Drainage Ditch Research Reveals Opportunities for Cleaning Up Runoff

"There is no typical drainage ditch," says Agricultural Research Service ecologist Matt Moore. "And until recently, farmers just thought of them as something they need to drain water off their fields. But we can use these ditches to minimize pesticide and nutrient losses in runoff—and it can be done without taking any cropland out of production."

Moore, who works at the ARS National Sedimentation Laboratory in Oxford, Mississippi, has been wading through edge-of-field drainage ditches since he was a boy planting rice on his family's farm in Arkansas. The ditches—as common in agricultural landscapes as the fields they drain—range from shallow gullies that sometimes run dry to much larger channels that hold either standing or flowing water throughout the year.

Many farmers control ditch vegetation with trimming or dredging to eliminate barriers that could impede the flow of runoff. But Moore has conducted a number of studies over the past 10 years showing that drainage ditches where plants are allowed to flourish are strikingly effective at keeping agricultural pollutants in field runoff from reaching surrounding surface waters.

Blocking a Path for Pesticides

In one of Moore's first studies, he spent 28 days evaluating the transport and capture of atrazine and lambda-cyhalothrin in a 160-foot section of a vegetated agricultural drainage ditch in Mississippi. One hour after he started a simulated runoff event, 61 percent of the atrazine and 87 percent of the lambda-cyhalothrin had transferred from the water to the ditch vegetation, and at the end of the ditch, runoff pesticide concentrations had decreased to levels that were generally nontoxic to downstream aquatic fauna.

"I was surprised by the short distance the runoff needed to travel in the drainage ditch to lose its pesticide load," says Arkansas State University researcher Jerry Farris, who was one of the coauthors on the study. "This suggested that we could use these ditches as one tool in managing agriculture from an ecological perspective."

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In tests to see how well vegetated drainage ditches like this one reduce agricultural pesticide and nutrient runoff, ecologist Matt Moore (left) and soil scientist Martin Locke assess the biomass of plants growing in the ditch.

Encouraged by initial results, Moore conducted a followup study to measure the capture of lambda-cyhalothrin and bifenthrin, both pyrethroid pesticides that can be extremely toxic to aquatic fauna even in low concentrations. Just 3 hours after the start of a simulated runoff event, he found that 96 percent of the lambda-cyhalothrin and 99 percent of the bifenthrin were already captured by the ditch vegetation.

Just 7 days after the simulated runoff event, lambda-cyhalothrin and bifenthrin concentrations in some ditch water samples collected downstream had declined so significantly that they were well within acceptable toxicological threshold ranges. This meant that the pesticide concentrations now posed a much lower risk to aquatic ditch fauna. Thirty days after the simulated event, water samples from all the collection sites contained pesticide concentrations within acceptable toxicological threshold ranges.

Sample analyses also suggested that in a worst-case event, a ditch would need to be at least 395 feet long to reduce both lambda-cyhalothrin and bifenthrin to concentrations below 1 percent. A ditch would need to be at least 920 feet long to reduce both pesticides to concentrations below 0.1 percent.

Moore and colleagues conducted a similar study on the pyrethroid esfenvalerate with similar results—3 hours after the runoff simulation began, 99 percent of the pesticide was associated with the ditch vegetation. Using data from the study, the researchers constructed a model that suggested esfenvalerate concentrations in runoff that traveled the length of a 1,675-foot vegetated ditch could be reduced to 0.1 percent of the initial concentration.

Finds on Fertilizers

Robert Kröger, a South African Ph.D candidate who was completing his studies at the ARS laboratory in Oxford, decided to investigate whether drainage ditches could help mitigate nutrient loads in field runoff.

"You can manage nutrients that contribute to the development of oxygendeficient 'dead zones' in downstream ecosystems in three ways," says Kröger, who is now a research professor with Mississippi State University. "You can just not use them; you can use edge-of-field systems like buffer strips to capture them; or you can use drainage ditches—and every single agricultural landscape has a drainage system."

