



**ILLINOIS**  
NUTRIENT LOSS  
REDUCTION STRATEGY

Improving our  
water resources  
with collaboration  
and innovation

**2017 Inaugural Illinois NLRs Conference**  
**RESEARCH SHOWCASE**  
**Abstracts**

# Ongoing research into phosphorus and nitrogen and sediment dynamics in two Illinois reservoirs

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## Abstract:

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Most tributaries of the Mississippi River have been modified to have reservoirs whose primary purposes are to control flood waters and to supply municipal drinking water. However, reservoirs also impact the nutrient and sediment content of rivers, sometimes acting as a sink and other times a source. Beginning in summer 2016, the National Great Rivers Research & Education Center (NGRREC) along with Saint Louis University (SLU) began extensive boat-based sampling of water and sediments in Carlyle Lake on the Kaskaskia River and in summer 2017, efforts were expanded to include Lake Decatur on the Sangamon River. Agriculture is the primary land use in both watersheds, but the Sangamon is dominated by tile-drained row-crop farming whereas the Kaskaskia landscape is a more diverse collection of row-crops, pastures, forages, and woodlands. In addition to the boat-based monitoring, NGRREC maintains a real-time, continuous water monitoring buoy on each lake as part of their Great Rivers Ecological Observatory Network (GREON). The objective of the sampling is to understand phosphorus and nutrient dynamics in the reservoirs and to ascertain whether phosphorus release from the sediment layer contributes to episodic algal blooms. A secondary objective is to compare lake-wide boat-based sampling results to those obtained with the GREON buoy in order to determine if data from the GREON buoy effectively represents the entire lake system. This poster presentation will describe the various methods used by NGRREC, SLU, and the University of Wisconsin-Oshkosh to carry out the monitoring project. Current results will be presented and discussed. Our future plan is to expand monitoring activities to include Lake Shelbyville on the Kaskaskia River upstream from Carlyle Lake in order to see how the two reservoirs work in tandem to reduce the nutrient load of the Kaskaskia River. We seek feedback and input from INLRS participants on how relevant reservoirs are to reducing the amount of nutrients delivered to the Mississippi River and whether reservoirs will play a more important role in managing water resources in the Mississippi River basin given the increasing occurrence of extreme weather events caused by global climate change.

# Evaluating the effectiveness of winter cover crops as nutrient-loss reduction practices using coupled optimization-watershed model

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## Abstract:

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This study evaluated the use of winter cover crops as best management practices to provide optimal reduction of nutrient loss from agricultural lands at a watershed scale. It focused on two tributary subwatersheds of Lake Decatur, namely Big Ditch and Big/Long Creek, which were selected for the preparation of watershed implementation plans. Lake Decatur is a public water supply reservoir, serving a population of more than 80,000. Winter cover crops are commonly planted during or after the corn and soybean growing season with the primary goal of improving or maintaining the provision of multiple ecosystem services that include but not limited to scavenging residual soil nutrients and reducing soil erosion. The Soil and Water Assessment Tool (SWAT) coupled with a multi-objective optimization algorithm known as AMGA2 was used to generate alternative implementation scenarios of three cover crops (i.e., cereal rye, annual rye grass and crimson clover) in the study watersheds, providing optimal tradeoffs between their implementation costs and resulting nitrate-N load reductions. The best tradeoff scenarios for all cover crops provided average nitrate-N and total phosphorus load reductions of at least 7.8 percent and a sediment load reduction of 4.4 percent, requiring 4,600 to 5,050 hectares of watershed treatment area. The lowest and highest average costs per nitrate-N reduction were obtained for cereal rye (\$18.9/kg N/ha) and crimson clover (\$46.1/kg N/ha), respectively, and the highest cost per reduction was partly due to expensive seed cost. Evaluation results indicated that all three cover crops caused water yield reductions in the months of October and November (i.e., as high as 16 percent). This could be detrimental to the lake's water storage during drought years if cover crops are extensively implemented in the lake's drainage area. Therefore, due consideration should be given to its impact on watershed water yields, particularly in periods of low flows. The developed model can also be used to evaluate user-specified placements of winter cover crops in the two watersheds, allowing comparison of different implementation scenarios in terms of load reduction and cost.

