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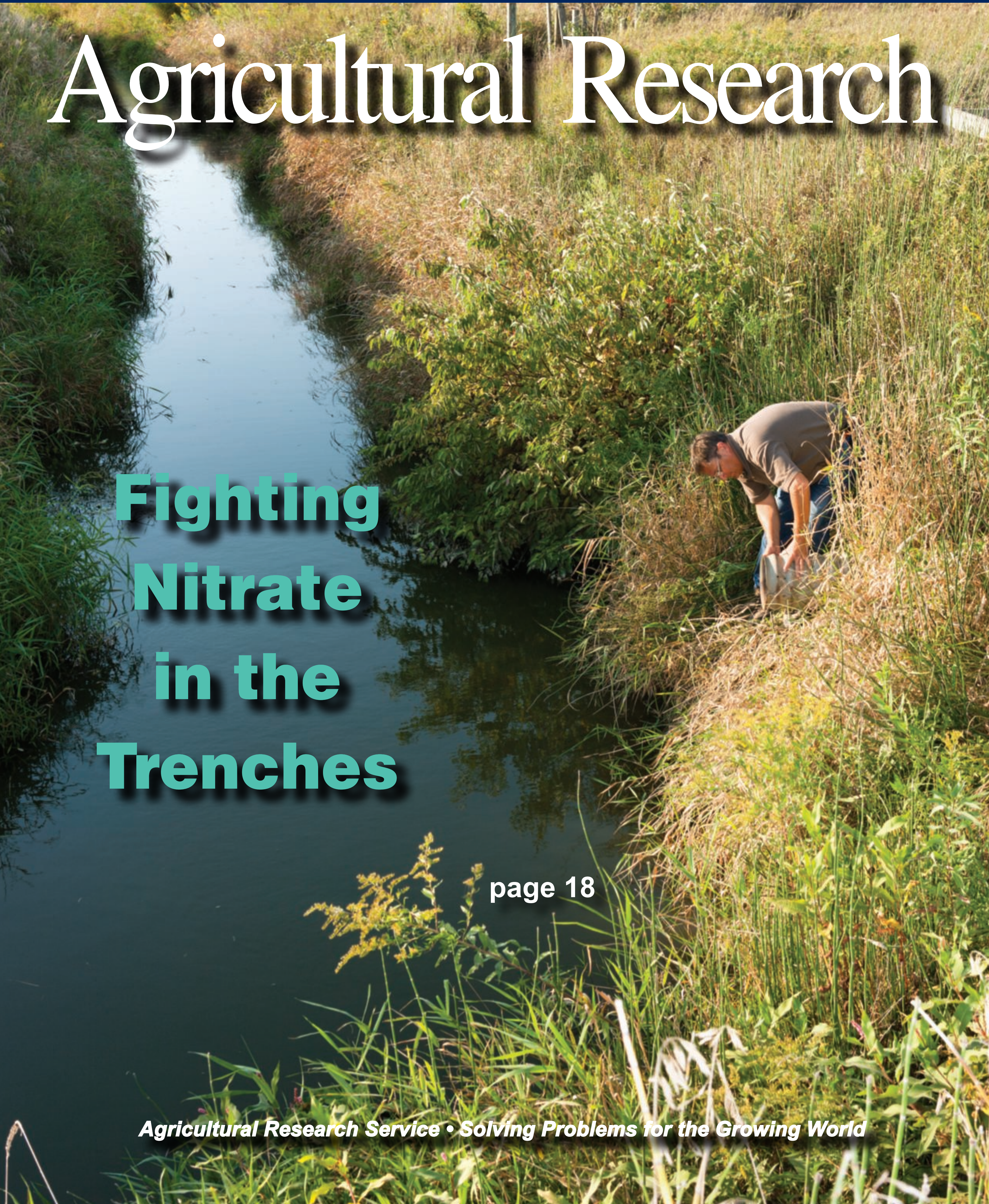

Fighting Nitrate in the Trenches

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Agricultural Research Service • Solving Problems for the Growing World

Can a Prairie Teach Us About Agricultural Water Quality?

One place to figure out how agricultural practices affect water quality is in a crop field that is being converted to native prairie vegetation. In Iowa, natural resource managers are conducting this type of landscape restoration at the Neal Smith National Wildlife Refuge near Prairie City. So this is where Agricultural Research Service soil scientists Mark Tomer and Cynthia Cambardella partnered with colleagues from Grinnell College, the U.S. Fish and Wildlife Service, and the Iowa Geological Survey Bureau (part of the Iowa Department of Natural Resources) to describe changes in water quality during prairie establishment.