For 2 years, Kröger and Moore collected runoff samples from two Mississippi drainage ditches adjacent to experimental no-till cotton fields. They collected monthly samples and also obtained samples of runoff generated by storms.

Sampling analysis indicated that the ditches alternated throughout the year between being a sink and source for dissolved inorganic phosphorus and particulate phosphorus. Around 5.5 percent of the fertilizer applied annually to the fields was transported into the ditches, where around 44 percent of inorganic phosphorus in the runoff was removed by attaching to ditch sediments or vegetation before the runoff was discharged.

The ditches reduced runoff concentrations of dissolved inorganic phosphorus during the growing season by 61 percent. When the fields were fallow, average loads were decreased 47 percent. But it wasn't possible to determine whether some of that phosphorus load was from the accumulation of "legacy" nutrients—those that linger in the soil years after they are applied.

The team used the same experimental fields to determine whether the ditches also helped reduce inorganic nitrogen from field runoff. Runoff samples collected during the 2-year study contained 2.2 percent of the initial fertilizer application, but only 1.1 percent of the inorganic nitrogen remained in the runoff when it was discharged from the ditch. This means that the ditch was responsible for reducing runoff levels of inorganic nitrogen by 57 percent over 2 years.

The researchers wanted to see if they could make these good results even better. They were already familiar with the riser pipes producers placed at the edge of drainage ditches to create a dam that temporarily impounds runoff. This reduces runoff volume and velocity, which in turn reduces field erosion. It also helps raise the water table, which improves crop access to soil water.

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Working with a water sample collected from a drainage ditch, technician Lisa Brooks extracts a portion of it for pesticide analysis.

The team installed low-grade weirs—small dams—at several points throughout three drainage ditches. They also placed riser pipes at the ends of three other ditches. Then they conducted two simulated nutrient runoff events and tracked nutrient loads in each impoundment pool for the next 7 days.

The scientists observed that levels of several nutrients in the trapped runoff dropped significantly 7 days after the runoff event began. Average median levels of dissolved inorganic phosphate dropped 93 percent, and average median levels of total organic phosphate dropped 87 percent. Average median nitrate levels declined 97 percent, and average median ammonium levels dropped 76 percent. This indicated that using either riser pipes or weirs to temporarily trap field runoff could increase the capacity of drainage ditches to lessen runoff nutrient loads.

Tests in the West

Moore was asked by U.S. Environmental Protection Agency (EPA) environmental scientist Debra Denton to test the effectiveness of vegetated drainage ditches for mitigating pesticide runoff in California crop fields. Moore conducted a preliminary field trial in Yolo County, California, using a U-shaped vegetated ditch, a V-shaped vegetated ditch, and a V-shaped ditch with no vegetation. Each 545-foot ditch was amended for 8 hours with a mixture of diazinon, permethrin, and suspended sediment.

Afterwards, Moore's team analyzed water, sediment, and plant samples for pesticide concentrations. They found that differences in half-distances—the distance that runoff travels in a ditch to reduce initial pesticide concentration by 50 percent—ranged from 69 feet in the V-shaped vegetated ditch to 485 feet in the V-shaped unvegetated ditch.

The researchers followed up with another study that evaluated the ability of existing drainage ditches alongside California tomato and alfalfa fields to mitigate runoff loads of the pesticides chlorpyrifos and permethrin. The scientists planted creeping wildrye and slender sedge—both native to California—in the V-shaped ditches about 5 months before the start of the irrigation season.

Water, sediment, and plant samples collected after the runoff events indicated that chlorpyrifos concentrations in alfalfa field runoff decreased 20 percent by the

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Using a gas chromatograph, technician Renee Russell analyzes the pesticide content of samples collected at various points along a vegetated drainage ditch. The goal is to determine how the ditches affect the fate and distribution of pesticides.

time it left the ditch. Thirty-two percent of the measured chlorpyrifos was associated with ditch plant material. Permethrin concentrations in runoff from tomato fields decreased 67 percent by the time it left the ditch, and suspended sediment concentrations dropped 35 percent.