# Estimation of soil inorganic nitrogen age to mitigate nitrogen losses in intensively managed landscape

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## Abstract:

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While strategies to reduce inorganic nitrogen loadings from drained agricultural lands have been widely studied, changes in the dynamics of the “age” of inorganic nitrogen in the soil due to tile drain systems have not been well investigated, which limits our understanding of complex nitrogen dynamics due to the time legacy of nitrogen. The objective of this study is to explore the impacts of tile drains on the age dynamics of nitrate, immobile ammonium, mobile ammonia/um, and a non-reactive tracer (such as chloride) by implementing two mobile interacting pore domains to capture matrix and preferential flow paths in a coupled ecohydrology and biogeochemistry model, *Dhara*. We applied this model to an agricultural farm that utilizes a corn-soybean rotation in the Midwestern United States. Although it may be expected that the presence of tile drains decreases the age of soil nutrients due to nutrient losses through tile drainage, an increase in the age of mobile ammonia/um is observed; that is in contrast to the cases for nitrate, immobile ammonium, and non-reactive tracer. These results arise because the depletion of mobile ammonia/um due to tile drainage causes a high mobility flux from immobile ammonium to mobile ammonia/um, which also carries a considerable amount of relatively old age of immobile ammonium to mobile ammonia/um. In addition, the ages of nitrate and mobile ammonia/um in tile drainage range from 1 to 3 years and less than a year, respectively, indicating that there is the potential legacy effect of policies for nitrogen load reduction in agricultural fields. This finding can motivate stakeholders who express doubt that the nitrogen mitigation strategies yield any immediate benefits and who would like to know how much time is required before seeing their full effects.

# Science and social networks for sustainable water and nitrogen management: The NitroShed analytical system

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## Abstract:

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The challenge of creating sustainable solutions requires consideration of not only hydrological, physicochemical, and ecological factors, but also social factors influencing management decisions. Farmers communicate information about their agronomic practices through social media, and we have begun developing models that estimate the timing of farming activities such as planting, fertilization, and irrigation at high spatial resolution. This advanced knowledge can be leveraged to inform more sustainable management practices that conserve water and nitrogen. Our goal is to develop the science of event-driven management, such that decisions are tangibly improved at all spatiotemporal scales, while managing risks for operators, improving productivity, and reducing environmental impacts. We will accomplish this goal through three integrated objectives. First, we will work with stakeholders to identify research needs and methods of evaluating research outcomes. Second, we will develop an analytical framework, the NitroShed Analytical System, based upon stakeholder input, for improving the quality of recommendations disseminated to farmers. The NitroShed System will leverage farmers' social media communications for information about their use of best management practices suggested in the Nutrient Loss Reduction Strategy. It will also help to identify how widespread their social networks are and the most influential actors and organizations in those social networks. The NitroShed framework will generate and disseminate recommendations to farmers and other stakeholders that combines real-time information from social media with scientific understanding embedded in crop yield and hydrological models to assist farmers with planning and implementation of management practices that maximize yield and profits while minimizing water resource usage and nitrogen pollution. Finally, we will create a transdisciplinary, integrative environment among stakeholders, researchers and extension that will support further activities, including training the future workforce.

# Applied science and strategic partnerships to reduce nutrient losses from tile-drained lands in the Mackinaw River watershed

Krista Kirkham and Adrienne Marino, The Nature Conservancy

## Abstract:

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The Nature Conservancy has been working to advance conservation on agricultural lands in the Mackinaw River watershed in central Illinois for more than 25 years. This watershed is heavily tile-drained and representative of many row-crop dominated watersheds in the Corn Belt region. Our current work focuses on reducing nutrient losses from tile drained fields through increased implementation of edge-of-field conservation practices like constructed wetlands and saturated buffers, and increased adoption of cover crop and nitrogen management practices.

Our proposed Research Showcase presentation includes two posters describing (1) how long-term water quality projects in the headwaters of the Mackinaw River are contributing to regional knowledge about the effectiveness of specific agricultural conservation practices, and (2) how a suite of engaged partners are integrating water quality data, state-of-the-art mapping tools, and targeted outreach to advance conservation efforts in the Mackinaw River watershed. Poster #1 is titled *Conservation Practice Effectiveness and Application for Water Quality Improvements in Agricultural Subwatersheds of the Mackinaw River, Illinois*<sup>1</sup>, and Poster #2 is titled *The Power of partnerships: Creating opportunities for conservation at a watershed scale*<sup>2</sup>.

Successfully meeting the goals of the Nutrient Loss Reduction Strategy will require additional research on the effectiveness of conservation practices, economics associated with those practices, and how best to promote them. Strong and diverse partnerships of agencies, organizations, and landowners dedicated to working together will be needed to achieve local watershed goals associated with the Strategy. The Conservancy's work with partners in the Mackinaw River watershed touches on both of these requirements and serves as a useful model for similar approaches throughout the state. Our research display will include the two posters listed above, information from our 2016 *Franklin Research and Demonstration Farm Report* and the Conservancy's work on soil health, and materials describing research and outreach opportunities associated with the Illinois Sustainable Ag Partnership and the Midwest Row Crop Collaborative's Upper Sangamon River Watershed project. Conservancy staff will be present to discuss the research and its growing agriculture program in Illinois with workshop participants.

