

# Plantwide Integration of Struvite Crystallization Processes with Kinetics Based Dissolution

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Managing phosphorus (P) within the Food-Energy-Water (FEW) network is essential for securing P fertilizers necessary for meeting projected food demands and preventing excess P leaching into waterways from municipal water resource recovery facilities (WRRF) and agricultural operations. Minimizing the release of P into waterways prevents impacts such as eutrophication, dead zones, deadly algal blooms, and biodiversity loss. WRRF's are increasingly implementing sidestream processes to reduce concentrated P streams generated from anaerobic digestion of BNR sludge. One such process in development is the crystallization of struvite ( $\text{MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O}$ ). Phosphorus removal and recovery through struvite precipitation at WRRF's reduces P recycling to mainline treatment while producing a P-rich fertilizer with the potential to reduce runoff. Two challenges faced by the widespread introduction of struvite recovery technologies are 1) A lack of models defining the plant size and configurations best suited for struvite recovery and 2) Limited data surrounding struvite dissolution kinetics.

Though models have been developed for many common WRRF processes, characterizing struvite recovery potential for varying plant sizes and configurations has not been well explored. Determining struvite recovery under differing conditions allows informed decision making for implementation at WRRF based on struvite recovery and P removal. Another underlying issue in struvite crystallization process models is the absence of fines loss from crystallization reactors and dissolution in the process chain. Unfortunately, modelling dissolution along the process train is not commonplace because of the limited data surrounding pure struvite's dissolution rate. No data has been reported for the dissolution rate of struvite seeds from full-scale fluidized bed reactors in the literature. Integrating struvite dissolution kinetics in struvite crystallization process models will demonstrate how dissolution will impact the function of the overall plant.

In this work, we characterized dissolution at the batch scale and integrate these results with accepted plant-wide WRRF modeling. The dissolution rate constant for struvite, hydroxyapatite, and struvite recovered from various WWTP's is elucidated from batch dissolution experiments under constant pH and ionic strength using the shrinking object model. Full-scale plant configurations are developed in GPS-X representing plants ranging in size and influent composition considering P removal and struvite recovery.

This research works towards integrating kinetics based dissolution processes with plantwide modelling. An integrated system will allow for an evaluation of the chemical impacts of treatment efficacy, life cycle costing, and life cycle assessment which have yet to be performed for these types of recovery systems. These types of assessments will inform future WRRF design by providing tools to evaluate what

combination of plant influent conditions and process chains would results in cost-effective P recovery.

### **Developing Innovative Training Programs to Build Capacity for Conservation on Agricultural Lands**

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Agricultural nonpoint source (NPS) pollution is the leading source of water quality impacts to rivers and lakes. Throughout Illinois, and the Midwest as a whole, agricultural lands deliver high nitrogen, phosphorus and sediment loads that impair local water systems and contribute to downstream water quality issues in the Gulf of Mexico and the Great Lakes. There is immense need for widespread adoption of conservation practices in these areas, and with that come tremendous opportunities diverse organizations to work in partnership with the agricultural community to implement sustainable solutions that rebuild healthy soils and reduce nutrient losses.

The Illinois Chapter of The Nature Conservancy is a leader and founding member of the Illinois Sustainable Ag Partnership (ISAP), a coalition of organizations working collaboratively on agriculture programs that promote whole system conservation solutions to meet sustainability goals. Through ISAP, Conservancy staff are facilitating two training programs designed to give agricultural conservation professionals technical knowledge, tools, and resources to be ambassadors for soil health and conservation drainage practices in their communities. In 2018, twenty individuals began an 18-month advanced soil health training program. A second, similarly-sized group completed a shorter series focused on practices that treat tile drainage, which is prevalent in central Illinois and much of the Corn Belt region. The training programs have several common elements, and both can be adapted for use in other parts of the state and/or region. Our poster describes the process we used to develop the training sessions and key elements others should consider in developing similar programs. We will also share sample materials from the training sessions and discuss opportunities for interested individuals and groups to engage further on these topics.

## **Cover Crop Species and Tillage Effects on Soil Greenhouse Gas Emissions and Production in Illinois, USA.**

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Large levels of soil nitrogen are routinely observed throughout the Midwest due to fertilization of cash crops, especially corn. The excess of N in the field stimulates N<sub>2</sub>O production through denitrification. Due to the excessive amount of N and P entering the Mississippi River Basin, a goal of reducing the amount of nutrients entering waterways was initiated; cover cropping was found to be the most promising in-field strategy to help reduce the N loads. The objective of this study was to determine the influence of tillage and cover crop type on greenhouse gas (GHG) emissions on typical Mollisols in Savoy, IL, USA. The experimental design was a RCB design with four replications; two levels of tillage were present, chisel plow and no-till. Cover crop treatments had six levels, which included cereal rye [*Secale cereal*], spring oats [*Avena sativa*], rapeseed [*Brassica napus*], daikon radish [*Raphanus sativus*], annual ryegrass [*Lolium multiflorum*], and an unseeded control plot. We measured GHG emissions – nitrous oxide (N<sub>2</sub>O), carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>) – in 2013, 2014, 2015, 2016, and 2017 following corn [*Zea mays*] harvest; we also sampled soil N concentrations to 10 cm at each GHG sampling. Preliminary results indicate that GHG emissions and soil properties were not affected by cover crop type or tillage option, but instead an effect due to the year was observed. However, nitrate intensity did observe a year by tillage interaction.

