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Reconnecting Iowa riparian buffers with tile drainage (1)

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Abstract
Changing the configuration of tile drainage structures to allow subsurface flow through a riparian buffer could offer farmers another option for nitrate removal. This project examined the effects of using tiling and buffers to enhance the denitrification process.

Keywords
Natural Resource Ecology and Management, Conservation practices, Water quality quantity and management

Disciplines
Natural Resources and Conservation | Natural Resources Management and Policy | Water Resource Management

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Budget:
$6,702 for year one
$5,202 for year two
$27,977 for year three

ECOLOGY

Q Can a portion of tile drainage be reconnected to the shallow groundwater system of riparian buffers and by doing so remove nitrate from the tile water before it enters surface waters?

A A literature survey indicated that riparian buffers have a large capacity for nitrate removal via denitrification. But in much of Iowa and the Midwest this removal mechanism is limited by the lack of water flowing through buffers as groundwater by the prevalence of tile drains out letting directly to surface waters. This idea was tested by re-plumbing a tile outlet to route some of the tile water through an existing riparian buffer and measured the amount of water redirected and the fate of the nitrate contained within the water.

Background

Riparian buffers are a proven practice for removing the nutrient nitrate from overland flow and shallow groundwater before entering receiving waters. However, in landscapes with tile drainage, most of the subsurface flow leaving agricultural fields bypasses the buffers in subsurface drainage, leaving little opportunity for nitrate removal. The researchers investigated the feasibility of re-routing a fraction of field tile drainage as subsurface flow through a riparian buffer to increase nitrate removal.

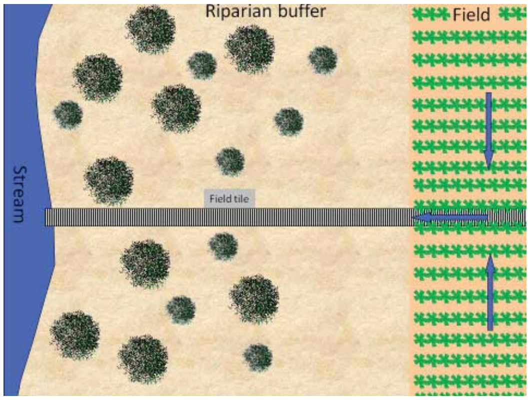
Approach and methods

The research site was a 118-acre privately owned field in Hamilton County, Iowa. The field is in the Bear Creek watershed, a stream that drains 16,821 acres, most of which are tile-drained and used for corn and soybean production.

A riparian buffer was established on both sides of Bear Creek in 1995. The buffer consisted of silver maple trees planted along the stream followed by a mixed shrub-grass planting. The upper part of the buffer consisted of switch grass.

The poorly and somewhat poorly drained upland soils within the field were tile-drained for the production of corn and soybean grown in a two-year rotation. The tiles within the study field drain to the stream through three outlets that run through the buffer to Bear Creek. The outlet selected for interception had the highest flow rate and longest duration of flow after rainfall events observed in summer 2010.

The tile outlet was intercepted just inside the buffer as it left the row-crop portion of the field. The 15-cm diameter tile was excavated and reconnected to an in-line water-level control box. The control box consisted of three chambers separated by two sets of stoplogs that could be used independently to set the water level within the upstream and middle chamber of the box. The field tile outlet was connected to the inlet chamber of the control box. The outlet end of the control box was reconnected to



Overhead schematic of the buffer before creation of a saturated buffer.

the existing pipe that emptied directly into Bear Creek. The middle chamber had outlets on both sides of the box connected to 10-cm diameter slotted corrugated plastic drainage pipe. This new pipe was installed perpendicular to the field tile along the top of the buffer at a depth of 76 cm below the ground surface. The pipe served to introduce tile water as shallow groundwater within the buffer.

Monitoring wells were installed within the buffer along four transects. Each transect consisted of three wells equally spaced between the distribution pipe used to convey water along the top of the buffer and Bear Creek. Each well was equipped with a pressure transducer and datalogger to measure and record water table depth every six hours. Water samples were collected from each well weekly when the field tile was flowing and returned to the laboratory for the determination of NO_3 concentration. At the same time, water samples from Bear Creek and tile water flowing within the control box were collected for measurement of NO_3 concentrations.