The ARS researchers work at the National Laboratory for Agriculture and the Environment in Ames. Their group studied concentrations of nitrates and phosphorus in ground water in a 17-acre field while it was being converted from corn and soybean row-cropping to a reconstructed prairie. The researchers set up ground-water monitoring wells and collected water samples from 2002 through 2009.

After a final soybean harvest in 2003, the field was seeded with native grasses and forbs. As the prairie became established, nitrate concentrations declined and stabilized within 5 years. Initially, nitrate levels in ground-water wells higher up the slopes averaged 10.6 parts per million (ppm), levels that can fuel downstream development of the "dead zone" in the Gulf of Mexico.

But nitrate levels along ephemeral waterways averaged only 2.5 ppm, and after 2006, nitrates disappeared from the shallow ground water near the waterways. Further upslope, ground water still had measurable nitrate levels in 2006, but levels diminished to around 2 ppm after 2007.

"The rate of nitrate loss mostly came down to two things: how much available carbon was in the soil and the depth of the water table," Tomer notes. "Along the waterways, there was carbon available in the saturated soils. This provided an environment promoting denitrification that can decrease nitrate concentrations fairly rapidly—within one growing season. Upland soils were drier and had less available carbon, so nitrate loss occurred more slowly."

These results didn't surprise the researchers. But phosphorus measurements did, because unlike nitrate, phosphorus levels did not decline. Between 2006 and 2009, phosphorus concentrations averaged 0.14 ppm along the ephemeral waterways, while average upland concentrations were only around 0.02 ppm. The higher phosphorus concentrations were found in shallow ground water along the waterways—and if ground-water levels rose enough to produce overland flows that contribute to streamflow, the phosphorus concentrations were high enough to threaten local water quality.

"We learned that while conservation practices that plant grass along waterways and in riparian buffers can trap sediments from field runoff, the sediments contain phosphorus that can leach into the water," Tomer says. "Under certain conditions, legacy nutrients in soil might still pollute nearby waterways, even though eroded soil has been trapped." Legacy nutrients remain in the soil long after producers have stopped using them to fertilize crops.

Tomer wants to learn more about this tradeoff between phosphorus and nitrate in shallow ground water, how often it occurs, and what controls it. "We think studying this prairie has given us insight that can help farmers better manage water quality, from their fields right down to the Gulf of Mexico."—By **Ann Perry,** ARS.

This research is part of Water Availability and Watershed Management (#211) an ARS national program described at www.nps.ars.usda.gov.

To reach the scientists mentioned in this article, contact Ann Perry, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1628, ann.perry@ars.usda.gov. ✻

ARS researchers are studying how nitrates and phosphorus affect water quality in a crop field that has been converted to native prairie vegetation at the Neal Smith National Wildlife Refuge near Prairie City, Iowa.

JEFF COOK (D2415-1)

Nixing Nitrate Flow From the Farm

A farmer's subsurface drain pipe. Subsurface drainage may account for 50 percent of the stream flow in midwestern watersheds.

When early settlers arrived in the Midwest, they began constructing an underground network of tile drains to channel water away from the soggy prairies, which then became some of the most fertile crop fields in the country. But now when nitrate from soils and fertilizers leaches out of those flourishing fields, the subsoil engineering also facilitates the discharge of nitrates into nearby streams and rivers.

Because these local waterways are part of the vast Mississippi River Watershed, the nitrates are eventually transported into the Gulf of Mexico, where they can feed the development of oxygen-deficient "dead zones." But nitrate management isn't just an issue for the folks downstream. The U.S. Environmental Protection Agency has mandated that nitrate concentrations in drinking water—obtained either from surface water or ground water—cannot exceed 10 parts per million. Minimizing nitrate loss can also help producers obtain the greatest economic returns from the application of expensive fertilizers. So everyone benefits when nitrates are stopped from contaminating local water supplies.

Agricultural Research Service soil microbiologist Tom Moorman and others at the National Laboratory for Agriculture

PEGGY GREB (D2398-1)

Left: Technician Kent Heikens prepares a large core sampler to take a core sample of the wood chip bioreactor beneath a soybean field for lab analysis of denitrification rates and bacterial populations. Below: Kent Heikens and Ben Knutson examine a core sample from the bioreactor. The topsoil covering the wood chips is seen in the foreground.

PEGGY GREB (D2399-1)

Sample of wood chips taken from the bioreactor from beneath a soybean field.

