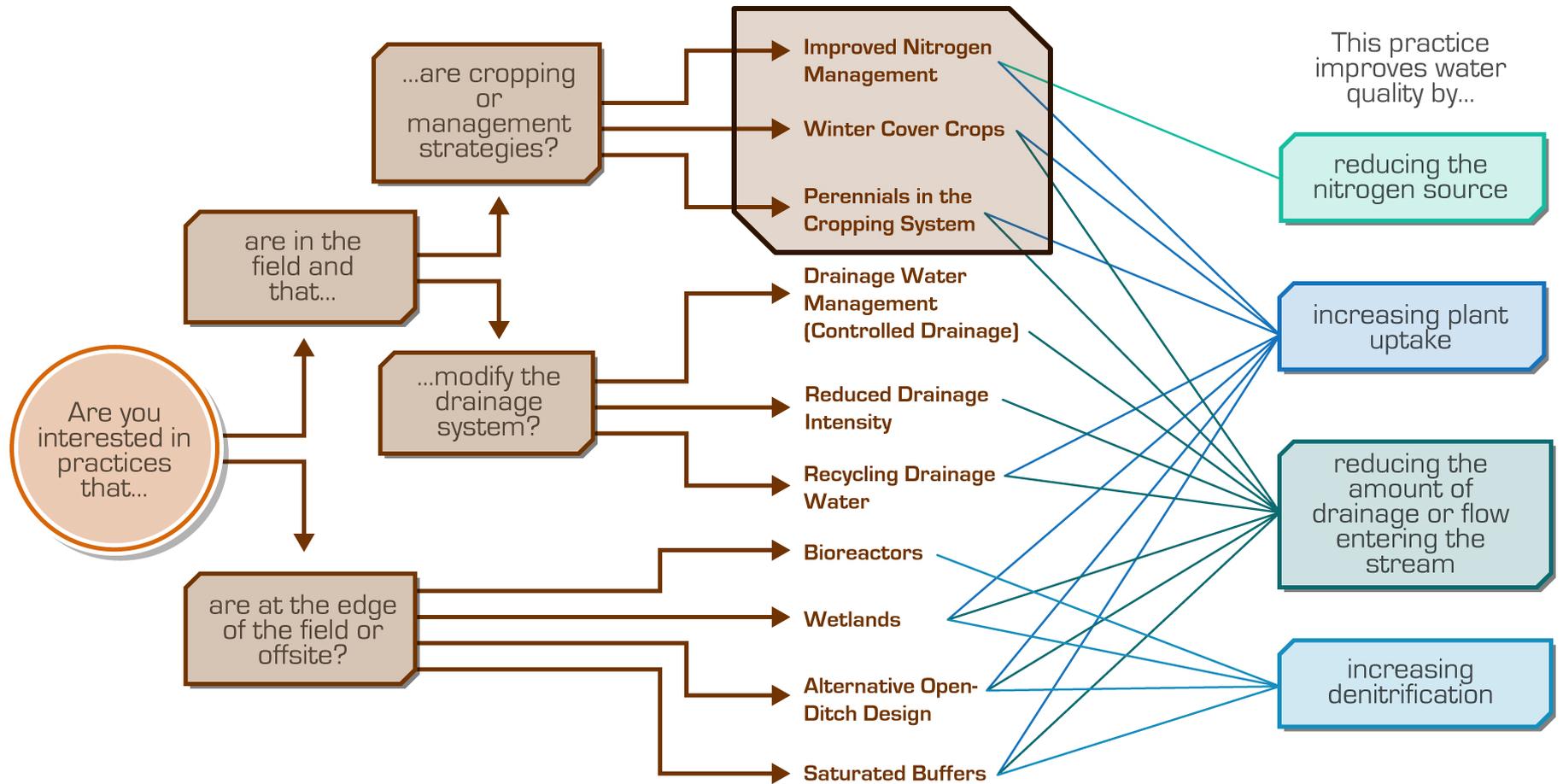












IN-FIELD MANAGEMENT PRACTICE: IMPROVED N MANAGEMENT (4RS)

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



4R Principles of Nutrient Stewardship



RIGHT SOURCE

Matches fertilizer type to crop needs.



RIGHT RATE

Matches amount of fertilizer to crop needs.



RIGHT TIME

Makes nutrients available when crops need them.



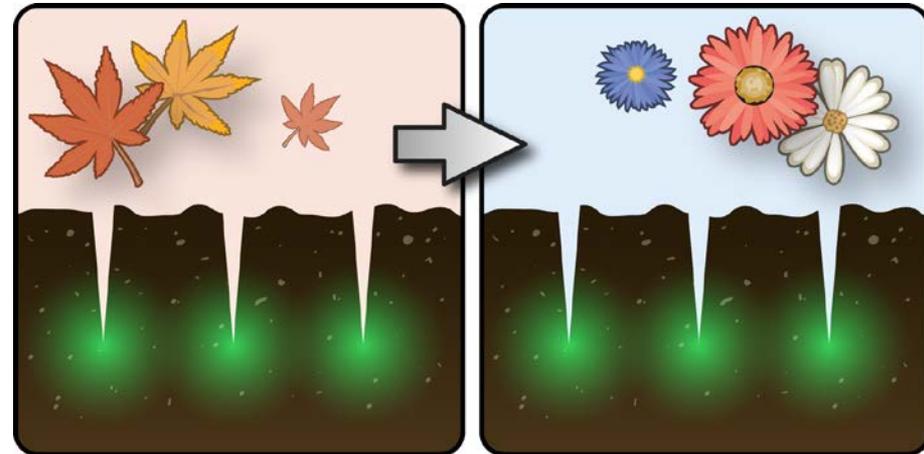
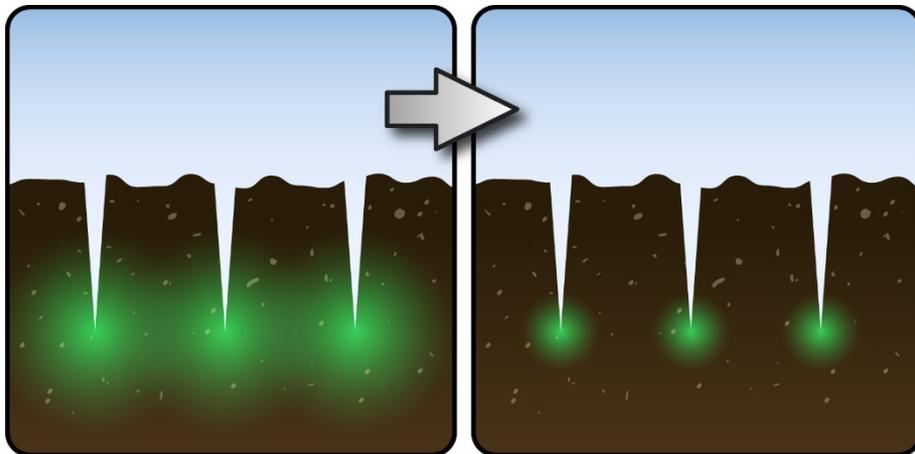
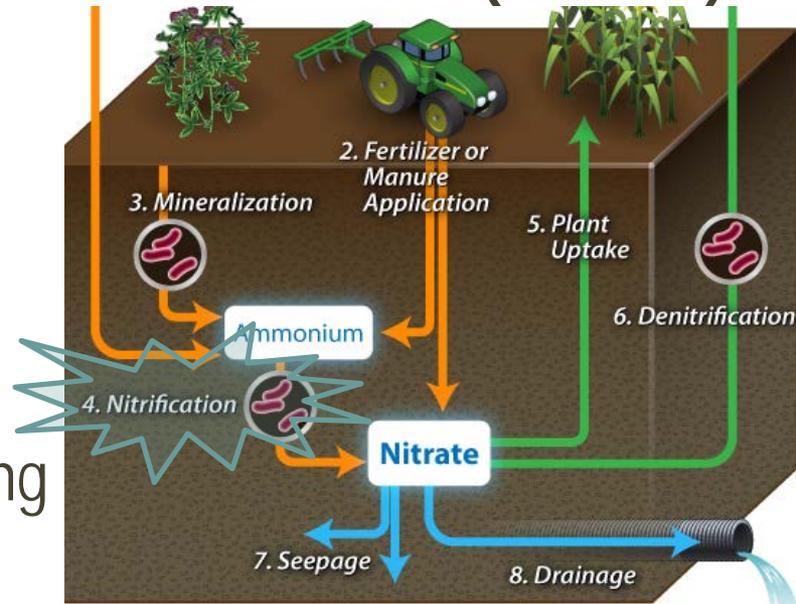
RIGHT PLACE

Keeps nutrients where crops can use them.

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, nitrification inhibitor)



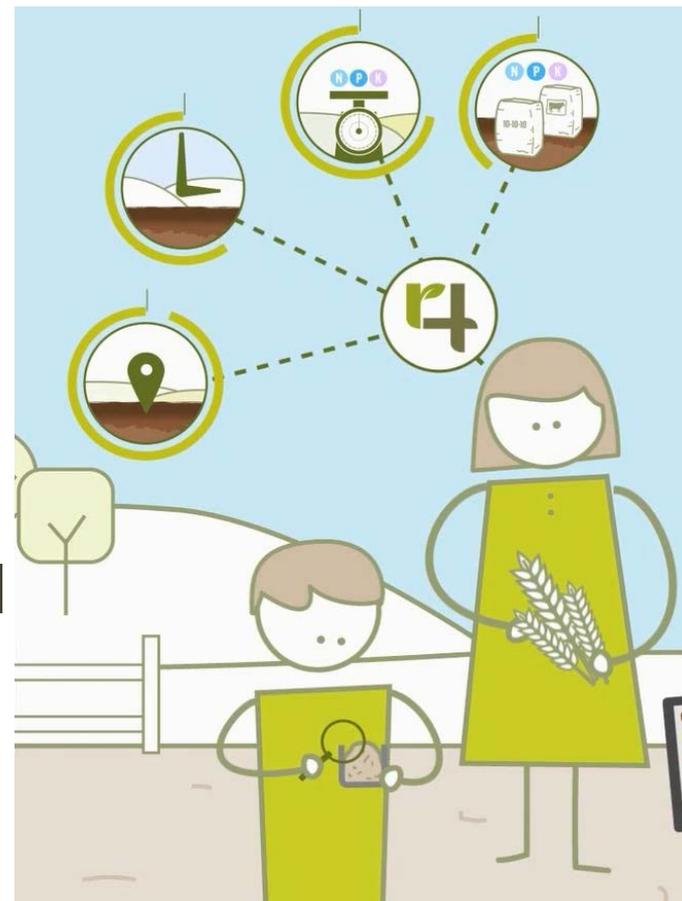
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What is it? Applying “the right source of nutrient, at the right rate, at the right time, and in the right place”

How does it reduce N loss in drainage?
Reduces the source of N (rate) or increasing plant uptake (timing, nitrification inhibitor)