<sup>1</sup>Poster Authors: Krista Kirkham\*, Maria Lemke, Adrienne Marino, Ashley Maybanks, Miran Day, David Kovacic, Mike Wallace, Jackie Kraft, Kent Bohnhoff, Terry Noto, Rick Twait

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## **Fulton County research program on nutrient loss reduction from agricultural fields:**

*The development, verification, and demonstration of soil and nutrient management practices for watershed-scale reduction of nitrogen and phosphorus loads*

G. Tian, O. Oladeji, A. Cox and H. Zhang

Metropolitan Water Reclamation District of Greater Chicago

### **Abstract:**

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The 45 percent nutrient loss reduction goal established in the Illinois Nutrient Loss Reduction Strategy could be achieved most quickly and economically through the collaborative effort of the point and non-point sources of nutrients. For non-point (agricultural) source, nutrient loss is mainly through surface runoff and tile drainage. Several best management practices (BMPs), such as cover crop, no-tillage, riparian vegetation restoration, runoff irrigation/drainage water management (DWM), denitrification bioreactor etc., can potentially reduce nutrient loss from agricultural fields. However, many of these BMPs are either not well developed for the Illinois climate condition or not extensively tested in a large (watershed) scale. There is also a lack of information on their long-term effectiveness and economics of these BMPs. Yearly variability in weather can lead to highly variable nutrient and sediment exports from one year to another, thus, long-term monitoring data are needed to adequately evaluate the overall benefits of BMPs.

In 2014, the Metropolitan Water Reclamation District of Greater Chicago established the agricultural nutrient loss reduction research program at its Fulton County site of about 13,000 acres. The goal of the program include: 1). Establish the Fulton County site as a model to foster collaboration between the point source and the agricultural sectors to develop and demonstrate the use of BMPs. 2). Develop and demonstrate the effectiveness of in-field and edge-of-field BMPs such as cover crops, riparian vegetation buffer, runoff irrigation/DWM, and bioreactor. 3). Characterize a series of paired field-based watersheds with respect to nutrient loss and establish BMPs for watershed-scale nutrient reduction study. 4). Disseminate improved management practices to farmers via field days and various media.

Since 2015, research and demonstration projects have been established at the site in collaboration with the University of Illinois at Urbana-Champaign, Illinois Central College, and Ecosystem Exchange, Iowa. The projects established include interseeded cover cropping, riparian vegetation buffer, runoff irrigation, and field-based watershed nutrient reduction. Findings from these projects are reaching local and regional agricultural communities, through field days and annual meetings, and publications (project reports and peer-reviewed journal articles). We envision that with the long-term continuous monitoring, the results of efforts at the Fulton county site will be regionalized to develop general guidance for implementation of BMPs throughout the entire Illinois state. The poster will feature some of the projects by showing how they were established in the fields and some of the results obtained to date.

## **Nitrogen recovery and biomass production: Environmental and economic benefits**

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### **Abstract:**

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High nutrient loadings in aquatic and terrestrial ecosystems due to runoff and nutrient leachate from agricultural systems has led to research interest in the value of multifunctional landscapes to improve resilience of ecosystems. This six-year study introduced shrub willows (*Salix miyabeana* SX64), an energy crop, on marginal (low-yielding and environmentally susceptible) areas within a 6.5-ha continuous corn field in east-central Illinois to quantify their impact on the environmental ecosystem services. The primary focus has been on the extent of nutrient interception from an upland corn field as well as evaluating the influence of energy crop placement on the agricultural landscape. Nutrient cycling at the field scale was measured by sampling soil, soil water, groundwater, and vegetation for nutrient loss and uptake. Additional field measurements included soil moisture, groundwater elevation, greenhouse gas flux, transpiration, and biomass. Results show that since willow establishment in 2013, willows significantly reduced concentrations of nitrate leachate compared to corn crop cover. Additionally, willows were comparable to corn in terms of rates of water use and soil N reserve utilization.

Our research has shown that shrub willows could be cost-competitive, when compared on a nitrogen removal basis, to mainstream conservation practices, because the value of the biomass generated compensates for part of the costs of implementation. The recovered nutrients reduce the need for fertilizers, and land is used more efficiently in an annual and perennial double cropping system. Converting “marginal land” to perennial crops may provide biomass feedstock and substantial water quality benefits whose value may exceed that of the costs of production. By intercepting nitrates in the subsurface, willows can efficiently self-serve for their nutrient requirements. This provides yield and water quality improvements at little to no additional cost.