## **Removing Dissolved Phosphorus with Edge-of-Field Phosphorus Filters**

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Phosphorus (P) loss from intensively managed agricultural landscapes in Illinois is an ongoing concern. The Illinois Nutrient Loss Reduction Strategy proposes management practices to reduce the state's P loss load by a target of 45% of the 1980-1996 annual average, corresponding to a reduction of 8.97 million pounds per year from non-point sources. Edge-of-Field P filters are a novel practice that provides landowners with an off-field option to remove P from runoff or drainage waters. The filters are filled with a media containing aluminum, calcium, and/or iron which captures dissolved P from water. This NREC-supported work, showcased using a traditional poster while informing participants of the work, will evaluate potential mitigation strategies for P loss by focusing on a select group of media shown to have high P sorption potential, with a focus on re-use of regionally-available waste materials. The potential media (fly ash, steel slag, acid mine drainage waste, zeolite, alum-based drinking water treatment plant residuals, and gypsum) will be evaluated for P sorption capacity as well as factors relevant to field-feasibility, including heavy metal concentrations, P desorption potential, and hydraulic conductivity. These factors influence the potential reuse or lifespan extension of a material. Six potential P-sorbing media have been assessed using traditional batch isotherm studies to quantify sorption kinetics and potential, and as influenced by media particle size. Media will be assessed using column experiments to mimic realistic contact times and P concentrations anticipated for edge-of-field filters. Additionally, the hydraulic conductivity and costs of media will be assessed to provide comprehensive assessment of engineering and economic feasibility of candidate media. Finally, the potential of portable X-ray fluorescence spectroscopy as a rapid, low-cost, on-site method to evaluate P saturation and thus life expectancy of the potential filter materials will be investigated. Ultimately, this combination of experiments will be used to identify specific media type and characteristics (e.g., particle size) to optimize field-ready P-sorbing filters. These results will lead to the selection of 'best bets' media for field-scale implementation of an edge-of-field P filters in southern Illinois, a priority region for P mitigation from agricultural landscapes.

## **Toward a Model of How Policies Affect Crop Markets, Fuel Markets, and Water Quality in the Mississippi River Basin**

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We propose to create an integrated FEW model and with user-friendly software to 1) enable individual farmers to examine the predicted economic and environmental impacts of their fertilizer management strategies, and 2) provide policy makers with a user-friendly tool in order to design policies that will lead to efficient reduction of N-nitrate contamination in the Mississippi River Basin. The model will be based on the ideal CyberGIS computation platform, and expand to the scale of the Mississippi River Basin the DSSAT crop growth model and the SWAT water drainage model. The model will also integrate the BioScope model of biomass supply, and a partial equilibrium economic model of crop, energy, and biomass markets in the U.S. Midwest and beyond. We argue that the principal shortcoming of current agricultural “Big Data” is that there is little record of variance in *managed input use*. Of course, managing inputs efficiently *is the whole point of farm management*, whether the goal is to increase monetary returns or environmental sustainability. Therefore, we propose to parameterize our integrated model with data we generate from *large-scale, on-farm agronomic field trials over an entire small watershed*. Those trials will randomize N application rates and cover-crop management strategies to measure both yield and water quality results of varying these managed input variables. We will use the generated data with existing agricultural “Big Data” to create “decision tool” software to improve private and public crop fertilization strategies. The proposed research will rely heavily on the proven abilities and infrastructure of the CyberGIS Center for Advanced Digital and Spatial Studies, and on the software, administrative capacity, and scientist-farmer relationships developed in an on-going USDA-NIFA Food Security project on data-intensive fertilizer management. In addition, we will provide opportunities for underrepresented undergraduates to gain research experience through an extension of the WE CAN program.

## Nitrogen Loss Reduction Performance at Ongoing Saturated Buffer Studies in Illinois

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A saturated buffer is novel edge-of-field conservation practice to mitigate nitrate-N loss from drainage water. This is a modification of a tile drainage outlet that allows tile drained water to flow laterally through a vegetated buffer, removing nitrate-N through denitrification and plant uptake. The objective of this study is to evaluate the nitrogen (N) and phosphorus (P) reduction performance of two saturated buffers to assess this practice's inclusion as a recommended practice in the Illinois Nutrient Loss Reduction Strategy. A newly established saturated buffer in Knox County, Illinois and a 5-year-old saturated buffer in Piatt County, Illinois have been monitored since January 2018. Preliminary data show the Knox Co. and Piatt Co. saturated buffers treated 98% and 78% of the total drainage volume from 9.0 and 6.9 ha drainage areas, respectively. This was equal to 85 mm and 52 mm drainage depths at the sites, respectively. During the current monitoring period, the Knox Co. saturated buffer received a total of 221 kg-N and 0.45 kg-P, and the Piatt Co. buffer received 342 Kg-N and 0.14 kg-P. Monitoring well networks at both sites showed reductions in nitrate-nitrogen (NO<sub>3</sub>-N) concentrations compared to the concentrations in the saturated buffer control structure. Nitrate-N concentrations in the control structures of the Knox Co. and Piatt Co. sites were between 5.21 - 10.3 mg/L and 14.8 - 19.5 mg NO<sub>3</sub>-N /L, respectively. The NO<sub>3</sub>-N-concentrations across four monitoring well transects at the Knox Co. saturated buffer ranged from 0.21 – 4.13 mg NO<sub>3</sub>-N /L which was about 46% - 97% removal. Similarly, three monitoring well transects at the Piatt Co. buffer showed a range of 5.00 - 12.0 mg/L NO<sub>3</sub>-N which was about 30% -70 % removal. While the magnitude of the reduction in these-sites directly depend on rainfall and drainage volume, both sites showed potential to reduce nutrient loads being delivered to the stream.

