Rainfall Simulators Target Runoff

As simulated rain falls from a nozzle (upper right), hydrologic technician Terry Troutman (right) and soil scientist Andrew Sharpley collect the runoff for laboratory testing.

PEGGY GREB (K9572-1)

From a distance, the portable rainfall simulator resembles a large cube jutting out of the earth. At close range, the simulator appears to be an outdoor shower stall, enclosed in a black tarpaulin and fed by a hose connected to a trailer-mounted water tank. In use, the simulator showers a field or pasture, creating runoff that can carry pesticides, nutrients, pathogens, and soil.

Andrew Sharpley, a soil scientist with USDA's Agricultural Research Service (ARS), uses the device to study how soil, manure, field management, and other factors affect the risk of losing crop nutrients, particularly phosphorus, in runoff water. This simulator is a portable version of one designed a few years ago by scientists at the University of Arkansas.

"We can place the simulators anywhere in a field and collect runoff for analysis of sediment, nutrients, pesticides, or other chemicals," says Sharpley, who is in the Pasture Systems and Watershed Management Research Unit at University Park, Pennsylvania.

As part of an ARS-coordinated program called the National Phosphorus Research Project (NPRP), 37 teams of scientists nationwide are using the simulators to standardize collection of soil and runoff data from agricultural areas. Currently, 20 ARS labs, 17 state universities, USDA's Natural Resources Conservation Service (NRCS), and the Environmental Protection Agency (EPA) are participating in the project, now in the second of 5 years.

"The main questions," says Sharpley, the project's coordinator, "are how much phosphorus in soil is too much and how can we best manage soil, commercial fertilizers, manure, and other agricultural phosphorus sources to maximize farm production while protecting water quality?"

A Race Against Runoff

Driving this effort is concern about agriculture's contributions to pollution of lakes, reservoirs, rivers, streams, estuaries, and coastal waters. According to a recent EPA survey, agricultural pollutants are one of the main causes of poor water quality for most impaired waters. Runoff, leaching, soil erosion, and artificial drainage are just some of the ways these pollutants are carried from land to water.

In recent years, phosphorus has risen to the forefront of water quality concerns involving agriculture. This is because in fresh water, phosphorus accelerates eutrophication, a process by which a body of water becomes too enriched with organic material. This process occurs naturally, but at a very slow rate. EPA says eutrophication is the most pervasive water-quality impairment factor nationwide. Eutrophication often shows itself through the growth of undesirable aquatic weeds and blue-green algae, which can crowd out beneficial aquatic plants. Only minor concentrations of phosphorus in fresh water, as little as 0.02 parts per million, are required to induce such a change. In contrast, soft drinks contain phosphorus in concentrations up to 2,000 parts per million.

Additionally, "algal blooms resulting from eutrophication clog filters at water treatment plants and reduce the recreational value of lakes and marinas," notes Sharpley. "The bloom's subsequent death and decay deprive fish and other aquatic life of oxygen."

PEGGY GREB (K9569-1)

Sharpley collects a soil sample from a test plot. The amount and type of phosphorus in the soil affect how much is lost in runoff.

In a recent ARS article on agricultural phosphorus and eutrophication, Sharpley and co-authors stated: "In many areas of intensive, confined animal production, manures are applied at rates designed to meet nitrogen requirements, often resulting in phosphorus being applied beyond crop needs, increasing phosphorus in surface soil and enriching runoff with enough phosphorus to accelerate eutrophication."

Until recently, research has been primarily confined to the laboratory and carried out by scientists using different methods, making results difficult to compare, says Sharpley. The NPRP is an attempt to coordinate such efforts by experts at the state, university, and federal levels. One of its goals is to collect field data in a uniform, comparable manner countrywide so it can be compiled into a national database.

"If everyone is using the same type of equipment, the resulting data is easier to share," says Brad Joern, an associate professor and NPRP coordinator at Purdue University, West Lafayette, Indiana. "Part of my charge is to help develop a protocol for cropland studies."

To further ensure accurate results, Joern's team is studying the impact of using different water sources—such as well water—on phosphorus' movement during rainfall simulations. This could have an important bearing on how scientists interpret simulator research to establish the phosphorus threshold levels for 45 to 50 different benchmark soils from across the country.