With these findings in hand, Denton worked with USDA's Natural Resources Conservation Service (NRCS) state office in California to include vegetated agricultural drainage in its Environmental Quality Incentives Program (EQIP). NRCS approved this designation in 2008, which meant that farmers who installed the ditches could be reimbursed for up to 50 percent of the cost.

"One of the best things about this project is that ARS and EPA were working side by side for the same goal—to help the farmers and improve water quality," says Moore.

"Because of this work, other researchers in California are now studying ways to use vegetated drainage ditches to reduce pesticides, nutrients, and sediment loadings into waterways," adds Denton. "But one of the things Moore emphasizes is that using vegetated ditches is just one practice in a suite of practices farmers can use to reduce agricultural pollutants in field runoff."

Moore's research contributed to the decision by NRCS managers in Mississippi to include vegetated agricultural drainage ditches in the state's EQIP. Meanwhile, Moore is continuing his research.

"Our next step is figuring out the best ways to manage vegetation in the ditches," Moore says. "But the farmers we talk with are cautiously optimistic about how the ditches can work for them. They do see that it could be a low-cost option for controlling nutrients and pesticides in runoff."—By **Ann Perry,** ARS.

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

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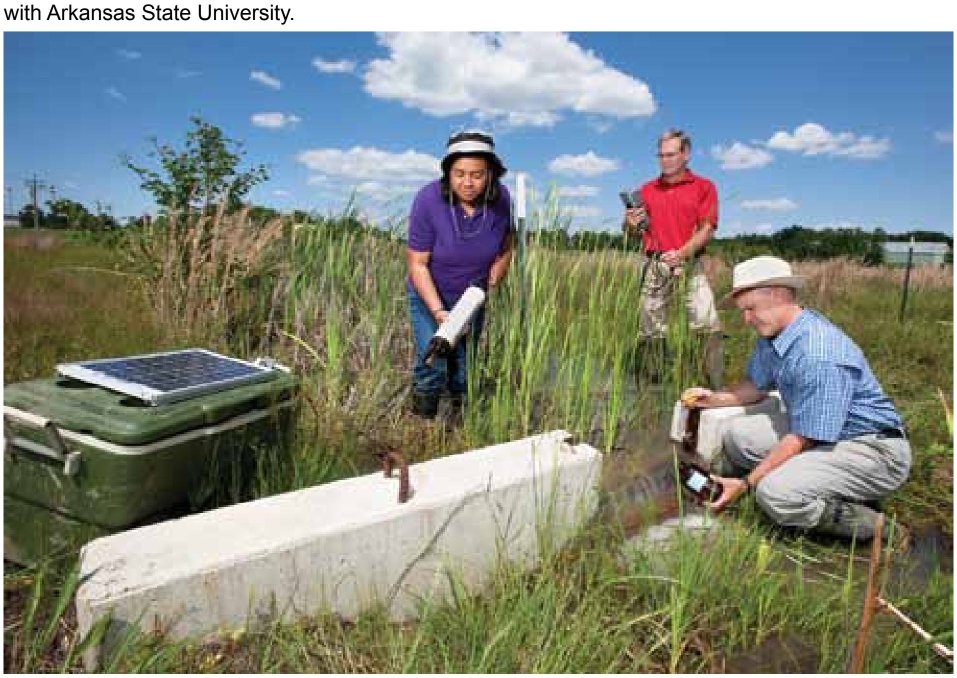
Graduate assistant Traci Hudson (left) and ARS soil scientist Martin Locke (center) measure water quality while professor Jerry Farris collects another water sample for analysis. Hudson and Farris are with Arkansas State University.



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Added Incentive To Target Nitrogen

Capturing nitrogen from field runoff is good for water quality. But research is needed to determine how much of the captured nitrogen is transformed and emitted as nitrous oxide, a greenhouse gas that holds 300 times as much heat as carbon dioxide.