How effective is it? Generally 6-20% annual N loss reduction

Where does it work? Everywhere N is applied



IN-FIELD MANAGEMENT PRACTICE: WINTER COVER CROPS

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



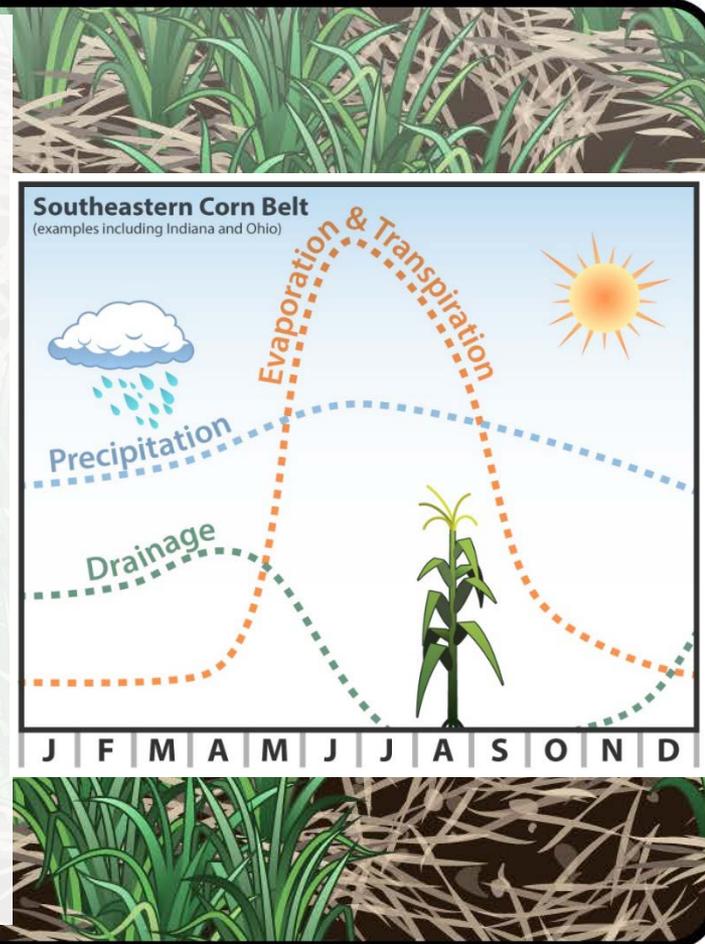
Winter wheat drilled into soybeans following harvest.



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? It takes up water and nitrate from the soil after the main crop is harvested and before the next crop starts growing



IN-FIELD MANAGEMENT PRACTICE: WINTER COVER CROPS

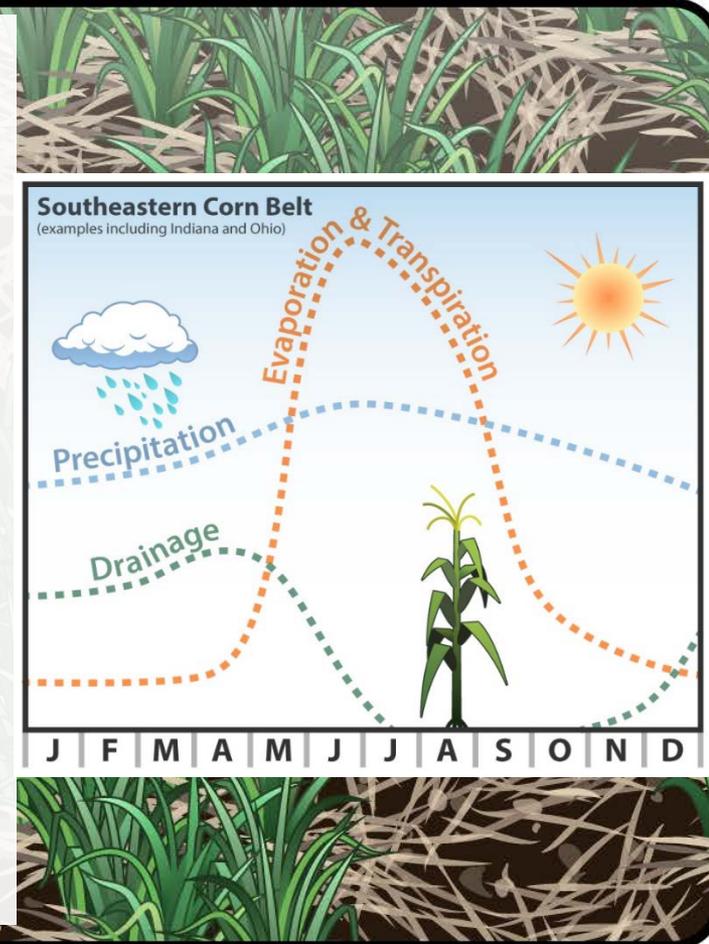
What is it? A crop planted in late fall to cover the soil over the winter

How does it reduce N loss in drainage?

Takes up water and nitrate from the soil over winter

How effective is it? Approximately 30% N loss reduction in the IA and IL Strategies

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



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 soil over winter

How effective is it? Approximately a 50% loss reduction in the IA and IL Strategies

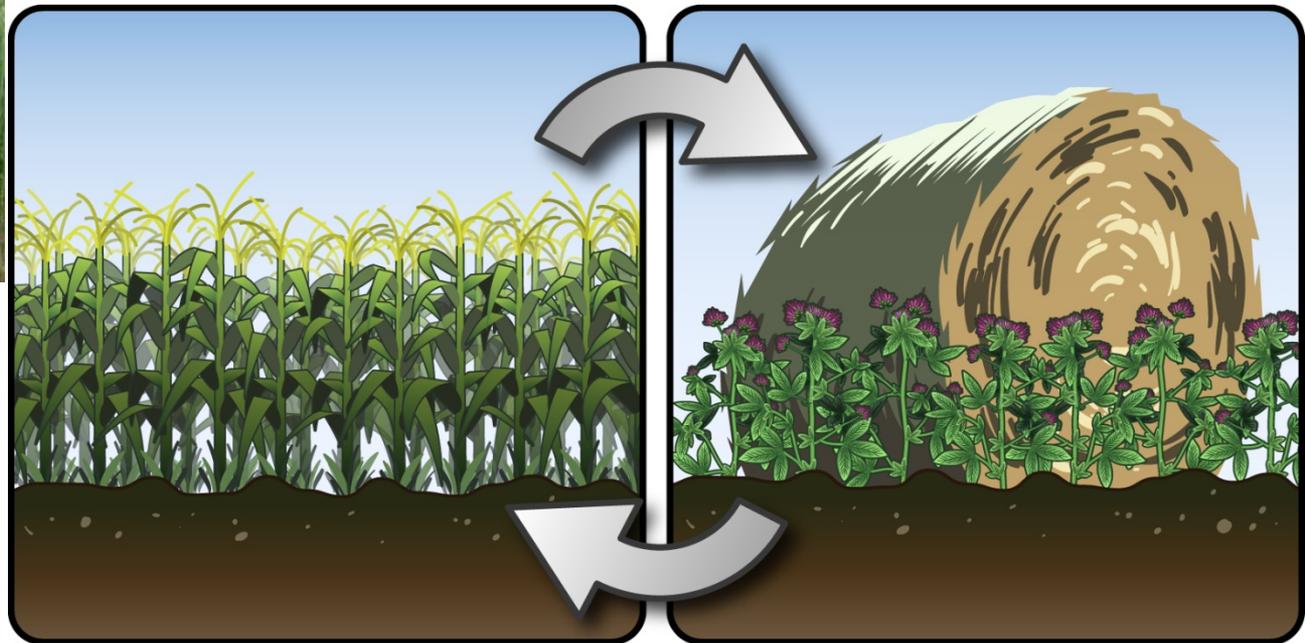
Where does it work? Robust establishment is the most important for water quality benefits

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

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

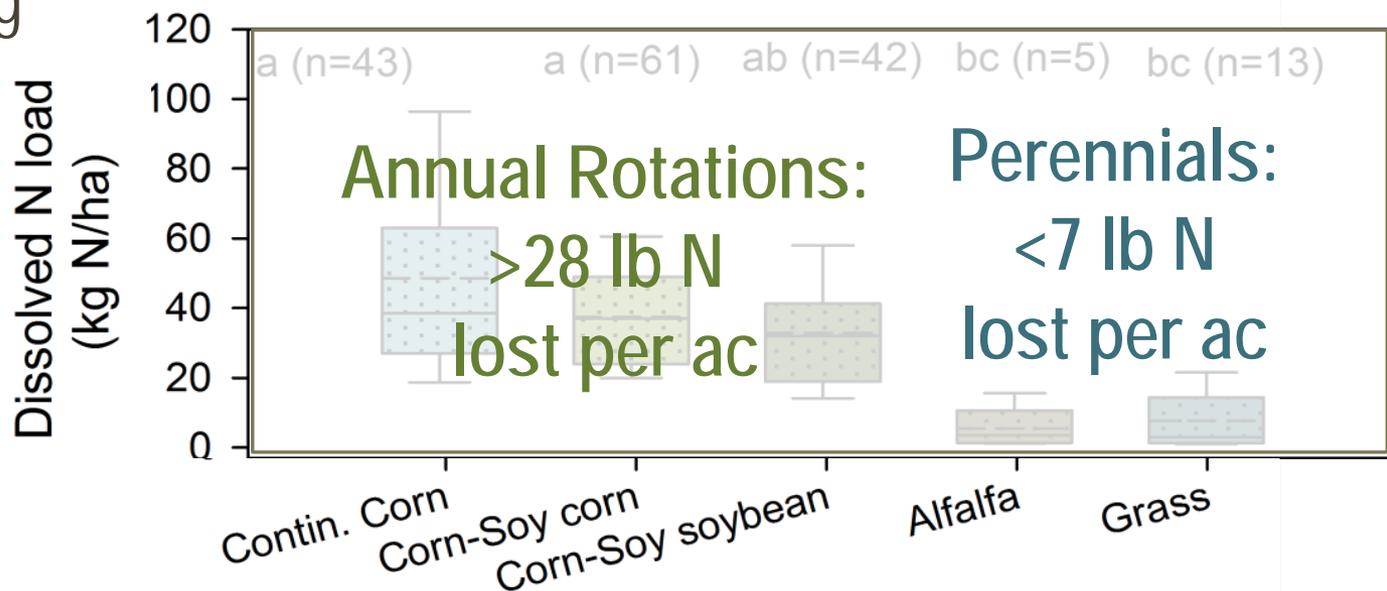


IN-FIELD MANAGEMENT PRACTICE: PERENNIALS IN THE ROTATION

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

Based on a recent meta-analysis of drainage studies:



IN-FIELD MANAGEMENT PRACTICE:

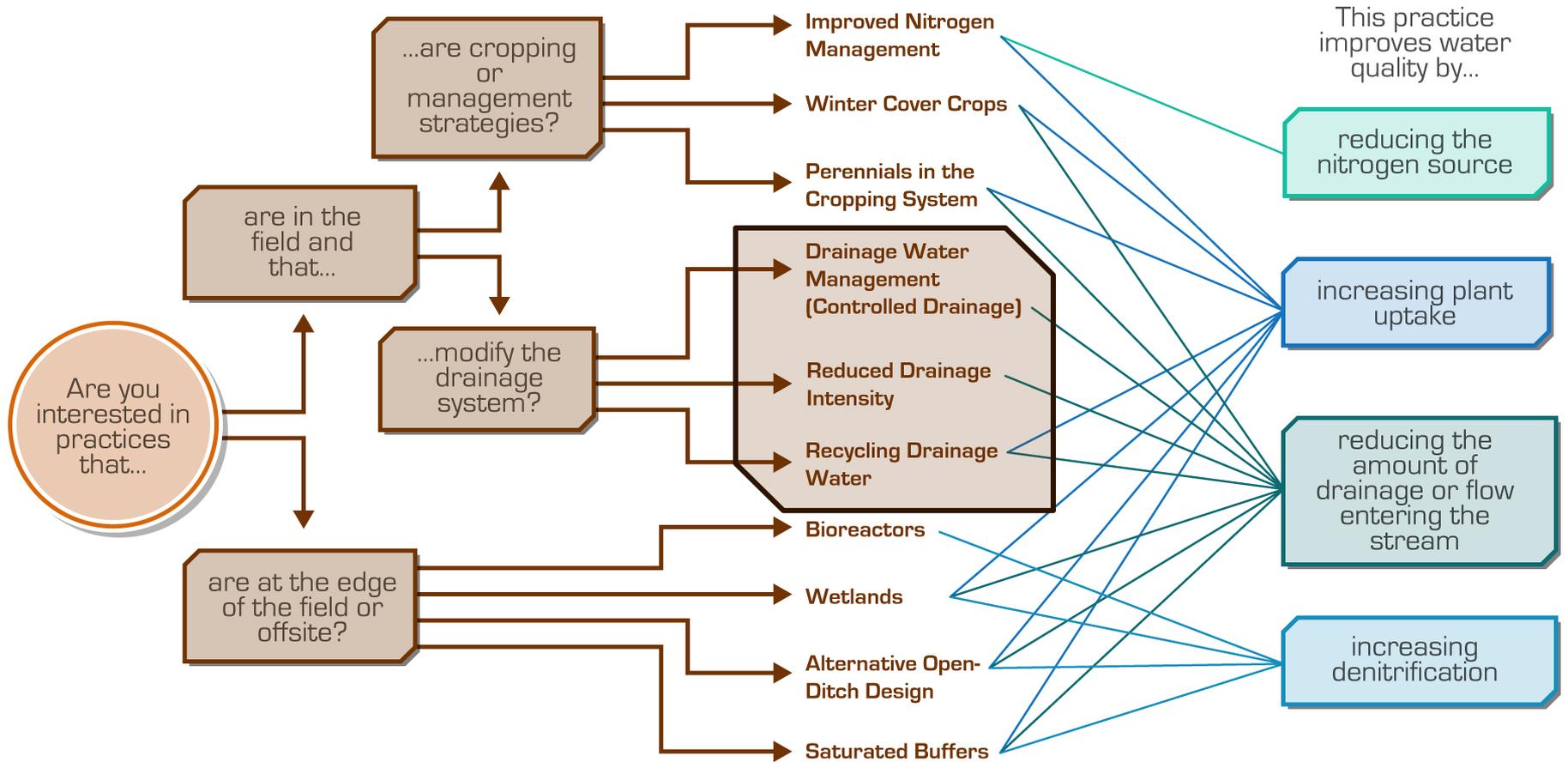
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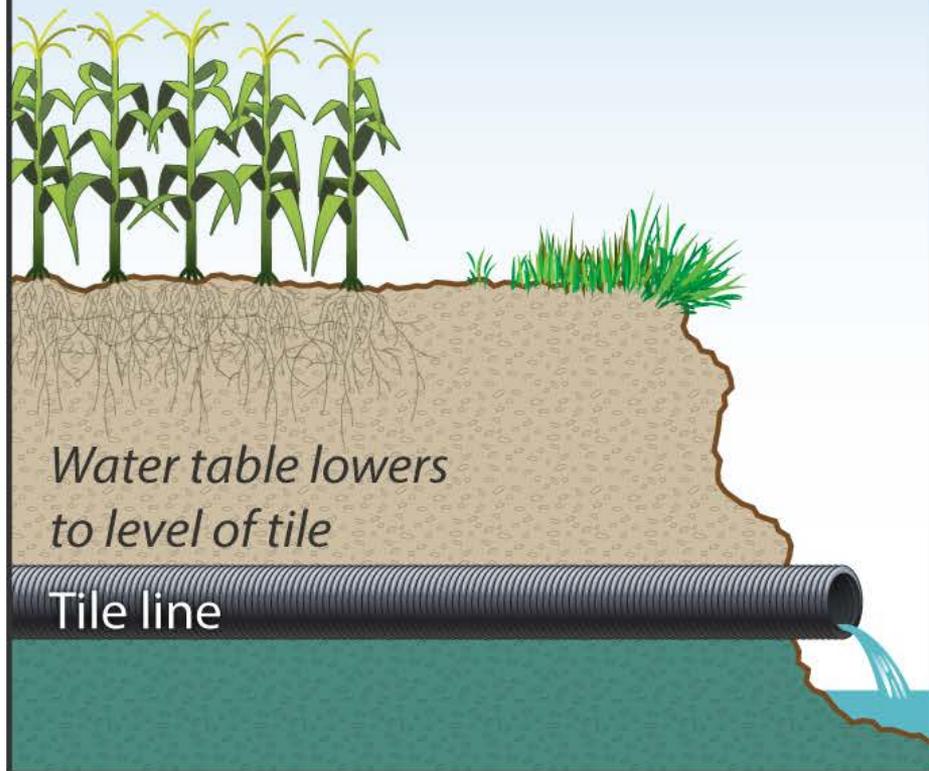
How effective is it? 72-95% annual N loss reduction in the IA, MN, and IL Nutrient Strategies

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

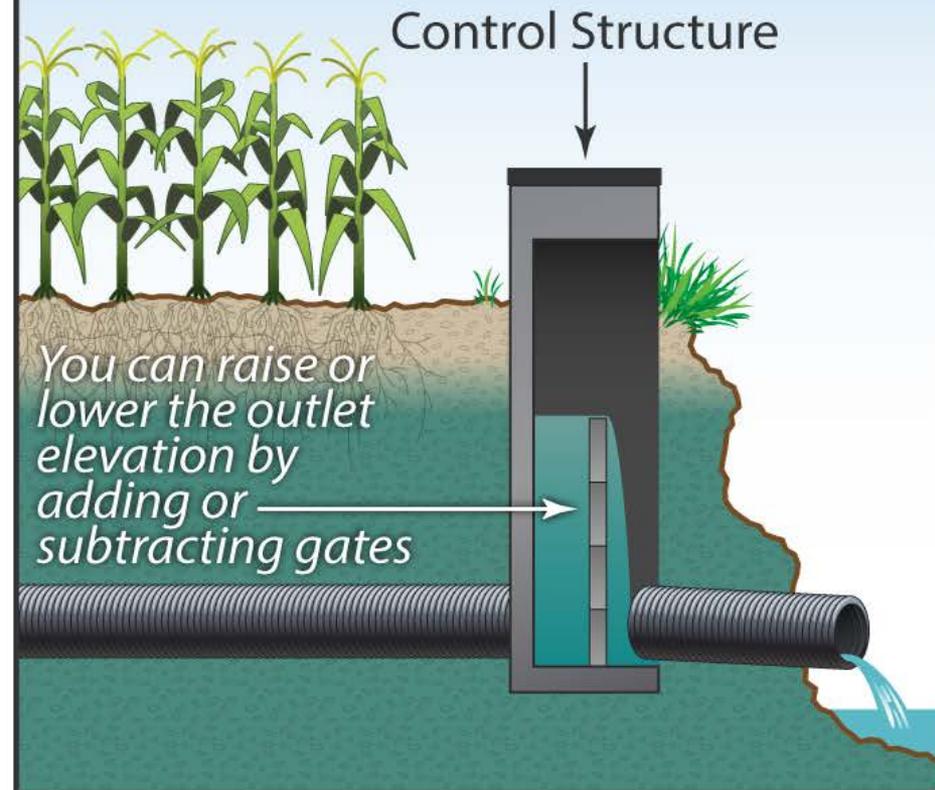


IN-FIELD DRAINAGE SYSTEM PRACTICE: DRAINAGE WATER MANAGEMENT

Conventional Drainage



Controlled Drainage

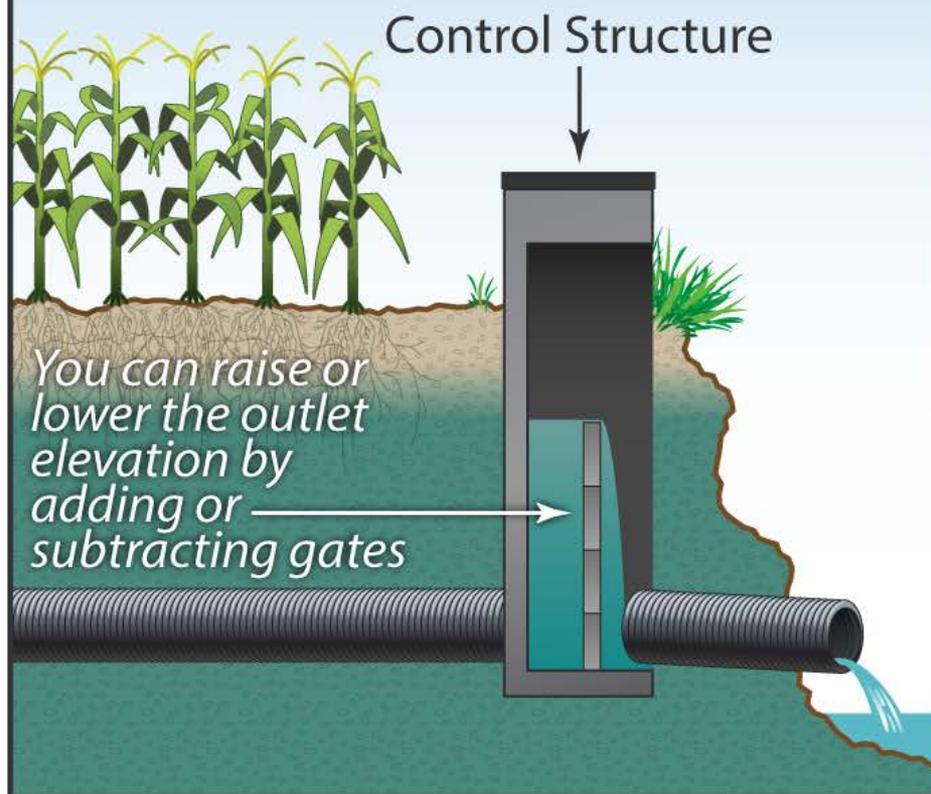


IN-FIELD DRAINAGE SYSTEM PRACTICE: DRAINAGE WATER MANAGEMENT

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



Controlled Drainage



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 soil during periods when drainage isn't critical