## Mitigating P losses via Slow-Release P fertilizer Struvite and Cover Crops

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The eutrophication of inland and coastal water bodies from non-point P leakage along the food production chains has necessitated better nutrient stewardship. To mitigate off-farm P losses while maintaining agricultural productivity, there is a need for P management tools that can be integrated into existing crop production practices. Two emerging tools for P management are slow-release P fertilizers such as struvite and cover crops. Struvite ( $\text{MgNH}_4\text{PO}_4$ ; 5-28-0) derived from wastewater streams, has low water solubility (1-5%) but is 27% citrate soluble enabling its greater availability in the presence of crop root exudates. Contrary to MAP ( $\text{NH}_4\text{H}_2\text{PO}_4$ ; 11-52-0) which has a greater water soluble P content (44-49%) and only 1% citrate-soluble P, struvite could be a potential nutrient loss reduction measure to minimize soluble P losses via runoff and P fixation. However, its low water solubility may limit crop P uptake, especially during early growth. To enhance exudate-mediated P release from struvite prior to the following crop (corn or soybean), cover crops could be a potential solution. Independently of struvite, cover crops are a commonly proposed best management practice (BMP) that can minimize erosional and leaching losses of P but pose potential trade-offs in aggravated P loss risk due to surface stratification and dissolved reactive P (DRP) flushes of terminated cover crop biomass. This study aims to address the ambiguity over the potential benefits or disadvantages of cover crops for managing P losses. In this NREC funded study, a combination of greenhouse and field experiments will be employed to evaluate the agronomic potential of struvite and its interaction with tillage practices (no-till vs conventional till), fertilizer placement (broadcast vs banding) and timing (fall vs spring application). Cover crops (cereal rye) will be evaluated as a stand-alone P loss reduction strategy by quantifying the P speciation in soil (0-6 in depth) at three stages (living CC, decomposing CC and during cash crop growth stage), cover crop biomass P content and crop P uptake at P-critical growth stages (e.g. V6 and V12 for corn). Additionally, interactions of these two potential P management tools, struvite and cover crops, will be determined. The poster would describe the hypothesized potential of struvite and cover crops as P management strategies and the proposed experimental work to determine their agronomic and environmental potential. It will be formatted as a traditional research poster with prompts for discussion.

## **Using Unmanned Aerial Vehicles to assess Drainage Water Management Practices**

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Drainage water management (DWM) and saturated buffers are two methods to potentially reduce tile drainage nutrient loss, but they are not currently included in the Illinois Nutrient Loss Reduction Strategy. Two DWM sites containing a free drainage and DWM plot and two sites containing saturated buffers will be monitored to test the water quality and determine nitrate reduction effectiveness. The monitoring of these sites will help determine if these two practices should be recommended for inclusion in the Nutrient Loss Reduction Strategy. One way to help in this monitoring process is through remote sensing using Unmanned Aerial Vehicle (UAV) imaging, GIS, and digital elevation modeling. For example, the UAV imaging can be used to measure the biomass at a monitored site versus a site that does not follow one of the desired tile drainage nutrient loss reduction methods. This poster presentation will describe the ways UAVs are currently being used in agriculture and water quality management to help map and better understand monitored fields. Unmanned Aerial Vehicle usage in water quality management is a relatively new area of interest, but there is potential to collect valuable research data. This poster will provide an overview of how UAVs can be used in this line of nutrient loss reduction research and intends to initiate and facilitate discussion of such possible research questions.



## Hydraulic Evaluation of a Flow-Routing Baffle Denitrifying Bioreactor Design

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Denitrifying bioreactors are woodchip-filled excavated pits used as an edge-of-field conservation practice to augment the denitrification of nitrate-nitrogen in tile drainage water. These 'woodchip bioreactors' must be cost effective, practical, and compact to justify their voluntary use by landowners. Such bioreactors have been researched for two decades, but there is still a need for more knowledge on design parameters due to variability in field-scale performance. This study used potassium bromide conservative tracer tests to evaluate a new wider bioreactor design that included baffles. The bioreactor (LWD: 16.8 x 10.7 x 0.91 m) was installed in October 2016 near Pana, Illinois, USA, and treated drainage from 14.2 ha. Tracer testing results were compared to tracer tests conducted at three other "conventionally" designed bioreactors. This new bioreactor design had statistically significantly greater effective volume, lower dispersion, and less short circuiting compared to conventionally designed bioreactors. However, this did not necessarily translate into improved NO<sub>3</sub>-N removal. The bioreactor with baffles had overall N load reductions of 21-30% which were similar to many other published studies (67-78% N removal for water treated in the bioreactor; 1.26-1.78 g N removed m<sup>-3</sup> d<sup>-1</sup>). Additionally, there was unexpected dissolved P removal (18-19%), mechanisms of which should be investigated further. While the baffles did not lead to increased N removal compared to conventionally designed bioreactors, they did improve bioreactor volume utilization, and thus, the idea of bioreactors with baffles is an idea meriting further exploration at additional sites.

## **The Role of Perennial Energy Crops for Biofuels in Reducing Gulf Hypoxia**

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Increased demand for biofuel production motivated by the Renewable Fuel Standards (RFS) has increased land under corn production to meet the 15 BG corn ethanol mandate. A major consequence of expanded corn-based ethanol production has been intensification of nitrogen application on cropland and worsening of the hypoxia problem in the Gulf of Mexico. Diversifying cropland to produce perennial crops such as Miscanthus and Switchgrass has the potential to reduce nutrient run-off from cropland. However, the extent of these benefits will depend on where energy crops are produced, the type of land allocated to energy crop production and the mix of crops and bioenergy feedstocks across the rainfed region of the US. This poster describes findings from research using integrated economic and agroecosystem models to understand the synergies between biofuel production and water quality impacts. Results from the analysis show feedstock mix, location and type of land that is economically optimal for the production of energy crops to meet growing biofuel demand. It will also show our findings on the impact of various types of biofuels on nitrate run-off and on the costs of improving water quality by diversifying land use to include perennial energy crops. Overall, research findings which will be presented using traditional poster style, maps and stakeholder discussion, will support relevant policy on sustainable intensification of bioenergy production and water quality improvement in the Mississippi Atchafalaya River Basin.