# Water and agricultural landscape in Illinois

Katherine Kraszewska

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## **Abstract:**

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Since the passing of the 1972 Clean Water Act, the United States has been fairly successful at reducing point source contaminant loads in our nation's water resources. However, despite our relative success, progress needs to be made to ensure water quality. Non-point sources are generally unregulated and continue to adversely affect water quality efforts. Agricultural runoff accounts for the majority of non-point source discharges. Unfortunately, the fertilizers that usually ensure crop health ultimately place distress on aquatic systems. The state of Illinois is one of the leading contributors of fertilizer contaminant loads to the Mississippi River, and in turn the state has a tentative goal of reducing nitrogen and phosphorus loads by 45%. By framing agricultural strategies in the context of landscape architecture, the project aims to provide thoughtful solutions to agricultural issues while keeping the well-being of farmers in mind. Instead of completely changing the science behind agricultural practices, the suggested series of interconnected projects offer complementary design strategies such as constructed wetlands to reduce the detrimental effects of nitrogen and phosphorus fertilizers.

# Elucidating tradeoffs between phosphorus removal, struvite precipitation rate and recovery

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## Abstract:

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To reduce plant discharge and recover phosphorus (P) fertilizers from nutrient-rich sidestreams, wastewater utilities increasingly elect to employ struvite precipitation processes without a clear understanding of the inherent tradeoffs associated with specific design and operating decisions. Specifically, the impact of reactor conditions on struvite crystallization rate and distribution between homogeneous nucleation of fines and secondary growth onto seed crystals represent critical knowledge gaps limiting the predictive capabilities of existing process models. In this work, the relative impacts of initial supersaturation ( $S_i$ ) and seed loading on P removal kinetics and struvite solids distribution were investigated. In experiments conducted at different levels of initial supersaturation (1.7 – 2.4) and seed loading (0 – 25 g L<sup>-1</sup>), struvite fines represented the majority of struvite solids formed in 10 of 12 conditions. While total P removal was dependent on  $S_i$ , and primarily attributed to fines production, the concentration of struvite seed granules had a significant impact on the rate of P removal. Struvite seed granules increased the rate of precipitation by reducing induction time of primary nucleation of struvite fines. Secondary crystal growth represented the majority of struvite solids formed at high seed loading and low  $S_i$ , but presented the tradeoff of low total removal and low rate of removal. To convey the significance of these findings, we show how a prominent kinetic model with a first order dependency on struvite concentration over-predicts P removal rate when mass is dominated by large diameter seeds (0.9 mm). This work reveals the critical role of struvite fines in P removal and highlights the need to account for their formation, agglomeration, and recovery in struvite process design and modeling.

# Water quality evaluation for agricultural management practices on producing bioenergy in an Upper Mississippi River tributary basin

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## Abstract:

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After previous assessments in 2005 and 2011, the U.S. Department of Energy in 2016 released a third assessment of biomass resource availability in the United States. The study proposed scenarios under which a billion dry tons of biomass per year would be available by 2030. Through the use of biofuels, bioproducts, and biopower, this biomass could replace approximately 30% of the United States 2005 petroleum consumption. This study is part of the *2016 Billion-Ton Report—Volume 2, Environmental Sustainability Effects of Select Scenarios from Volume 1*, which focuses on biomass production without negative impacts on food, agricultural products, or the environment. In particular, this work analyzes the effects that changing land uses will have on biomass production, and how select conservation practices could reduce the loss of nutrients and sediments to waterbodies. The study area is the Iowa River Basin (IRB), in Iowa, which is in the center of Upper Mississippi River Basin (UMRB). This region is the one of the highest non-point sources of nutrients for the UMRB. To simulate flows, nutrients, and suspended sediments in IRB, the Soil and Water Assessment Tool (SWAT) was used. The model was calibrated and validated for streamflow, suspended sediment, nitrate, and phosphorous, for 20 years. Future land use and feedstock production scenarios were applied to the SWAT. Biomass crop and agricultural residue are the main sources of bioenergy feedstock. Multiple corn-soybean rotation schemes (SCSC, CSCS, CCCC, CSCC, etc; C for corn and S for soybean), partial stover harvest, and the production of bioenergy crops such as miscanthus and short-rotation willow crops were simulated. In addition, conservation practices were applied to the future scenario BT2040 model, including riparian buffers, cover crop, tile drainage, and different nitrogen fertilizer applications designed to minimize environmental impacts. The results show substantial reductions of suspended sediment (up to 80.3% in the riparian buffer scenario), nitrogen loading (up to 50.3% in the tile drainage scenario), and phosphorus loading (up to 27.4% in the cover crop scenario), as well as increasing biomass production (up to 3 million dry tons) from energy crops and stover harvest at the outlet of the Iowa River Basin. This study could potentially guide farmers and decision-makers in bioenergy production that maintains soil and water quality in the Midwest. Perennial biomass production would also be beneficial in decreasing downstream nutrient loading to the Gulf of Mexico.