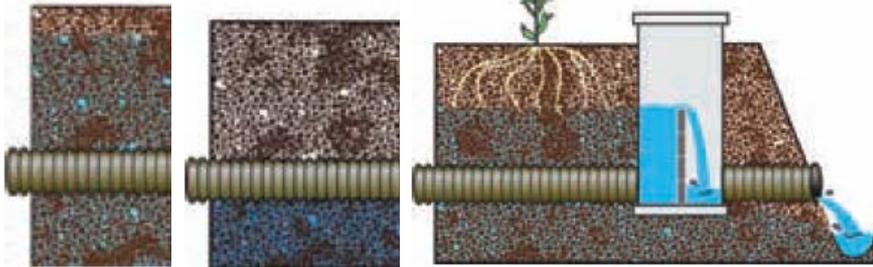
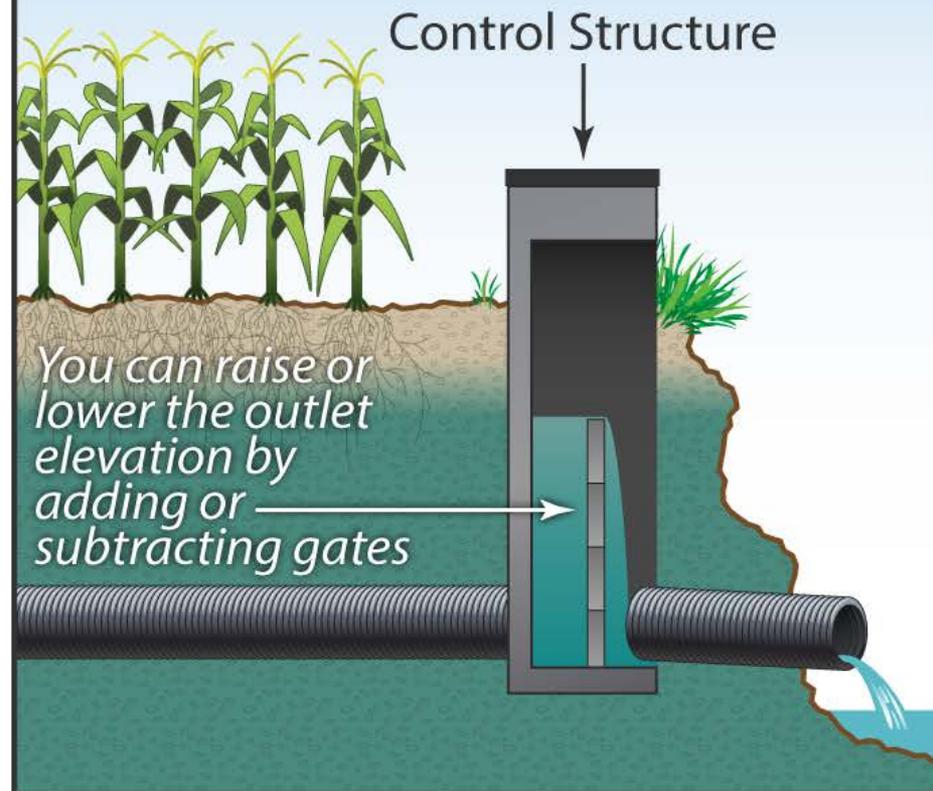


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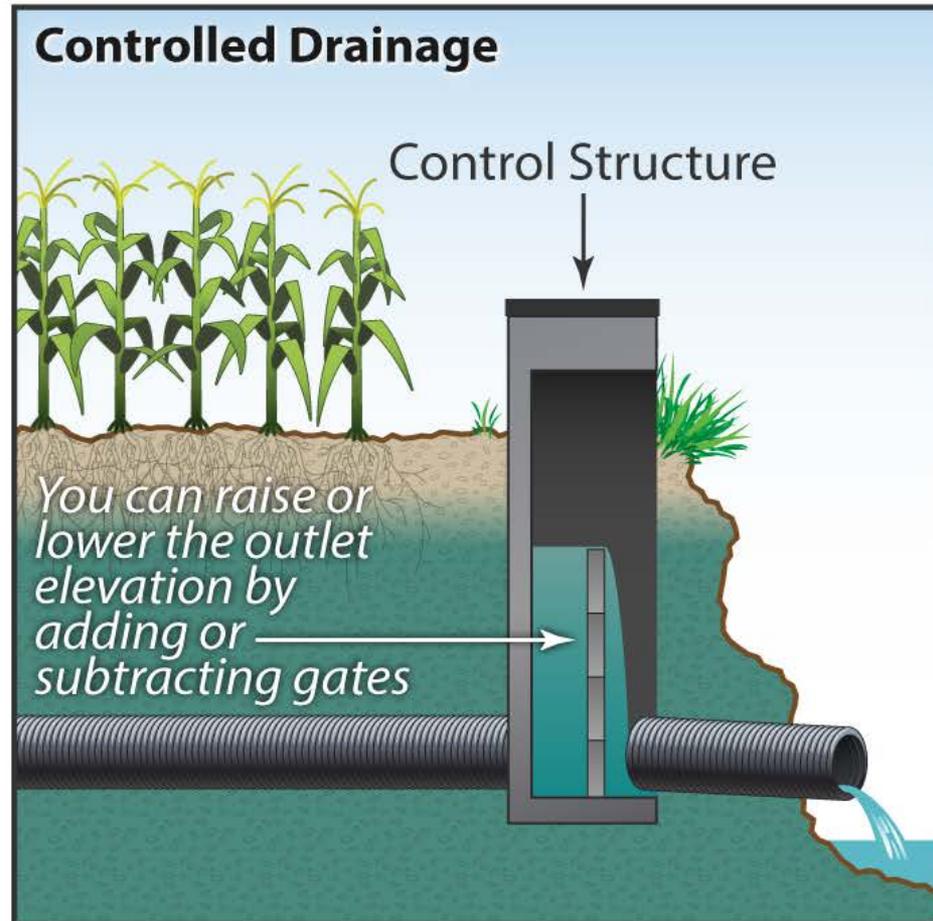
Figure 3. The outlet is raised after planting to potentially store water for crops.

Controlled Drainage

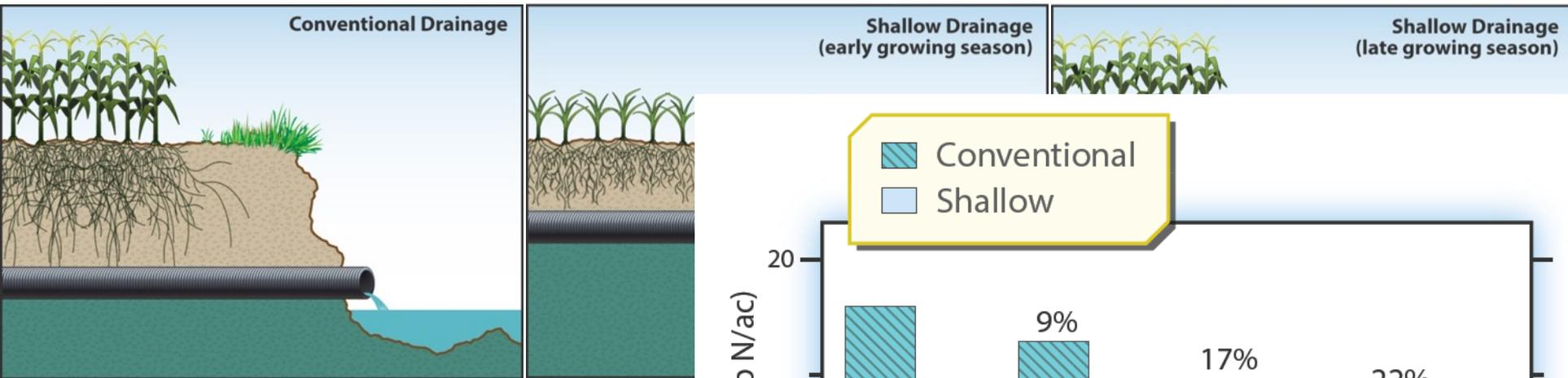


IN-FIELD DRAINAGE SYSTEM PRACTICE: DRAINAGE WATER MANAGEMENT

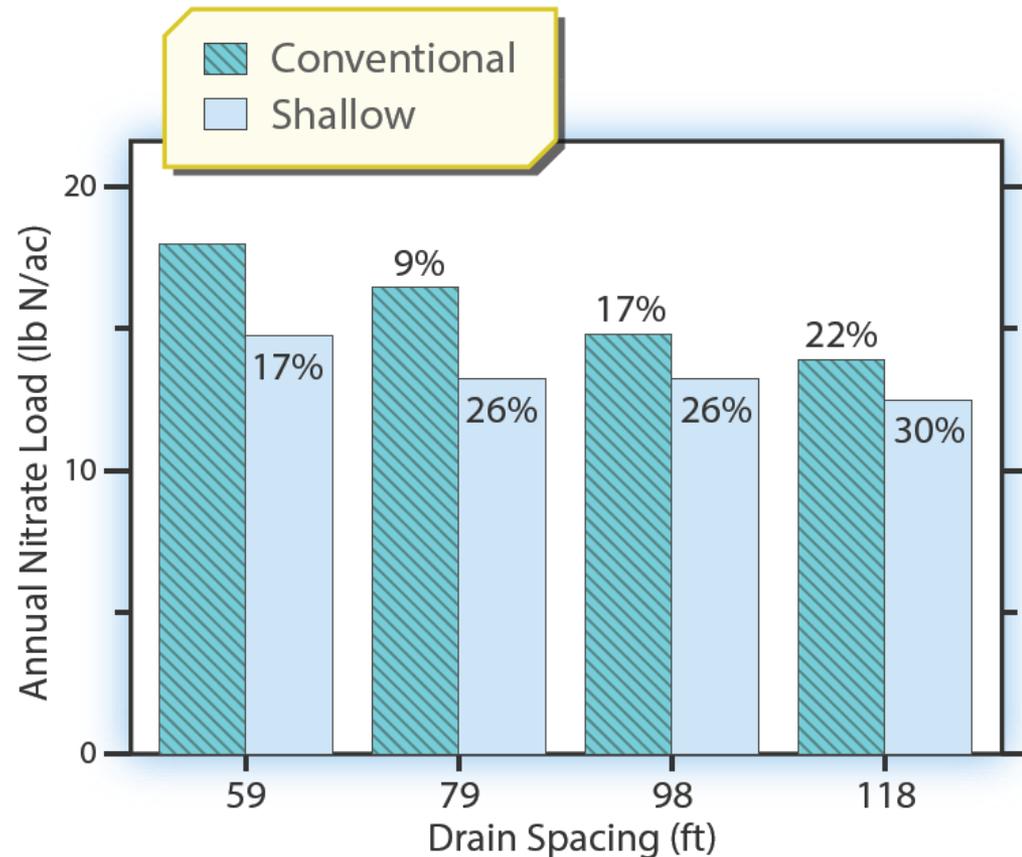
What is it? Adjustable structures
How does it reduce N loss in drainage? Holds back water and nitrate in the water
How effective is it? Generally a 30% N loss reduction (15-75%)
Where does it work? Most practical on slopes of $<0.5\%$ because more structures are needed with steeper slopes