PEGGY GREB (D2400-1)

and the Environment in Ames, Iowa, have spent the last decade studying whether underground trenches filled with wood chips could help stem this nitrate flow. Microorganisms that live in the wood use a process called "denitrification" to convert nitrates in the field leachate into nitrogen gas or nitrous oxide, which then diffuse into the atmosphere.

"Soils have some capacity to denitrify field leachate, but it generally decreases with soil depth," Moorman says. "So we wanted to see how well wood chip 'denitrification walls' could protect nearby waterways from the nitrates that leach out of the soil. We also wanted to see how quickly the wood breaks down in the subsoil."

Digging For Answers

Moorman and his team—technician Colin Greenan, microbiologist Timothy Parkin, plant physiologist Tom Kaspar, and soil scientist Dan Jaynes—set up experimental sites in a field north of Ames. They installed perforated plastic drainage pipes 4 feet below the soil surface and then dug trenches on either side of the pipe and filled the trenches with wood chips. They buried the trenches and the pipes, and then cropped the fields with a corn-soybean rotation for the next 9 years.

The researchers also filled mesh bags with wood chips and buried the bags at depths of 2 feet and 5 feet in a nearby trench that was also filled with wood chips. The fields above this trench were also cropped with a corn-soybean rotation. Establishing this extra trench allowed them to dig up wood chips to see how fast they decomposed without removing wood from the experimental trenches.

The team found that over the 9-year study period, the wood chip "bioreactors" consistently removed nitrates from the field leachate, with removal rates remaining steady in the last 5 years. From 2001 to 2008, annual nitrate loss in plots with conventional drainage averaged 48.6 pounds per acre, but losses dropped to 21.8 pounds per acre in plots with the denitrification walls.

The data also indicated that, compared to subsoil, the average denitrification potential of wood increased from 31-fold in 2003 to 4,000-fold in 2004. These findings supported an earlier laboratory study by Greenan that indicated denitrification by microbes is the main mechanism in wood chip bioreactors responsible for removing nitrate from leachate.

The scientists also found that the population of denitrifying microbes exceeded 454 million per pound of wood, compared to 45 million per pound of surface soil and 4.5 million per pound of subsurface soil—strong evidence that the wood chips provided a habitat that favored the denitrifying organisms.

Long-Lasting Success

The scientists periodically checked the bagged wood samples over the 9-year study period to see how quickly the wood was decomposing. They found that 50 percent of the wood buried between 35 and 39 inches deep had decomposed 5 years after it was buried, and 75 percent of the wood buried at this depth decomposed after 9 years.

However, less than 13 percent of the wood buried between 61 inches and 70 inches deep had decomposed after 9 years. The decreased decomposition rates at greater depths was probably due to lower oxygen levels in the subsoil, which was saturated with water for longer interludes than the subsoils at shallower depths. These findings can help in the design of denitrifying wood trenches, since wood decomposition rates will be needed to calculate the functional life expectancy of a denitrification wall after it is installed.

Denitrification also results in the production of the greenhouse gas nitrous oxide, and the team was concerned that the bioreactors might increase these emissions. But they found that overall nitrous oxide emission rates did not notably change with increasing denitrification in the bioreactor. This is partly because overall soil nitrate losses were reduced, which prevented nitrates from leaching out of the ground and into nearby waterways, where discharged nitrates are converted into nitrous oxide. "Until this study, very little work had been conducted on nitrous oxide loss from these bioreactors," Moorman says.

The results from this work were published in 2010 in a special issue of *Ecological Engineering*. In part because the benefits of using wood chip bioreactors for denitrification were so conclusive, Agriculture's Clean Water Alliance—a group of leading farm retailers in west-central Iowa—and the Iowa Soybean Association, in partnership with Wisconsin-based Sand County Foundation, are now encouraging farmers to install the denitrification walls to help mitigate the nitrate pollution associated with regional agricultural production.

"This study helped us confirm that using wood chips to build denitrification walls will result in a significant level of denitrification in field leachate," says Moorman. "We also understand much more about the different mechanics of denitrification itself, and now we have good numbers on how many denitrification bacteria live in wood and how long that wood can last in a trench under typical field conditions."—By **Ann Perry,** ARS.

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PEGGY GREB (D2402-1)

Subsurface drainage water from individual field plots is routed to this sump where flow is measured and samples are prepared for nitrate testing. Here, soil microbiologist Tom Moorman takes a water sample for nitrate analysis.