# **The Two-Stage Saturated Buffer: Integrating the Use of Cover Crops into Saturated Buffer Designs for Nitrogen Mitigation in Southern Illinois Agriculture Systems**

John Gale

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Water quality impairment from agricultural runoff has received growing attention and requires immediate action to adapt or develop best management practices (BMPs) to reduce impacts on the environment. Illinois is a major ag production state and its farmers have been taking a proactive stance in nutrient and sediment management in order to prepare for potential nutrient regulations. To date, there have been many BMPs proposed to attenuate nutrients and trap sediments along the field borders and within agricultural fields. Both saturated riparian buffers (SRBs) and cover crops have proven to be effective BMPs for nitrogen management in row crop agricultural areas (Jaynes and Isenhardt 2018). This research seeks to quantify nitrate-N leaching from three drainage scenarios in a tile-drained system: 1. a control (i.e., a grassed buffer with no tile diversion), 2. a standard saturated buffer (i.e., a diversion draining through a grassed buffer), and 3. a two-stage saturated buffer that drains into both a cover crop strip (stage 1, diversion 1) and a grassed buffer (stage 2, diversion 2). This research takes place in Southern Illinois and is one of the first to blend the two BMPs into one management design used for assessing nitrogen management in row crop agriculture. Water flow and nitrate-N in the tile outlets, diverted into the buffers, and nitrate-N concentration changes within the buffers have been measured, bi-weekly, throughout the year at each site. Preliminary results have shown that nitrate is the predominate form of Nitrogen leaving the field and cover crop and grass buffers have had higher nitrate-N concentrations than the field wells due to the lateral lines in the saturated buffer systems conveying water towards the wells in the vegetated buffers. Additionally, a partial budgeting approach will be used to quantify the economic costs and benefits of the various saturated buffer designs.

## **Tile Nitrate Loads: Not Simply a Matter of Excessive N Fertilization**

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Hypoxia in the Gulf of Mexico is often partly attributed to excessive N fertilization, suggesting that leaching of leftover N from corn fields during the following winter and spring is the predominant source of riverine N loads delivered to the Gulf each year. From previous work, we know that tile drainage is the major pathway for nitrate from fields to streams in Illinois, but little is known as to when and how nitrate is lost via tile drainage under a variety of modern corn production systems. Our on-going replicated tile drainage study indicates that fall fertilizer N application loses more tile nitrate than spring N or split N applications (spring + side-dress); however, corn yields were not significantly affected. Although tile nitrate loads were greater following corn, our results show that substantial amounts of tile nitrate can occur following unfertilized (for N) soybean production. Overall, our results clearly implicate timing of N fertilization as a major factor controlling tile nitrate export and that cereal rye after corn can be an effective management strategy to further reduce tile nitrate loads. It is interesting to note that after two years, cumulative tile nitrate loads were similar (42.5 vs. 44.2 lbs/A) between the reduced N rate (120 lbs/A) and the split application of the full rate (160 lbs/A), yet the reduced rate treatment decreased corn yields by about 10%. Our current research documents the complexities of nitrate leaching and shows that tile nitrate loads are not simply a reflection of excessive N fertilization, but rather the interaction of weather patterns (temperature and precipitation), timing and rate of fertilizer N application, and previous crop.

## **Institutional and Market Obstacles to Increasing Adoption of Nutrient Loss Reduction Practices**

Ben Gramig, Associate Professor<sup>1</sup>, Steve John<sup>2</sup> and Tim McMahon<sup>2</sup>

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We are engaging farmers and other stakeholders as part of our research process to ensure that agricultural practices, watershed modeling scenarios, design of policy instruments and choice experiments conducted to estimate farmer willingness to adopt to new practices and public willingness to pay for reduced nutrient losses are feasible and address practical constraints at the farm and landscape level. We report on findings from two focus groups that were conducted recently in the Decatur area to get farmers' input into an ongoing research project to find engineering, technological, policy and farm management solutions to address agricultural and point source phosphorus problems in the Upper Sangamon river basin. We discussed farm and nutrient management, conservation practice adoption, watershed modeling of farm management, and drivers of and obstacles to behavioral and management change with 16 farmers and local soil and water conservation professionals. The two largest obstacles identified to changing management practices or growing perennial crops to reduce nutrient losses were very high land rental rates and the role of farm management companies that commonly mandate high input rates and do not allow non-uniform crops or practices on rented land. We highlight the importance of addressing such institutional and market-related barriers to make achieving Illinois nutrient loss reduction targets possible.

## **Effectiveness and Value Proposition of Nutrient Reduction by Riparian Buffer in the Lower Mississippi River Basin**

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Agricultural land has been recognized as the major source of nutrients and sediments that discharged into the Gulf of Mexico through Mississippi River. Lower Mississippi River Basin (LMRB) receives a majority of the nitrogen and phosphorus inputs from Upper Mississippi River basin and Ohio Tennessee River basin, and sediments from Missouri River basin. The goal of this study is to investigate the role of riparian buffer in mitigating environmental loadings from cropland in LMRB from both management and economic perspectives. First, we established a baseline nitrogen, phosphorus, and suspended sediments loadings at geospatial and temporal scales by developing a watershed model using SWAT that was calibrated and validated with 20-year climate and water quality records. Modeling and analyses were conducted to determine the contribution of each upstream basins to the nutrient and sediment in the LMRB, and to simulate impacts of land slope, land cover and land use, agricultural management operations, and conservation practices such as riparian buffer on water quality at the outlet of LMRB. Regional watershed analysis was further conducted to identify potential nutrient hot spots in the basin to which buffer could provide effective mitigation and to quantify the degree of nutrient reduction. The study further examined potential value proposition of growing biomass as bioenergy feedstock in riparian buffer in the agriculture dominant regions in LMRB by using the nutrients trapped in the buffer. The cost and benefit analysis considered multiple factors including crop growth, fertilizer application, biomass yield and harvest, buffer installation, loss of production due to land use change, potential savings of fertilizer under a set of biomass market price. Our results illustrate that riparian buffer is effective in reducing suspend sediment, nitrogen, and phosphorus loadings up to 65%, 35%, and 39%, respectively, at the regional scale across the LMRB and to the Gulf of Mexico. Largest reductions appeared to be concentrated in major agricultural dominant regions. Estimated annual net economic returns of harvested switchgrass in LMRB ranged -\$66/ha to \$727/ha based on future biomass prices between \$20 and \$80. Total net returns for agricultural areas may be reduced by 20% if switchgrass is grown without fertilizer addition. This study provides a practical estimates of riparian buffer in agriculture land from both economic and environmental perspectives, which could aid to policy development that addresses nutrient loss reduction strategy in bioenergy and agriculture production.