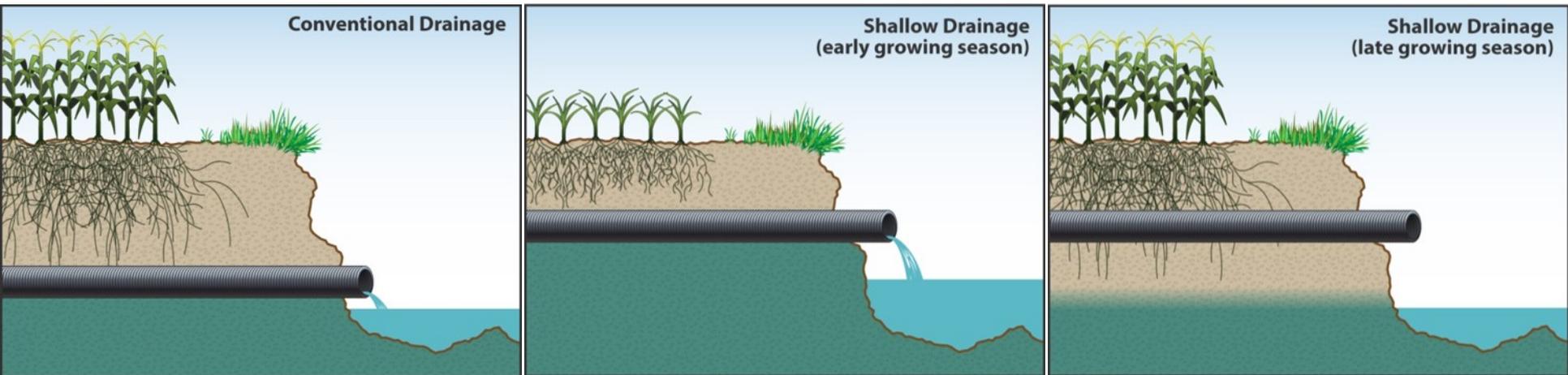
IN-FIELD DRAINAGE SYSTEM PRACTICE: REDUCED DRAINAGE INTENSITY



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



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? Approximately a 20-30% annual N loss reduction

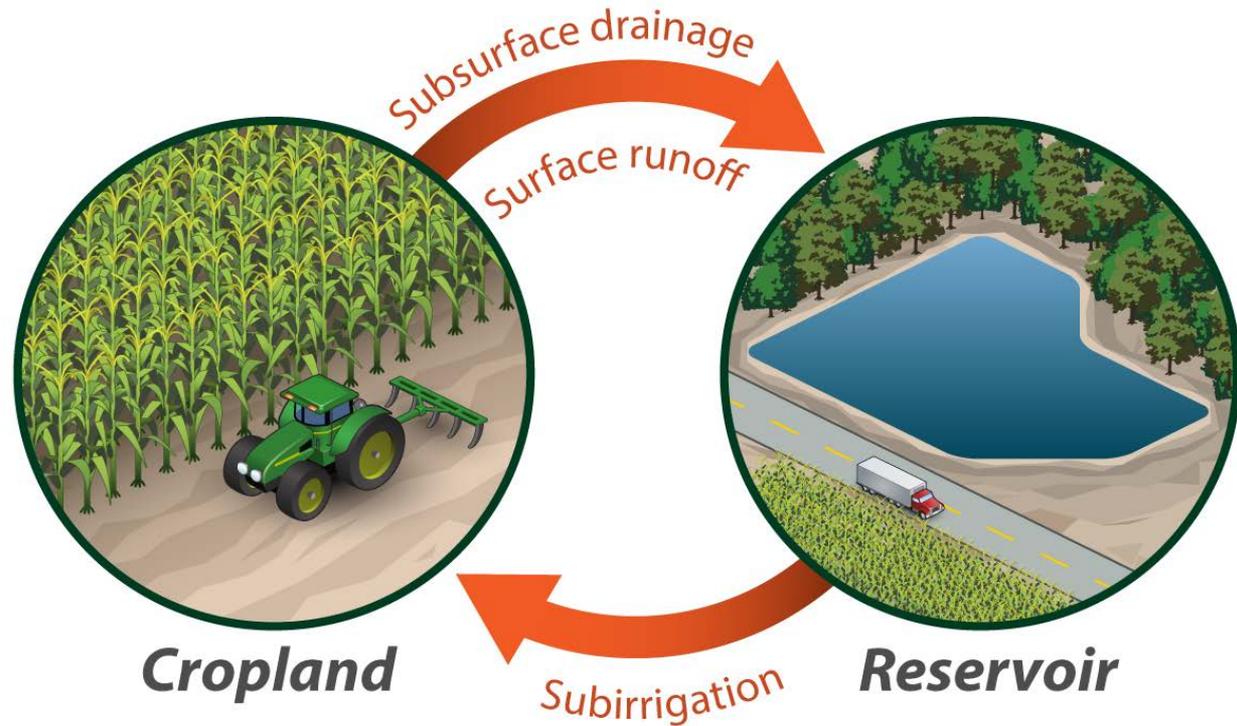
Where does it work? Anywhere subsurface drainage is installed

IN-FIELD DRAINAGE SYSTEM PRACTICE: RECYCLING DRAINAGE WATER

What is it? Drainage water is stored in a pond or reservoir and then returned 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



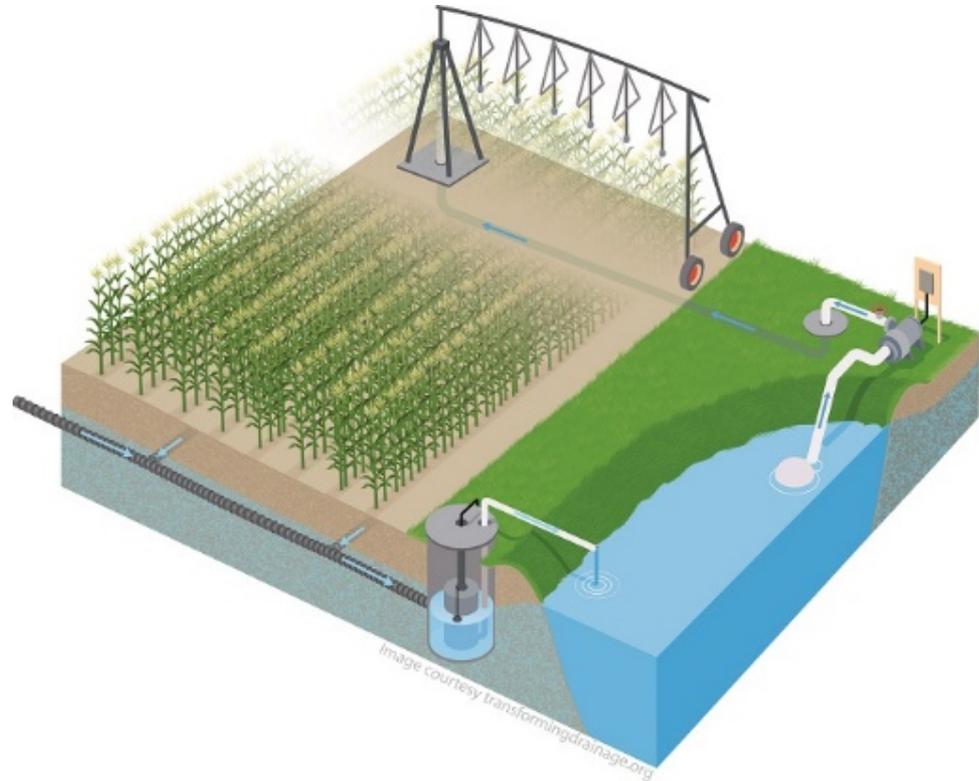
IN-FIELD DRAINAGE SYSTEM PRACTICE: RECYCLING DRAINAGE WATER

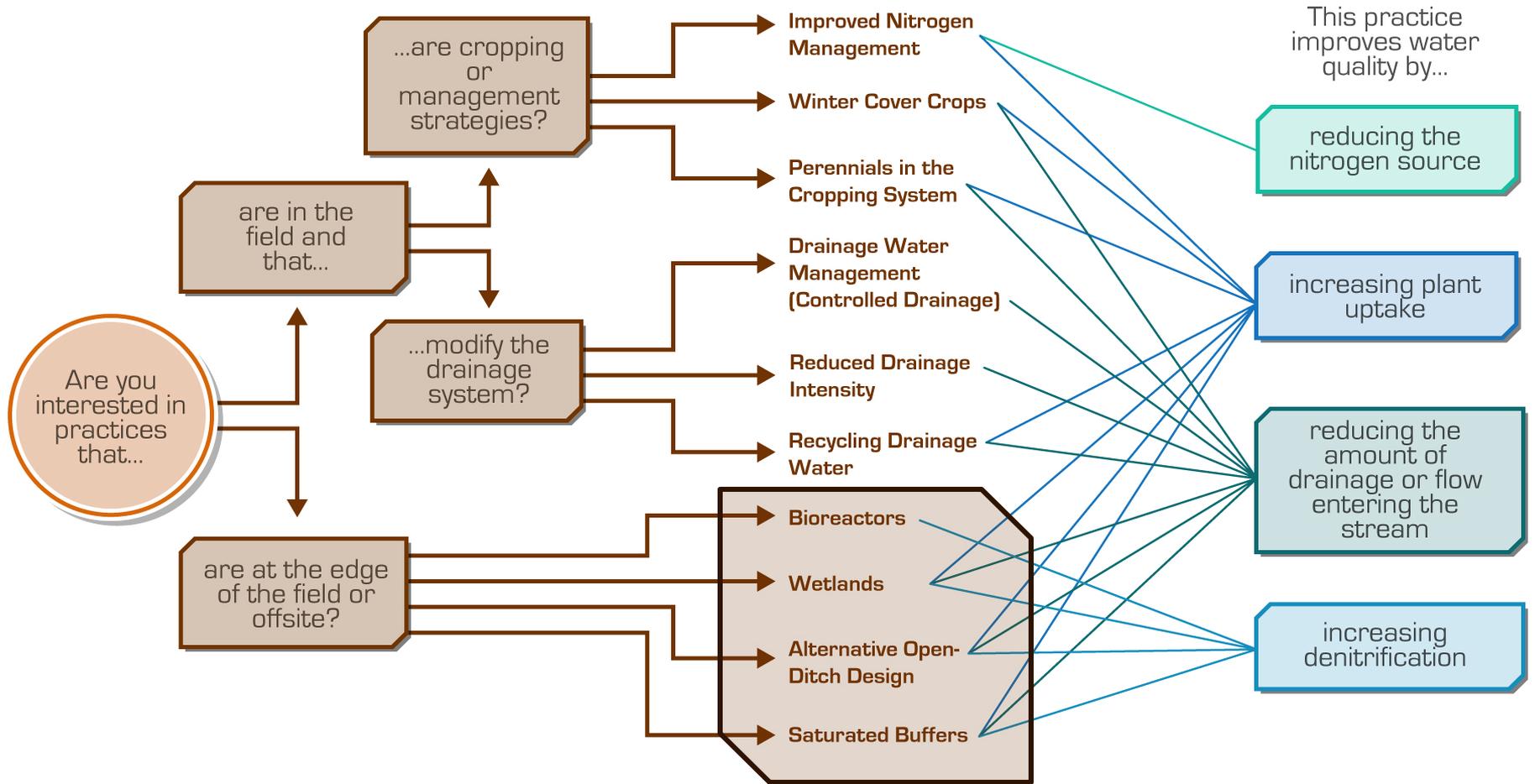
What is it? Store drainage water for later crop application