Results and discussion

Over two years, the project was able to redirect more than 19,000 m^3 of flow from a field tile as subsurface flow along 335 m of an existing riparian buffer. This flow represented about 55 percent of the total flow coming from a tile outlet draining 10.1 ha of a field in corn-soybean. The redirected water seeped through the 20-m wide buffer, raising the water table approximately 30 to 40 cm. The redirected tile flow contained 228 kg of NO_3 and based on the strong decrease in NO_3 concentrations with no change in Cl concentrations within the shallow groundwater across the buffer, the researchers believe that all of this NO_3 was removed within the buffer and did not enter the stream. Thus, over two years, the saturated buffer removed 228 kg N of NO_3 that otherwise would have entered Bear Creek as tile discharge.

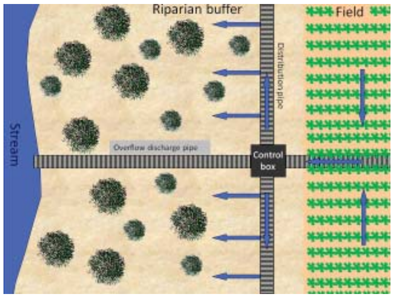
There was a rapid decrease in NO_3 concentrations within the groundwater as it entered the buffer. This pattern has been observed in many other riparian buffers and indicates that these systems have a large capacity for NO_3 removal.

Denitrification permanently removes NO_3 from the system and is the most desirable mechanism for NO_3 removal. While the PIs did not measure the fate of the lost NO_3, most studies of riparian buffers have found denitrification to be the main removal mechanism when the water table is present in a high organic matter soil layer.

Conclusions

Success in removing NO_3 from subsurface field drains by rerouting some of the flow through riparian buffers undoubtedly depends on the soil properties within the buffer – particularly soil permeability, organic carbon content, and proximity of the water table to organic-rich material. This initial study has shown great potential for reestablishing the hydrologic connection between riparian buffers and drained croplands and removing NO_3 before it can enter surface waters. If the success observed here can be replicated in other landscapes, this practice could be used to prevent substantial amounts of NO_3 from entering surface streams throughout the midwestern United States.

Materials and labor for installing the control box and additional tile cost $3,500. With an estimated life expectancy of 20 years and an interest rate of 4 percent, the



Overhead schematic of the buffer after creation of a saturated buffer.

total cost of implementing the practice in an existing riparian buffer is $4,960 or $248 per year. Given the observed NO_3 removal rate, the cost of removal for a kg of N is $2.17 kg-1 or $0.98 lbs-1. This compares favorably to other NO_3 remediation practices such as wetlands ($3.26 kg-1 or or $1.48 lbs-1) or rye cover crops ($11.06 kg-1 or $5.02 lbs-1).

The control box used for diverting water into the buffer may not be feasible in nearly level fields because raising the water table within the buffer also would raise the water table within the field and negate the purpose of draining the field. However, in many areas of Iowa and other midwestern states, drainage systems are installed in poorly drained upland soils and there are frequently a few meters of elevation relief between these drained soils and the stream outlet. This elevation difference offers an opportunity to raise the water table within a streamside buffer without affecting the drainage within the field.

In this study's design, tile flow that did not infiltrate the buffer was discharged directly into the stream. This can be important because water in the field was not backed up in the field. Thus, field drainage was not affected–a critical consideration for farmers who rely on subsurface drainage to maintain a well-aerated root zone for their crop and are wary of any changes that may restrict field drainage.

In the first two years, more than 516,000 gallons or 55 percent of the total flow from the tile outlet was infiltrated as shallow groundwater within the riparian buffer. The infiltrated tile flow contained 214 kg (472 lbs.) of nitrate which was completely removed within the buffer and did not enter the stream. Redirecting tile drainage as subsurface flow through a riparian buffer increased the buffer's nitrate removal benefit and is a promising management practice for farmers interested in improving surface water quality within tile-drained, agricultural landscapes.