## **University of Illinois Extension Watershed Outreach Associates Update**

Haley Haverback and Jennifer Woodyard

University of Illinois Extension

Two Watershed Outreach Associates were hired by University of Illinois Extension through a grant provided by the Illinois Environmental Protection Agency in 2018. These individuals were tasked with serving as educators and technical advisors on the Illinois Nutrient Loss Reduction Strategy (NLRS) and the best management practices (BMPs) within it in order to reduce agricultural nutrient loss. Haley Haverback, located in the Galva, Illinois, Extension Office, works in two nitrogen priority watersheds: the Mississippi Central/Henderson Creek Watershed and the Lower Rock River Watershed. Some in-field BMPs to reduce nitrogen loss include using nitrification inhibitors on any fall-applied nitrogen fertilizers, switching from fall to spring or split applied nitrogen, using the maximum return to nitrogen, and cover crops. Edge-of-field practices include woodchip bioreactors, saturated buffers, constructive wetlands, and two-stage ditches. Jennifer Woodyard, located in the Effingham, Illinois, Extension Office, works in two phosphorus priority watersheds: the Embarras River Watershed and the Little Wabash River Watershed. In-field BMPs to reduce total phosphorus loss include switching to no-tillage or reduced till, cover crops, and testing soil P levels before applying fertilizer. Edge-of-field practices include constructed wetlands, buffers or waterways, and two-stage ditches. Haley and Jennifer will present a traditional poster to inform participants at the poster session of their work activities since beginning in these roles, and to discuss possible future activities.

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## Utilizing Struvite as a Slow Release Phosphorus Fertilizer to Mitigate Agricultural P Losses

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The Illinois Nutrient Loss Reduction Strategy (NLRs) has set a goal of a 25% reduction in total P losses to the Mississippi River by 2025 and 45% overall. Struvite ( $\text{NH}_4\text{MgPO}_4$ ; NPK 5-28-0) recovered from wastewater treatment is a candidate renewable P source. This recovered P has the potential to reduce dependence on non-renewable P resources and P losses from agricultural systems. Struvite production in the United States is currently concentrated in the Midwest, overlapping with the region of intensive agriculture that employs high P inputs that can contribute to water quality issues. The low water solubility and high citrate-solubility of struvite suggests its potential to better synchronize P dissolution with crop demand compared to highly water-soluble P fertilizers such as monoammonium phosphate (MAP). However, there are limited assessments specific to the soil and crop types of this potential agricultural sink for P recovered as struvite. A greenhouse experiment evaluated the effects of monoammonium phosphate (MAP)-struvite blends (100-0, 75-25, 50-50, 25-75, 0-100) on early season P availability in V12 corn (*Zea mays* L.) and R1 soybean (*Glycine max* L.) in a Flanagan silt loam from Illinois (0-30 cm of A horizon and pH 5.6). MAP-struvite blends were evaluated for biomass, soil P availability, and P loss potential for struvite granule size (1.5 vs. 3mm) and placement (incorporation vs. banding) in a replicated factorial design. Results will be used as a first step toward identifying MAP-struvite blends optimal for the soil and cropping characteristics of Midwestern agriculture and to assess the efficacy of struvite to reduce fertilizer related P losses while maintaining crop productivity. Field-scale trials of struvite as a P fertilizer will enable its evaluation as a potential best management practice to help achieve the Nutrient Loss Reduction Strategy target for state-wide P loss mitigation.



## **Continuous Monitoring of Nutrient and Suspended Sediment in Illinois Rivers; Results from 2015 through the 2017 Water Year**

Tim Hodson, Paul Terrio, Colin Peake, David Fazio

U.S. Geological Survey, Central Midwest Water Science Center

Since 2015, the U.S. Geological Survey in Illinois has operated a 'super gage' network, which continuously monitors a range of physiochemical parameters across Illinois' major watersheds including nitrate, orthophosphate, turbidity, and streamflow. Data from this network are used to develop models for estimating statewide nitrate, total phosphorous (TP), and suspended-sediment loads to the Mississippi River and other state-border rivers, thereby fulfilling a core component of the Illinois Nutrient Loss Reduction Strategy.

Compared to periodic water sampling, loads estimated through continuous monitoring offer better precision, enabling more sensitive detection of changes resulting from watershed management or climate variability. In addition, short-term structures and patterns within continuous data can serve to fingerprint specific pollutant sources and transport pathways, which is critical as policy makers and land managers seek to tailor management decisions to more efficiently meet their water-quality goals.

Despite the initial success of many components of the super gage network, monitoring phosphorus remains a challenge. Field-deployable TP analyzers are not yet commercially available, so TP must instead be estimated from surrogates, such as turbidity and orthophosphate. However, not all surrogates are equal, and some perform well in certain watersheds but poorly in others. This poster highlights some preliminary results from the Illinois super gage network, including examples of how continuous data could better inform management decisions as well as best practices for estimating phosphorus loads from surrogates

## **Recovering Phosphorus from Corn Wet Milling Plants: Technical and Economic Feasibility Analysis**

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Wet milling (WM) plants contribute to both point source and non-point source phosphorus (P) pollution by concentrating P in the coproduct corn gluten feed (CGF), the majority of which is undigested when consumed by ruminants, leading to manure management concerns. Phosphorus run off from the manure consequently causes eutrophication in the water bodies downstream. This study investigates the economic feasibility of recovering the phosphorus at the front end from light steepwater to reduce P in CGF. A model for a wet milling plant processing 2544 MT/day corn was developed in SuperPro Designer, with phosphorus recovery section added to WM plant producing natural starch and WM plant producing modified starch. The phosphorus removal in the recovery unit was calibrated with laboratory experiments. The amount of phosphorus in CGF was observed to reduce from 11.94 mg/g (db) to 2.44 mg/g (db). Direct fixed capital cost of \$6.9 MM was estimated for the phosphorus recovery unit in an existing wet milling plant. With a phosphorus recovery rate of 0.17 MT/hr, the operating cost of P recovery at the front end was estimated to be \$1.23/kg-P removed.