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

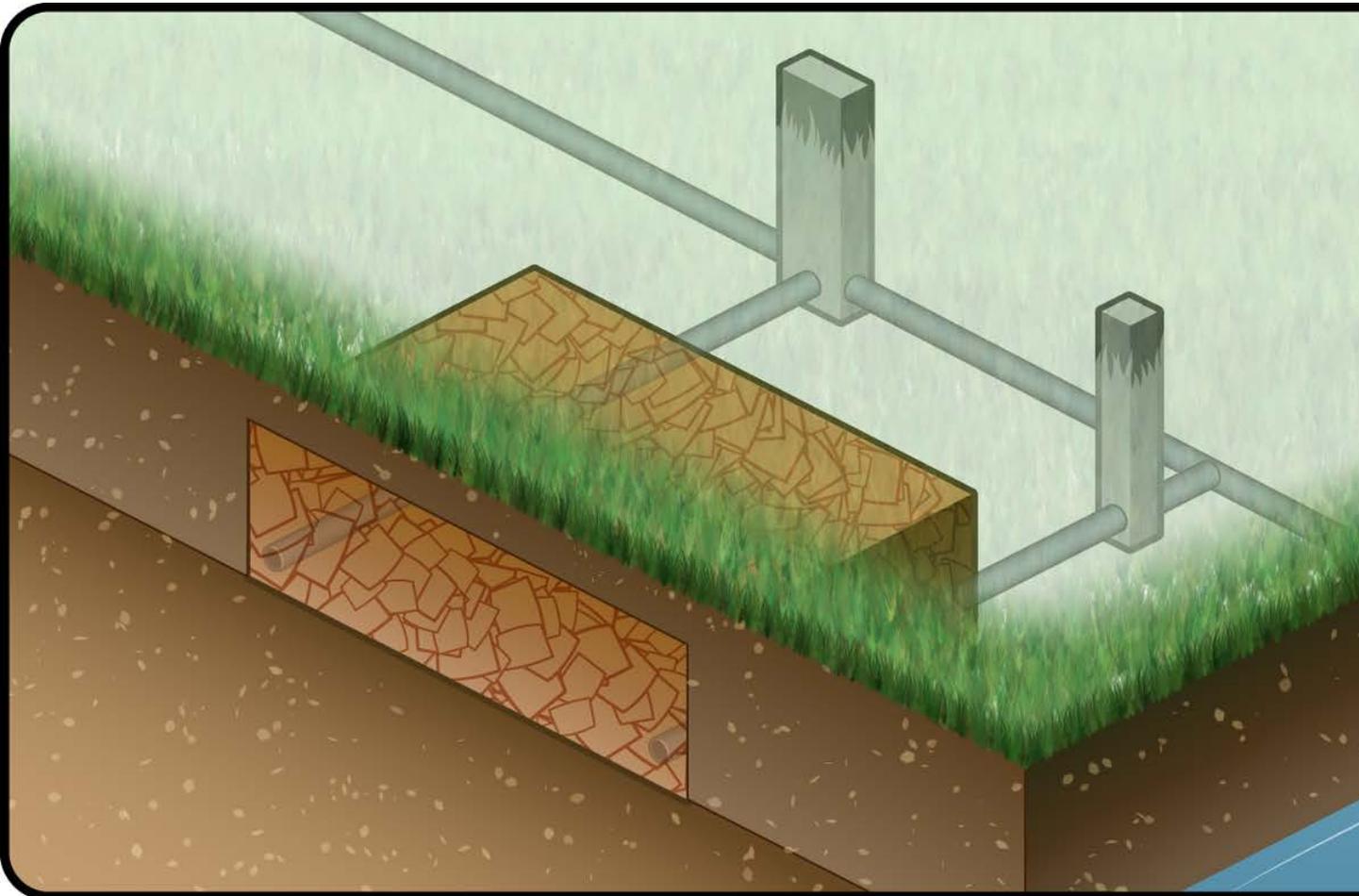
How effective is it?
Shows good potential, but is very new

