C4E ISSUE BRIEF 1301
Nutrient Management Challenges and Solutions

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On March 6, 2013, Purdue University’s Center for the Environment (C4E) partnered with the University of Notre Dame Environmental Change Initiative and the Indiana State Department of Agriculture to lead a workshop on challenges and opportunities in nutrient management. Through a series of presentations and a question and answer session, a panel of experts helped frame the challenge of how to manage agricultural inputs to support farm productivity while causing minimal harm to our water resources. A summary of the topics covered in the workshop is presented in this issue brief.

The Challenge of Excess Nutrients

Driven by innovation and investment, Indiana agriculture is among the most productive in the world. Significant gains in farm productivity have come through a variety of novel agronomic systems, soil maintenance practices and the use of automation and GPS data to achieve large savings in nutrient inputs. Although we have improved the efficiency of nitrogen use in farm fields over the last 30 years, nitrogen loss to our environment remains a challenge.

Given that in Indiana, greater than 90% of the over 50,000km of streams and ditches are located within 500m of a row-crop field, the importance of nutrient management for water quality is hard to overstate. In the Midwest, this excess reactive nitrogen in our water resources presents problems for human and ecosystem health, directly contributing to hypoxia in the Gulf Coast and reduced drinking water quality.

Nutrient Management Opportunities

Drainage Water Management

Approximately 50% of Indiana’s cropland has subsurface drainage (tile drains) to remove excess water from soils. This technology allows aeration of the soil, better conditions for plant root development, and trafficable conditions for field operations, all of which have increased the productivity of our farms.

Purdue University Professor Jane Frankenberger presented the innovation of drainage water management, a practice designed to decrease the quantity of nitrate in drainage water by managing the release of water from tile drains.
In this practice, the outlet from a conventional tile drain is intercepted by a water control structure that functions like an in-line dam, artificially varying the height of the outlet from the bottom of the drain to near the soil surface so as to drain the field only when necessary to grow crops and do field work. For example, this technology allows a farmer to let the water table rise in the winter when drainage is not needed, and then provide maximum drainage in the spring when farmers need to access fields with equipment for planting. More generally, this system allows farmers to adjust their drainage during the growing and harvesting seasons to optimize production given the local weather conditions, particular cropping system, and the particular soils the farmer manages.

Dr. Frankenberger described the latest drainage water management research underway at Purdue. Several pilot-scale, fully instrumented experiments continuously measure water quality and flow to compare conventional drainage to controlled drainage. Early findings show consistent reductions in nitrate-nitrogen loss from the controlled drainage.

**Woodchip Denitrifying Bioreactors**

Dr. Frankenberger also described a second drainage water management innovation: woodchip denitrifying bioreactors. Simply stated, a denitrifying bioreactor is a subsurface trench filled with a carbon source (usually woodchips) that allows soil bacteria to colonize and eventually convert the nitrate in agricultural drainage water flowing through the reactor to unreactive nitrogen gas. Preliminary data show that given a long enough residence time, the bacteria can effectively remove nitrate from the drainage water.

Purdue installed a demonstration bioreactor at the Throckmorton Purdue Agricultural Center in September 2012, and will evaluate the technology for nitrate reduction, water level and temperature across the bioreactor, and woodchip decomposition. Dr. Frankenberger concluded her presentation by indicating that these techniques are just two options to improve drainage water quality, and that other practices such as cover crops, wetlands, improved nitrogen application recommendations, and 2-stage ditches are also effective ways to address nutrient management issues.

**The Two-Stage Ditch**

Professor Jennifer Tank of the University of Notre Dame explored the efficacy of a nutrient management innovation known as the two-stage ditch—a redesigned drainage channel that can improve water quality as well as local biological conditions in and around the ditch itself. This novel in-stream management tool holds much promise in the Midwest, where “flashy” drainage from tiled-drained fields transports excess agricultural nutrients into adjacent water bodies during spring snowmelt and extreme rain events. These nutrients are then exported to sensitive downstream ecosystems such as the Gulf of Mexico and Lake Erie.

The two-stage ditch practice recreates lateral floodplains within formerly trapezoidal channels, which when inundated during storms reduces the speed and intensity of field drainage and agricultural run-off. The floodplain restoration triples the stream width during storm events, effectively slowing the water flow and increasing bank stability, as well as sedimentation rates and nutrient retention as particles have more time and space to settle out onto the wider floodplain.

**About the speakers**

Indrajeet Chaubey is a Professor of Ecolohy. His research integrates field data collection with simulation-based engineering and computational thinking to study ecolohylogic processes affecting fate and transport of sediment, nutrients, and pesticides from various land use activities and developing watershed management strategies to improve water quality. ichaubey@purdue.edu

Otto Doering is a Professor of Agricultural Economics at Purdue University. His experience on environmental issues includes service on the National Hypoxia Assessment, the National Academies’ Water Science and Technology Board, the U.S. Environmental Protection Agency’s Science Advisory Board, and he chaired EPA’s Integrated Nitrogen Committee. doering@purdue.edu

Jane Frankenberger is a Professor of Agricultural and Biological Engineering at Purdue University, focusing on improving water quality in agricultural watersheds. She conducts research and extension on drainage management and conservation practice effectiveness, and leads the Indiana Watershed Leadership Academy. frankenb@purdue.edu

Linda Prokop is an Associate Professor of Natural Resources Social Science in the Department of Forestry and Natural Resources at Purdue University. Her work focuses on what motivates farmers and other landowners to adopt conservation practices and how to help farmers in the Midwest adapt to climate change. lprokopy@purdue.edu