Impact of results

If the results of this pilot study are repeated at other locations, the researchers compute that this practice has the potential of preventing 18 million pounds of nitrate-N from entering Iowa streams each year. This research has received considerable interest as gauged by coverage in agricultural media, frequent requests for presentations, and the successful application for additional research funds to test this practice across the Midwest. These results also have led to USDA-NRCS developing an interim practice standard for Saturated Buffers ("Vegetated Subsurface Drain Outlet" # 739). While this practice was not included with other N reduction practices listed in the Science Assessment of the Iowa Nutrient Reduction Strategy, the Assessment did recommend that the practice receive more study and could be included in the future.

Education and outreach

Scholarly publications from the project:

Jaynes, D.B. and Isenhart. T.M. 2014. Reconnecting tile drainage to riparian buffer hydrology for enhanced nitrate removal. *J. Environ. Qual.* 43:631-38.
https://dl.sciencesocieties.org/publications/jeq/pdfs/43/2/631
Also at: doi:12.2134/jeq2013.08.0331

Jaynes, D.B. and Isenhart. T.M. 2013. Denitrification within Saturated Riparian Buffers Re-Designed to Remove Nitrate from Artificial Subsurface Drainage. In *2013 Agronomy abstracts*. ASA, Madison WI. https://dl.sciencesocieties.org/publications/meetings/2013am/11241/77388

Isenhart, T.M. and D.B. Jaynes. 2012. Re-saturating riparian buffers in tile drained landscapes. American Water Resources Association 2012 Summer Specialty Conference - Riparian Ecosystems IV: Advancing Science, Economics and Policy, Denver, Colorado.

Jaynes, D.B. and Isenhart. T.M. 2011. Re-Saturating Riparian Buffers In Tile Drained Landscapes. In *2011 Agronomy abstracts*. ASA, Madison WI. https://scisoc.confex.com/crops/2011am/webprogram/Paper64695.html

Presentations and tours related to the project:

- "Saturated buffers" at November 2011 Drainage Forum, Okoboji
- "Re-saturating riparian buffers in tile drained landscapes" at the Pheasants Forever 2012 Iowa Annual Meeting, Des Moines
- Tour of Bear Creek Saturated Buffer research site for NRCS personnel, May 2012
- "Saturated Buffers" at Conservation Drainage Field Day and Workshop, Granite Falls, Minnesota, July 2012
- "Saturating riparian buffers for improved water quality" at the 142nd annual meeting of the American Fisheries Society, St Paul, Minnesota, August 2012
- "Nitrate reduction practices for tile-drained landscapes" at the joint meeting of the National Association of State Departments of Agriculture (NASDA) and Gulf of Mexico Hypoxia Task Force, at the ISU BioCentury Research Farm, Ames, September 2012
- "Saturating riparian buffers in tile-drained landscapes" 2012 Illinois Water Conference, Champaign, Illinois, September 2012
- "Saturated buffers for removing nitrate from water" at the Iowa Drainage District Association Annual Conference, Ft. Dodge, December 2012
- "Saturated buffers for removing nitrate from water" at Practical Farmers of Iowa 2013 annual conference, Ames

Articles featuring this research appeared in:

- *Clean Water Starts with Us*, Fall 2011 publication of Iowa Department of Natural Resources, Iowa Department of Agriculture and Land Stewardship - Division of Soil Conservation, and USDA Natural Resources Conservation Service. http://www.iowadnr.gov/Portals/idnr/uploads/water/watershed/enews/wisnews0911.pdf
- *Corn and Soybean Digest*, "Buffer Booster | Cut Nitrates by Routing Tile Water Through Grass Buffer," April 2012 http://cornandsoybeandigest.com/conservation/buffer-booster-cut-nitrates-routing-tile-water-through-grass-buffer
- *Minneapolis Star Tribune*, "Conservationists, farmers look to the future" on efficacy of saturated buffers, August 2012

Leveraged funds

This grant helped leverage the 2012 NRCS-Conservation Innovation Grant, Demonstrate and evaluate saturated buffers at field scale to reduce nitrate and phosphorus from surface and subsurface field drainage systems, for $391,344 awarded to the Agricultural Drainage Management Coalition.

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