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



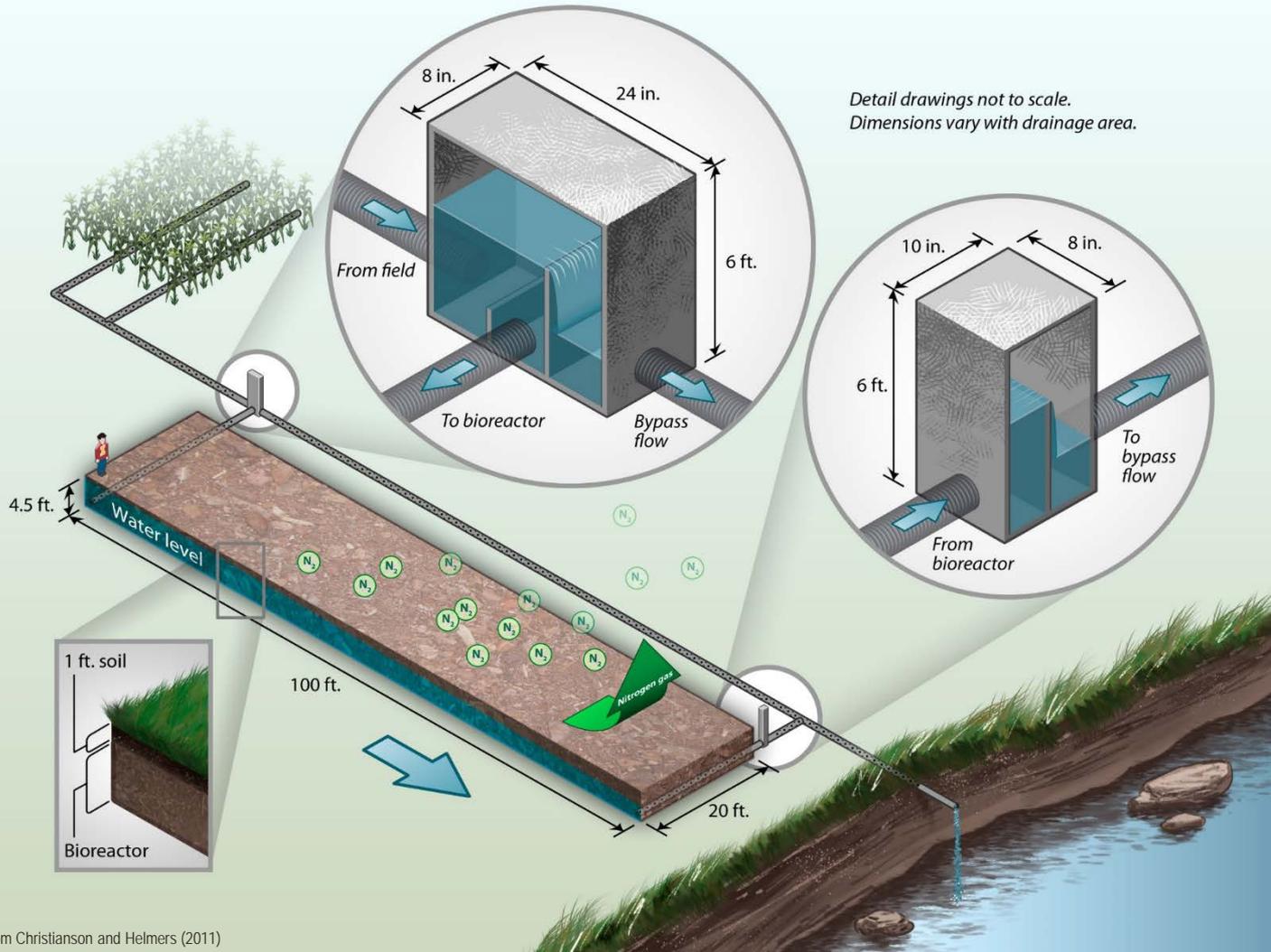


EDGE-OF-FIELD OR OFF-SITE PRACTICE:
WOODCHIP BIOREACTORS



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

EDGE-OF-FIELD OR OFF-SITE PRACTICE: WOODCHIP BIOREACTORS



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



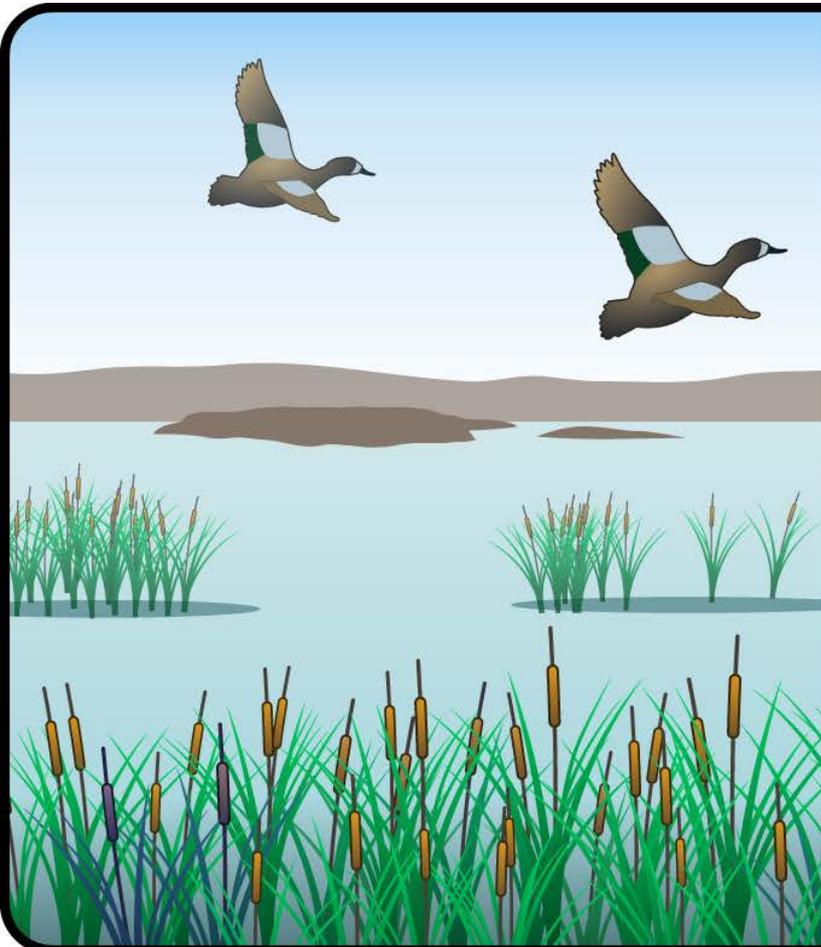
What is it? Woodchip-filled trench

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

How effective is it? 25-45% annual N loss reduction

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

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

EDGE-OF-FIELD OR OFF-SITE PRACTICE: WETLANDS



What is it? Constructed wetlands are dynamic ecosystems

How does it work? **drainage?** **like,** and **reduces**

How effective? **annual N** **loss** **retention, wildlife** **habitat...**

Where are they used? **concerns about** **the cost** **and** **out of production** **limits widespread implementation**

Lots of additional benefits!

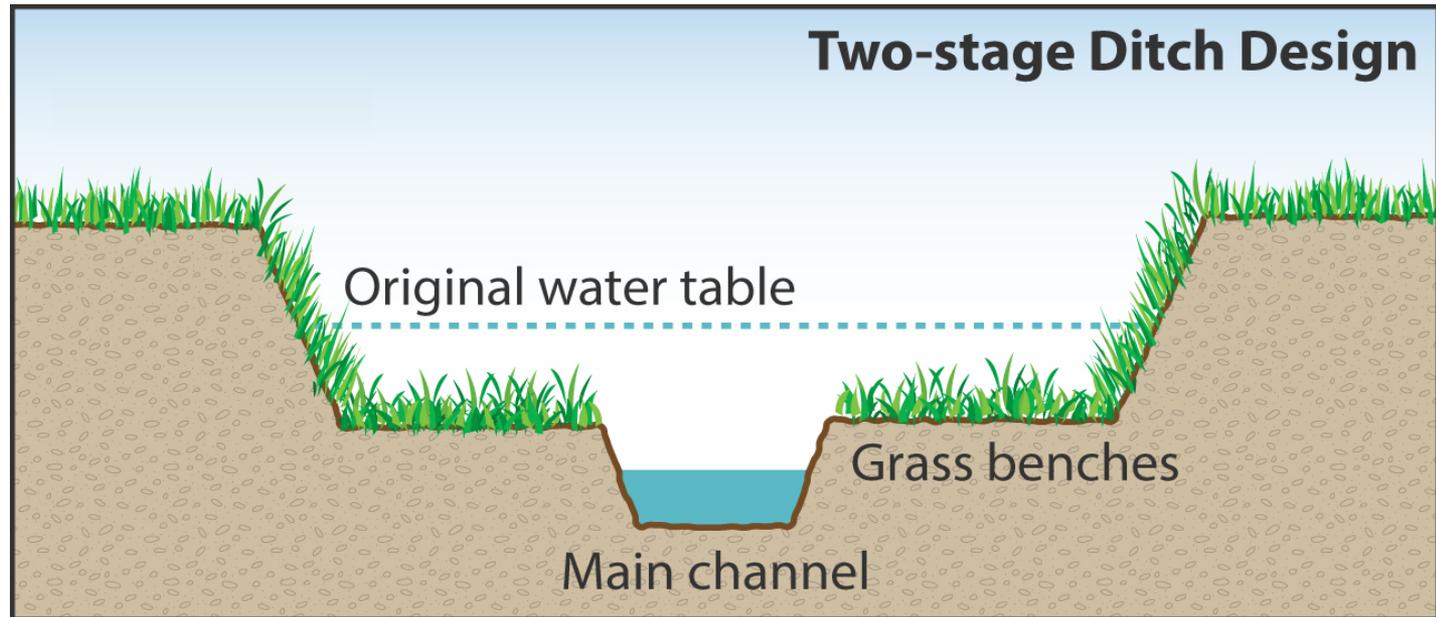
Flood retention, wildlife habitat...

EDGE-OF-FIELD OR OFF-SITE PRACTICE:

ALTERNATIVE DITCH DESIGN (TWO-STAGE DITCH)

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

EDGE-OF-FIELD OR OFF-SITE PRACTICE:

ALTERNATIVE DITCH DESIGN (TWO-STAGE DITCH)

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

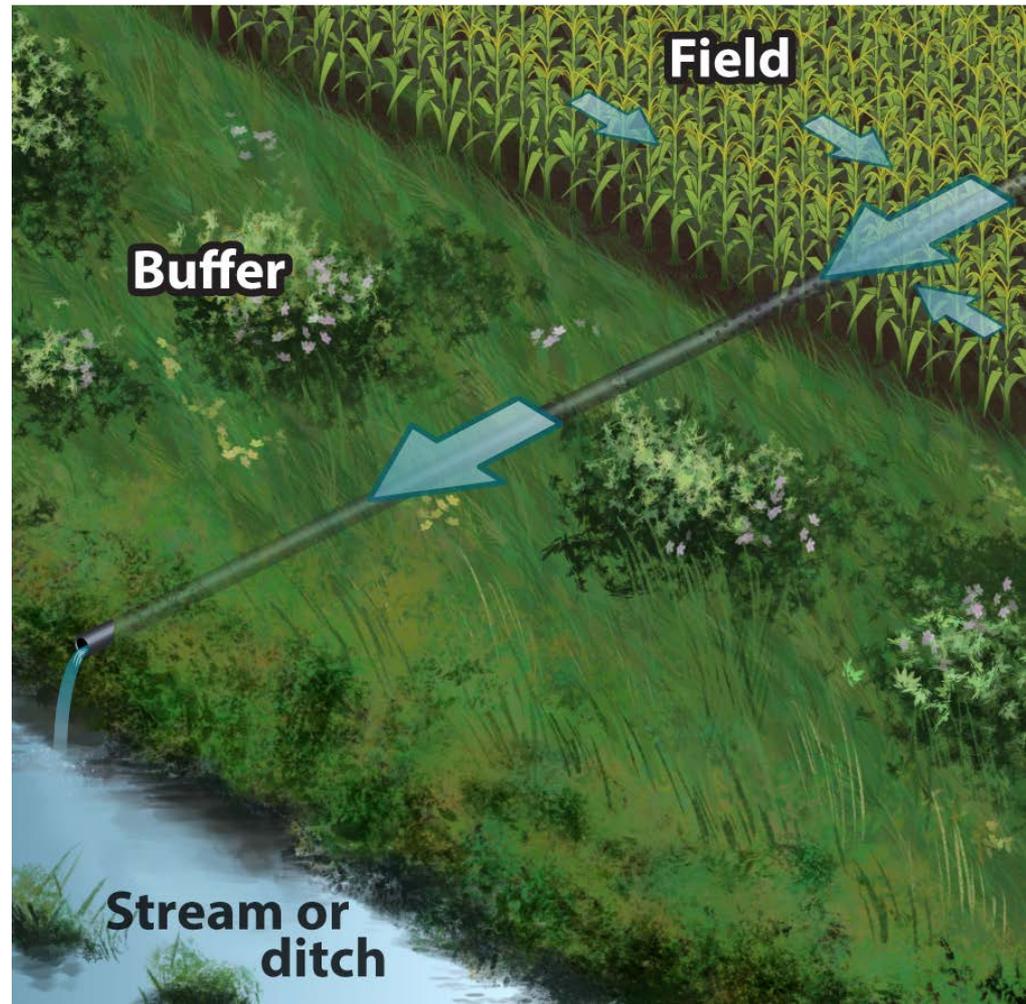
Where does it work? Where there are existing ditches; ditch may need to be widened, but may reduce cleanout costs



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

Conventional Outlet

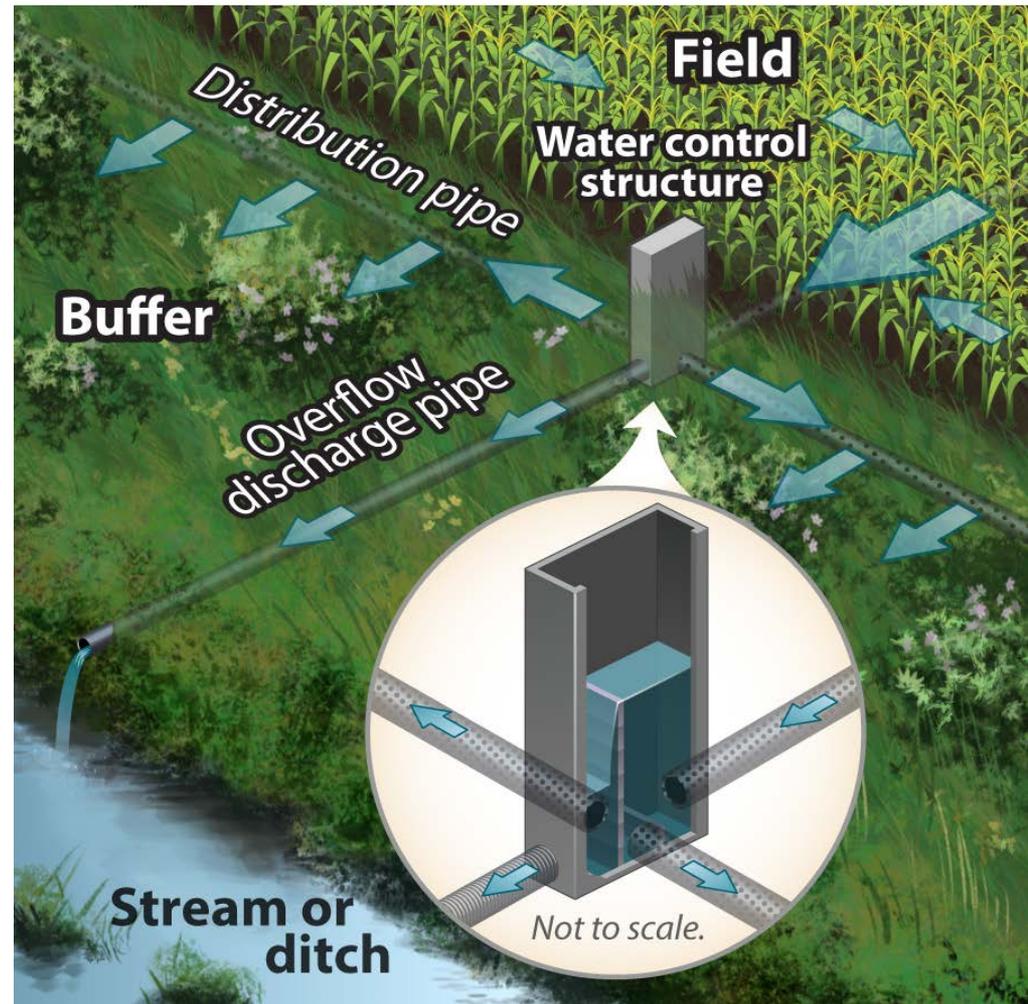


EDGE-OF-FIELD OR OFF-SITE PRACTICE: SATURATED BUFFERS

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

Outlet with Saturated Buffer



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? 20-50% annual N loss reduction, but more research is needed