## **Water Quality and Agronomic Impacts of Gypsum Application in Southern Illinois**

Harpreet Kaur, Karl W.J. Williard, Jon E. Schoonover, Jennie Snyder, and Gurbir Singh

College of Agricultural Sciences, Southern Illinois University Carbondale

The agricultural community has been challenged to improve crop yields to meet increasing food demands, while minimizing the environmental footprint of agriculture because of its contribution to eutrophication issues such as the Gulf of Mexico. Gypsum (calcium sulfate dihydrate) is a potential tool that has been researched in other Midwestern states (Ohio, Wisconsin) and regions (North Carolina) and found to be a reliable practice to reduce phosphate leaching as the applied calcium binds with available phosphate. Unfortunately, there has not been any research performed in Illinois soils to determine the impact of gypsum applications on water quality and grain yield. This project was designed to address that need and provide the Illinois agricultural community an independent assessment of gypsum's ability to serve as a phosphate abatement tool. The project is being conducted at two scales to effectively test two objectives: gypsum's impact on water quality and gypsum's impact on grain yields studied at three sites. Surface runoff flumes have been established on a high soil P level field on the SIU Farms to assess the effects of gypsum application rate on water quality by analyzing dissolved phosphate and total phosphorus in surface runoff when gypsum is applied at 1 ton/ac, 2 ton/ac, 6 ton/ac and a control. To assess gypsum's impact on yield, we are establishing a replicated large scale field study on three producers' farms in the medium P supplying soils of southern Illinois in Jackson county, St. Clair county and Ewing, IL. The large-scale experiments will include four treatments: gypsum (1 ton/acre), calcium (Ag Lime at the same rate of Ca as supplied by the gypsum), sulfur (elemental S at the same rate of S as supplied by gypsum), and a control (no addition) in attempt to determine which element in gypsum may be impacting yield. The impact of gypsum applications on soil physical (penetration resistance, infiltration, bulk density, and aggregate stability) will also be assessed. The economic cost of the gypsum addition and practicality of farmer adoption will be evaluated through a partial budget analysis. This research is planned for four years through support by the Illinois Nutrient Research and Education Council.

## **Emerging Opportunities and Challenges to Reduce Hypoxia Problem in the Gulf of Mexico**

Madhu Khanna, Evan DeLucia, Praveen Kumar, Ben Gramig, Ximing Cai

University of Illinois at Urbana-Champaign

The growing hypoxic zone in the Gulf of Mexico continues to be a major environmental concern. Nitrogen runoff from agricultural sources hundreds of miles to the north in the Mississippi River Basin are a dominant contributor to poor water quality in the Gulf. The Institute for Sustainability, Energy, and Environment, at the University of Illinois, Urbana-Champaign organized a Critical Conversation in Chicago in Spring 2018 to engage researchers and external stakeholders in developing a research agenda on the nitrogen reduction challenge. Several strategies for reducing nitrogen runoff, including adoption of best management practices for fertilizer application, land use change and diversification of the crop mix were discussed. The potential for emerging “big data” gathered by remote sensing and GPS-guided variable-rate nitrogen application for site-specific N management was also discussed. Gene-editing and other bioengineering technologies offer the potential to tailor crop varieties to increase nitrogen use efficiency and tailor crop varieties to site-specific conditions. Scientific uncertainties about the environmental and economic implications of these strategies continue to hinder action that can achieve meaningful reduction in the hypoxic zone. Concerns about data privacy and confidentiality pose challenges to using big data to design policy incentives to accelerate adoption of precision agriculture targeted to reduce hypoxia. This poster will present the outcomes from this multi-stakeholder Critical Conversation and discuss the gaps in scientific knowledge, the key economic and social barriers, and market and policy solutions for sustainably achieving a significant reduction in nitrogen runoff.

## **Technical Service for the Conservation Reserve Program from Landscape Architects**

Katherine Kraszewska and Ying Li

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The conservation reserve program (CRP) has been a positive asset to remediation and water quality in the Agrarian environment by providing farmers with incentives and cost share programs. These bequeath farmers the means to implement a number of best management practices, which improve runoff conditions in the major waterways of the United States (US). Even though recent studies have called for a more stacked approach to BMP implementation, a majority of farmers have not fully embraced this resource, and those that do implement these designed landscapes are rarely, if ever, landscape architects (LAs). In this critical review, we examine the successes of urban stormwater management BMPs and the opportunities to overlap agricultural methods for increased water quality – specifically nitrogen removal. We also explore the utilization of the CRP in the state of Illinois, its missed opportunities for water quality improvement, prospective stacked BMP locations, and opportunities for LA’s interventions. The implications of this synthesis for farmers, designers, and agroecosystems alike are discussed. Recommendations: increased involvement of LAs as technical service providers to the CRP and local farmers, designing stormwater facilities in the agricultural environment by combining BMPs, studying the current recommended agricultural BMPs by employing a cross-disciplinary approach to include LAs and other designers, and ultimately constructing policies which better illustrate the varied needs of current water quality conditions.