"By carrying out on-site studies," adds Sharpley, "we're looking at something that's much closer to real-world losses."

Developing Tools To Help Farmers

For several years, researchers have known that most phosphorus lost from agricultural lands comes from only a small area of a watershed, during a few storms each year. This fact, coupled with the need to manage farm nutrients for water quality as well as productivity, led NRCS, ARS, and university scientists to develop a phosphorus index that assesses and ranks a farm field's vulnerability to phosphorus runoff.

"The phosphorus index pinpoints hot spots for phosphorus runoff and is based on how much phosphorus is in soil, how much was recently applied to the soil, and how likely that phosphorus is to move and enter a sensitive water body," notes Robert Wright, ARS national program leader for soil-management research.

"It's a decisionmaking tool that can be used by farmers, consultants, farm advisers, and landscape planners," he adds. "It will let them find areas vulnerable to nutrient losses and develop appropriate, cost-effective management practices."

The NPRP's rainfall studies will help researchers provide technical support for the phosphorus index. Over the next several years, the research findings from the NPRP will provide the scientific backbone for state, NRCS, and EPA nutrient-management policies to guide farmers' use of fertilizer and manure. Most importantly, the index will provide farmers with options on how best to achieve their production and water-quality goals on a site-specific basis.

Showcasing Science

Showing science in action is yet another facet of NPRP. Last summer, for example, Sharpley and colleagues used the rainfall simulators to illustrate the effect of conservation tillage on runoff in a field demonstration at Cedar Meadow Farm, operated by Steve Groff near Lancaster, Pennsylvania.

"The rainfall simulator can easily show farmers the benefits of conservation practices such as no-till," says Sharpley. "The

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Inside the rainfall-simulator frame, Troutman (left) places metal borders in the soil to create side-by-side runoff plots. Soil scientist Peter Kleinman attaches plastic hose to direct the runoff into collection bottles.

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The rainfall simulator was designed for transport to remote locations on a trailer, along with a 300-gallon tank of water to supply the "rain."

other great thing about these demos is that farmers often come up afterwards and say, 'If you need them, I've got some good sites for rain simulator research on my fields.'"

For studies and demos, scientists generally set up two, 3-by-6-foot plots, with one plot serving as a control. "The first simulators were nowhere near as portable or easy to use as the simulators we now have," says Tommy Daniel, a professor at the University of Arkansas in Fayetteville and one of the original developers of the NPRP simulator.

"Today's simulator is a beautiful thing to behold," he continues. With the pull of a cord, a pump begins forcing water through the simulator's plumbing system and out a nozzle that converts it to rain, which falls onto the plots at about 3 inches per hour. After awhile, the first signs of runoff—usually small puddles—appear on the soil. Metal borders located downslope from the plots collect the runoff and direct it into gutters that empty into a plastic bottle. Devices called lysimeters are sometimes inserted into the ground to collect subsurface water, called leachate. Scientists weigh the collected runoff at the site to determine how much has occurred. Back at the laboratory, they measure concentrations of various forms of phosphorus that are important to water quality. For instance, they can measure the specific forms available to algae.

Using the devices, scientists can also:

- Compare sediment losses from plots having grass filter strips to those lacking filter strips.
- Evaluate the effect of no-till and conventional tillage on erosion and phosphorus loss.
- Examine how intensive grazing or trampling affects runoff from pastures.
- Study the effect of manure type, for example, poultry versus hog, on potential phosphorus loss.

"In each case," Sharpley notes, "we have a standardized protocol for using the rainfall simulators."

State and Federal Partnership

According to Wright, the project's participating universities and state and federal agencies offer unique expertise and resources. For example, EPA's involvement "helps agricultural scientists and the EPA itself understand what scientific information is needed for establishing federal regulations" regarding manure handling, transport, and use, he says. State extension services and NRCS help put research findings into practice. "They transfer the technology and management practices developed by ARS and university scientists to producers," he adds.

But no single tactic or technology is likely to curb phosphorus runoff losses alone. Rather, the emphasis is on combining "source and transport" control strategies. At the source level, this could involve refining feed rations, adding substances like phytase to improve animal absorption of phosphorus, or finding alternative uses for manure. On the transport front, it could be limiting runoff by reduced tillage, use of buffer strips or cover crops, or other techniques.—By **Jan Suszkiw,** ARS.

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