Where does it work? Where there is a buffer or room for one; Organic rich soil



SUMMARY

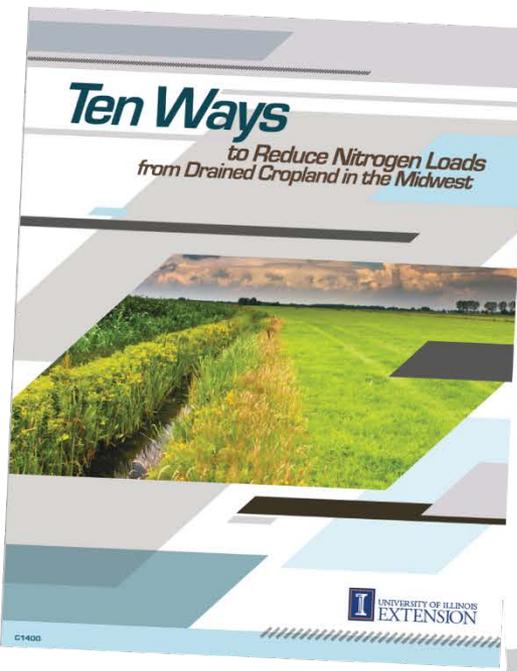
Practices to reduce N loads in drainage vary in:

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

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

TEN WAYS TO REDUCE NITROGEN LOADS FROM DRAINED CROPLAND IN THE MIDWEST

1. 44 page booklet
2. PowerPoint slide sets
3. Short summary factsheet (*In development*)
4. Online module (*In development*)



Practices that Reduce Nitrate in the Plant Root Zone

1. Improved Nitrogen Management

Many situations as to how much nitrogen is applied, how often, and in what form. The nitrogen rate, timing, and placement are all important factors that affect nitrogen use efficiency. Many situations as to how much nitrogen is applied, how often, and in what form. The nitrogen rate, timing, and placement are all important factors that affect nitrogen use efficiency.

What is improved nitrogen management?

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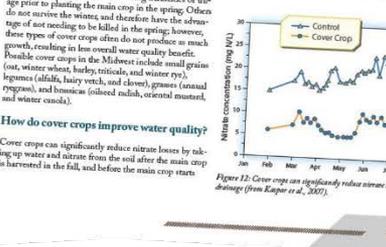
Practices that Reduce Nitrate in the Plant Root Zone

2. Winter Cover Crops

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How do cover crops improve water quality?

Cover crops can significantly reduce nitrate losses by taking up water and nitrate from the soil after the main crop is harvested in the fall, and before the main crop starts.



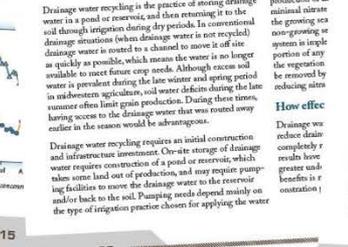
Practices that Reduce Delivery of Nitrate to the Field's Edge

6. Recycling Drainage

Drainage water recycling is the practice of storing drainage water in a pond or reservoir, and then returning it to the soil through irrigation during dry periods. In conventional drainage situations, when drainage water is not recycled, the water is routed to a channel to move it off site as quickly as possible, which means the water is no longer available to meet future crop needs. Although excess water is prevalent during the late winter and spring periods, summer often limits grain production. During these times, having access to the drainage water that was routed away earlier in the season would be advantageous.

What is drainage water recycling?

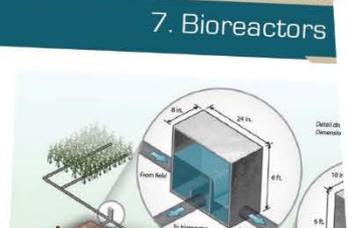
Drainage water recycling requires an initial construction and infrastructure investment. On-site storage, which water requires construction of a pond or reservoir, which takes some land out of production, and may require pumping facilities to move the drainage water to the reservoir and/or back to the soil. Pumping needs depend mainly on the type of irrigation practice chosen for applying the water.



Practices that Remove Nitrate at the Edge of the Field or Downstream

7. Bioreactors

Denitrification bioreactors are an edge-of-field water quality improvement system that reduces the nitrate in the soil. They are placed in the field to reduce nitrate in the soil. They are placed in the field to reduce nitrate in the soil.



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WHERE CAN I GET THESE MATERIALS?

<http://go.aces.illinois.edu/TenWays>

Or Google:
*"ten ways
drainage"*

Phone: 1.217.244.6173 Email: LEChris@illinois.edu

Illinois Drainage Research and Outreach Program (I-DROP)

Improving agricultural water quality in Illinois and beyond

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

Click to download an electronic copy of the *Ten Ways* booklet (pdf file):

[Ten Ways to Reduce Nitrogen Loads from Drained Cropland in the Midwest](#)

To order printed copies of the booklet, visit <https://pubsplus.illinois.edu/C1400.html>

Across the Mississippi River Basin, 45% reductions in nitrogen and phosphorus loads are necessary to meet national goals established to reduce the size of the Gulf of Mexico hypoxic zone. There are a number of practices now being promoted as a part of state nutrient strategies, all of which have different N-reduction effectiveness, spatial suitability, additional benefits and impacts, and cost. No one practice will be suitable for every acre, but every acre needs at least one new practice. A newly funded North Central Region Water Network Seed Grant project, led by the University of Illinois, is underway to develop a comprehensive package of information about these drainage water quality-improvement practices. This effort is leading off with the release of a booklet entitled *Ten Ways to Reduce Nitrogen Loads from Drained Cropland in the Midwest*, and will include presentations for educators, online modules for additional audiences, and a *Ten Ways* summary factsheet. Click the link above to download an electronic copy of the booklet.



Ten Ways
An Illinois Nutrient Loss Reduction Strategy

1. Improved Nitrogen Management
2. Water Cover Crops
3. Regulating Drainage
4. Bioreactors
5. Buffer Strips
6. Dissolved Phosphorus
7. Denitrification
8. Conservation Drainage Projects
9. Dissolving uncertainty: A comprehensive evaluation of dissolved P in tile drainage
10. Denitrifying 'Woodchip' Bioreactor Projects

Site Map

- I-DROP Impact
 - Ten Ways to Reduce Nitrogen Loads from Drained Cropland in the Midwest
- I-DROP Research
 - Conservation Drainage Projects
 - Dissolving uncertainty: A comprehensive evaluation of dissolved P in tile drainage
 - Denitrifying 'Woodchip' Bioreactor Projects
- Publications
- I-DROP: About us

Laura Christianson @IL_DrainDrop

That's right - nothing fishy here! #Bioreactor Great work from @FreshwaterInsti @ConservationFnd Thanks for the pr... <https://t.co/ENW6IE229F>

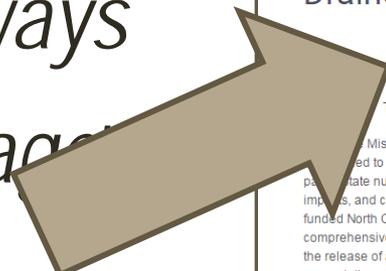
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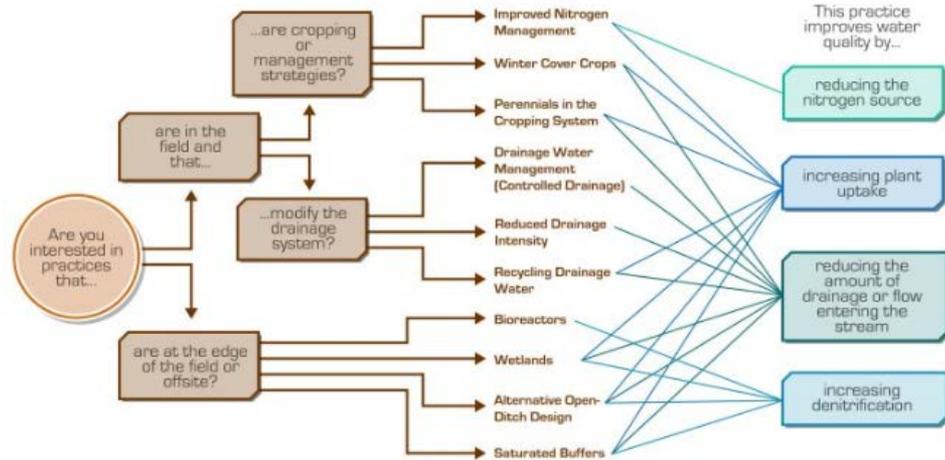
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Are you an educator?

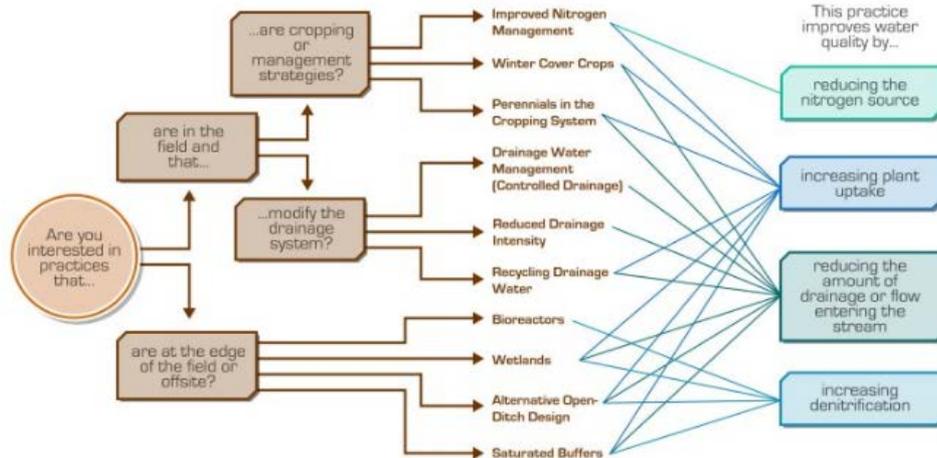
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