*Keywords:* Water Quality, Conservation Reserve Program, Landscape Design, Nitrogen, Phosphorus, Upper Mississippi River Basin

## **The Great Lakes to Gulf Observatory – Transforming Water Quality Data to Knowledge to Guide Conservation Practices and Policies**

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Shannon Bradley<sup>2</sup>, Jong Lee<sup>2</sup>, William Kruidenier<sup>1</sup>, Richard Warner<sup>1</sup>

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The Great Lakes to Gulf Observatory (GLTG), [www.greatlakestogulf.org](http://www.greatlakestogulf.org), is a publicly available interactive geospatial web application that integrates water quality data and contextual geospatial layers, with visualization and decision support tools. It advances the understanding of nutrient pollution in the Mississippi River watershed and efforts to reduce those nutrients. With the goal of lessening the nutrient load delivered by the Mississippi River to the Gulf of Mexico, GLTG is directed to helping researchers, managers, and decision-makers transform water quality data to knowledge that can help guide conservation practices and policies in the watershed. GLTG is of interest to state nutrient reduction strategies, the Federal Hypoxia Task Force, and localized watershed initiatives.

GLTG's web-based application allows users to dynamically browse, search for and visualize water quality information on the Mississippi River and its tributaries. Using a geospatial interface overlaid with a number of respected data sources, including long-term historical datasets and continuous real time sensors, the user can integrate datasets that would otherwise have to be manually compiled from disparate databases. Those datasets are related to contextual geospatial layers describing nutrients and their transport (including fertilizer inputs), edge of field and other farm conservation practices, and precipitation. GLTG is beginning to include data visualization and decision support tools using data in the observatory. For example, in a tool called exploratory analysis, the user can select data filters, identify sites of potential interest, and visualize trends in water quality parameters. GLTG currently has data for over 1400 sites representing nearly 26 million data measurements. In addition to the main GLTG site, a sub-site focused on the Illinois' Nutrient Loss Reduction efforts has been developed. This site is still in progress and has been developed with information specific to Illinois, such as the Supergage network and with narrative around the Nutrient Loss Reduction Strategy and progress toward its goals. The Illinois Nutrient Monitoring Council and Illinois EPA have guided development of this sub-site.

Founded in cooperation with Illinois Indiana Sea Grant, and National Center for Supercomputing Applications (NCSA) at the University of Illinois, the National Great Rivers Research and Education Center leads the project and data integration and visualization occurs within a cyber-infrastructure framework constructed by the NCSA.

## **Enhancing Conservation Outcomes in Illinois through Land Tenure Security**

Olga Lyandres, David LeZaks, Ryan Smith, Ben Shorofsky, Caitlin Dillon

Delta Institute

In order to achieve the 2025 nitrogen and phosphorus loading reduction goals in Illinois, wide support and adoption of the Conservation Cropping System (CCS) approach is key. Barriers to implementation of conservation practices vary, although in Illinois, in particular, a primary factor in the uptake of CCS is secure land tenure. Across Illinois, about 60% of cropland is rented, and the majority of leases are annual cash rent leases. For example, in Livingston County, and majority of the Vermilion River watershed (a priority under the Nutrient Loss Reduction Strategy), 70% of the land is rented. In addition to millions of acres of privately-owned cropland, state agencies, local jurisdictions, and land trusts rent public land for agricultural activities. To drive uptake of regenerative agriculture systems, we need to develop programs and policies that align with needs and drivers of various ownership classes and that incentivize long-term investment in conservation practices. With improved understanding of barriers and opportunities associated with different land ownership classes, we can design policies and programs utilizing tools, like land valuation and leasing standards, as well as financing, lending, and risk mitigation structures that create lasting conservation incentives. Doing so will increase farmers' resilience to climate change, achieve measurable improvements in soil and water health, and provide economic stability for farmers. This project focuses on designing conservation incentive programs and policies on land owned by public and private conservation organizations (e.g. forest preserve districts and land trusts) in Illinois through their farmland leasing programs. The poster presents an inventory of working lands across Illinois, totaling over 67,000 acres, and an analysis of the current management of that land. Public universities and utilities also own and lease approximately 22,000 acres of farmland, however they are not included in the analysis due to differences in how the land is acquired and managed. Furthermore, we share recommendations for program design that would result in transition of current working lands to conservation cropping systems and regenerative agriculture. Transforming agricultural landscapes in Illinois is critical in achieving the goals of the Nutrient Loss Reduction Strategy.

## **Irrigation with Runoff and Drainage Water as a Strategy to Mitigate Nutrient Loss and Increase Crop Yields**

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Irrigation with runoff and drainage water from agricultural fields can recycle nutrients and water for crop use, and reduce fertilizer needs, thereby mitigating nutrient loss from agricultural fields while increasing crop yield. In a three-year field study located at MWRD's Fulton County site, we evaluated agronomic impacts of 50% reduction in corn agronomic fertilizer rate when supplemented with irrigation with runoff collected in a pond. Data from the first two years (2016 and 2017) show that irrigation increased corn total biomass by 29% and N and P uptake by 44% and 60% respectively, as compared to the control. Nutrient use efficiency (NUE) estimated as corn total biomass yield per kg of N and P applied was greater at 50% fertilizer rate with irrigation (0.11 – 0.15 tons DM kg<sup>-1</sup> N applied and 0.41 – 0.55 tons DM kg<sup>-1</sup> P applied) than at 50% fertilizer rate without irrigation (0.10 – 0.11 tons DM kg<sup>-1</sup> N applied and 0.36 – 0.40 tons DM kg<sup>-1</sup> P applied). Similarly, corn N and P uptake were enhanced by irrigation and greater for irrigation-supplemented 50% fertilizer rate (218 kg N ha<sup>-1</sup> and 45 kg P ha<sup>-1</sup>) than observed in field without irrigation treated with half fertilizer rate (152 kg N ha<sup>-1</sup> and 28 kg P ha<sup>-1</sup>). It appears that with irrigation, application of 50% agronomic N and P rate could achieve similar level of crop yield as 100% agronomic rate.