Jennifer Tank is the Galla Professor of Biological Sciences at the University of Notre Dame. Her research is focused on the impact of human land use on stream ecosystems. Her ongoing collaborations include projects that will inform the effective management of freshwater through assessment of strategies to improve the health of streams draining cropland in the agricultural Midwest. tank.1@nd.edu
Dr. Tank and collaborators from the Ohio State University and The Nature Conservancy of Indiana have collected and analyzed data from multiple two-stage ditch sites, and found that during storm events, the two-stage ditch can reduce sediments and increase nutrient removal via floodplain inundation. Important variables affecting the sedimentation rate include the height of the constructed floodplain and whether it is a dry or wet year. During baseflow, the two-stage ditch can also reduce nitrate from drainage water as tile outflow moves across vegetated floodplains; depending on the length of the flow path, reductions of nitrate have ranged from 6-20%. The researchers also found that the two-stage practice “ages” well over time and its denitrification function improves, making it a self-sustaining practice.

**Computer Modeling & Decision Support Tools**

Professor Indrajeet Chaubey of Purdue University discussed how computer modeling of water and nutrient flows can be used to improve nutrient management. These models can serve as decision-support tools for producers, land managers, and other stakeholders by allowing them to explore various “what if” scenarios for adopting different farming practices on a particular landscape. They can be used, for example, to estimate the extent to which adoption of conservation practices could improve water quality or how a shift in land use related to bioenergy production may affect local and regional environmental sustainability.

Dr. Chaubey described several projects underway at Purdue where researchers are working to improve the capability of model simulations to evaluate the impact of multiple nutrient management strategies at scales ranging from the farm to the watershed. The models consider complex interactions among a large number of processes and variables including, for example, land use, hydrology, fertilizer applications, weather, crop yields, and soil erosion. He noted that the model simulations are not forecasts; they are best estimates of the impacts of our management decisions based on the latest scientific research and painstaking monitoring and data collection of the results of previous management decisions on a wide range of land types.

Dr. Chaubey also presented an example of how a modeling framework can be used to optimize selection and placement of conservation practices in a landscape. Results from the Cedar Creek Watershed optimization study, for example, showed that pesticides in the raw water could be reduced by 30%, nutrients by 50%, and sediment loading could also be reduced by 50% through a particular set of management and cropping choices.

**Knowledge, Application, and Adoption of Best Management Practices**

In the final presentation, Professor Linda Prokopy of Purdue University reviewed a decade of research on why farmers choose to adopt (or not adopt) new management techniques. As a starting point, Dr. Prokopy reviewed a meta-analysis of 25 years of prior research on farmers’ reasons for adopting best management practices (BMPs) which identified few generalizable trends. The review found that older farmers are slightly less likely to adopt BMPs, and larger farms are more likely to adopt new practices that are motivated by the presence of strong local networks and farmers' sense of ownership of those practices.
practices. Additionally, the more positive a farmer’s environmental attitudes, the more likely he or she is to adopt a practice. However, the largest finding from this review is that social networks are incredibly important determinants of whether or not a farmer adopts a new practice.

In subsequent research, Dr. Prokopy’s team found that smaller farms were more willing to try new practices but were less informed about new practices to reduce run off pollution. Characteristics of the practice itself are also important determinants of farmer adoption, with important considerations including on-farm and financial benefits, environmental benefits, and compatibility with current farm practices. Another key finding from Dr. Prokopy’s work shows that it is important who in a community is an early adopter of a new practice – if early adopters are not well-respected, subsequent uptake of the practice will be limited.

The majority of work in this area focuses on what motivates farmers to adopt practices but it is equally, if not more, important that farmers continue to use the practice after adoption. Work in Dr. Prokopy’s group shows that continued use of BMPs over time is motivated by the presence of strong local networks (connections to community groups) and the farmer’s sense of ownership in the BMPs.

Dr. Prokopy’s research allows us to more sharply focus investments on programs promoting BMP adoption that are likely to succeed. She outlined typical characteristics of programs with a high probability of success: a focus on communities with sufficient implementation capacity, including paid watershed staff; active conservation groups; inter-agency trust and collaboration; clear understanding of the environmental problem; previous adoption of “basic” BMPs; and examples of some farmers in the region that are conservation leaders. Conversely, attributes that can lead to program failure include a focus on the individual farmer, a lack of consistent farmer network engagement, a focus only on preliminary adoption not long-term maintenance, no consideration of constraints such as local drainage boards, and a lack of landscape-scale planning and geographic targeting.

Concluding Thoughts

Purdue University Professor Otto Doering moderated the question and answer session following the presentations. Dr. Doering pointed out that nutrient management is an all-encompassing topic. It involves not only the individual management practices like those presented in this workshop but also much broader issues of citizen participation and policy decisions. The larger issue of nutrient management is not fully addressed by traditional science focused on the movement and control of nutrients, but also involves a broad set of stakeholders who may be recipients of excess nutrients or agricultural producers reluctant to spend resources on controlling nutrients.

In addition, society has concerns about protecting water quality and the environment. The presentations at the workshop could only give a flavor of the overall dimensions of the nutrient management problem and potential approaches to ameliorate it. The workshop illustrates the necessity of cooperative efforts to manage nutrients that will have to involve different institutions and multiple stakeholders as well as scientists from different disciplines.

For More Information

Frankenberger, J., E. Kladivko, G. Sands, D. Jaynes et al. (2012). Questions and Answers About Drainage Water Management for the Midwest, Purdue Extension Publication WQ-44; see also: www.purdue.edu/watersheds/conservationdrainage