With over 10 million acres of tiled-drain fields, Illinois is particularly well positioned to implement drainage water reuse that can benefit a farmers' bottom line, and dramatically improve water quality. In 2018, we began a new collaborative research and demonstration project, sponsored by the Nutrient Research and Education Council to evaluate and demonstrate drainage water recycling through sub-irrigation as an effective management practice to reduce N and P losses and optimize crop yield at reduced fertilizer application rate. A 20-acre field was tiled and divided into four equal subfields with and without sub-irrigation. Control structures were installed in each subfield to manage the drainage water for sub-irrigation. On-going monitoring includes the measurement of water flow, the collection of water sample for N and P analyses, crop yield measurements, and cost analysis. Field days and other outreach activities will be held at the project site to demonstrate benefits such as reduced fertilizer application and improved crop yields, and to provide guidance on the implementation of this practice in Illinois nutrient.



## **Using Cover Crops at the Watershed Scale to Reduce Nutrient Loss and Improve Surface Water Quality**

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Illinois State University

Nutrient loss from the Midwest leads to pollution of drinking water sources and contributes to the development of hypoxic zones in the Gulf of Mexico. Application of cover crops shows the potential to reduce nutrient loss, but most of this work has been done at the plot or field scale. Our project aims to explore whether cover crop application can effectively be scaled up to the watershed, and whether the addition of cover crops alone with no other changes in farm management, can improve surface water quality. We compared nitrate and phosphorous loading from two tile-drained agricultural watersheds, in the Lake Bloomington watershed. One of these is 1000 acres and is planted with cover crops over 60% of the area, while the other is 700 acres with essentially no cover crops planted. Cover crops include radish with either oats or cereal rye, and are applied aerially. To obtain high-resolution loading data, we use automated discharge measurement and automated flow-based water sampling at both watersheds of the past three years. Water samples are analyzed for nitrate and phosphate. Additionally, we are using modeling approaches so that we can assess the impact of cover crops under different conditions, e.g. drier or wetter conditions. Our results so far indicate that cover cropping can be done effectively at larger scales and that cover cropping can substantially reduce nitrogen loading. However, the impact of cover crops on phosphorus loading is less clear. Our project illustrates the potential for cover crops to reduce nitrate losses at large scale, while highlighting some of unexpected results. We look forward to input that can help us shape the next steps in this research.

## **Balancing Water Quality, Nitrogen Management, and Corn Production Goals in Illinois**

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In-field conservation practices, such as improved nutrient management and cover crops, have been recommended by the Illinois Nutrient Loss Reduction Strategy to decrease nutrient losses from agricultural fields, particularly through tile drainage. Meeting the Strategy's water quality goals (to reduce nitrate-nitrogen and total phosphorous loading by 15 and 25% by 2025, respectively) is crucial for enhancing the sustainability of high-yielding cropping systems in Illinois, but there remains limited scientific evidence on the impacts of the recommended conservation practices, implemented alone or in combination, on corn productivity. A new replicated drainage plot research site was established in fall 2016 at the University of Illinois Dudley Smith Farm in Christian County (39° 27' N, 89° 6' W), with a goal of quantifying tile drainage losses for different combinations of conservation practices, while also assessing potential agronomic and environmental tradeoffs that have not been previously considered. The experimental layout includes 16 individually subsurface drained plots (~ 0.85 ha) containing three tile laterals at 18 m spacing (drainage design coefficient: 9.5 mm day<sup>-1</sup>). Each plot is hydrologically isolated using border tiles. This poster presentation will describe the methods -- from tile drainage water quality monitoring to soil nutrient analyses to evaluation of remotely sensed crop growth data -- used to carry out the research project. Results obtained to date will also be shown, with emphasis on the water quality aspect of the project. We envision the findings of this project will help identify and assess potential synergies and tradeoffs of in-field conservation practices for achieving sustainability goals in corn production systems in Illinois. In the future, field data will be combined with modeling efforts to scale up results and facilitate statewide discussions and guidance for implementation of conservation practices throughout the state of Illinois.

## Using ECOSYS to Assess Cover Crops' Effect on Resilience of the US Midwest Agroecosystems

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Currently, systematic assessment of cover crops is lacking in US Midwest cropland. Cover Crops can be used to increase the resilience and sustainability of Midwest agricultural ecosystem. In this study we select ECOSYS as the biogeochemistry model to achieve comprehensive simulation, as well as the effect of cover crops. ECOSYS is one of the few ecosystem models that have detailed processes in terms of physical and chemical theories, and it also incorporated major farming practices such as tillage, irrigation, and tile-drainage system. We implemented simulation in seven agroecosystem sites in Midwest US, to analyze the carbon dynamics. We then did parameter sensitivity analysis to identify parameters that needs to be tuned for further calibration. For site simulation in US Midwest Corn Belt, model performs well for carbon dynamics, with  $R^2 > 0.75$  for NEP between simulation and site measurements. We then did detailed simulation of N dynamics, with comprehensive N cycle represented using ECOSYS. We did nitrogen simulation in two corn-soybean rotation sites located in Mead, Ne. Nitrogen dynamics is simulated in organic and inorganic phases in soil and crop, which are based on explicit partial differential equations through a horizontally layered soil profile. The site-level simulation of nitrogen laid a good foundation for further extension to regional-level simulation. We are presenting this poster to demonstrate that the model will greatly help characterize current agricultural ecosystem and assess the cover crops effect of crop yield.

## **Two-Chamber “Booster” Denitrifying Bioreactor: A Novel Design for Improved Efficiency**

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Illinois has established nitrogen loss reduction goals contributing to the effort of reducing nitrogen loads into the Mississippi River that ultimately reach the Gulf of Mexico. A nitrogen loss reduction goal of 15% has been proposed to be achieved by 2025, with an ultimate reduction goal of 45%. Denitrifying woodchip bioreactors are a useful practice to reduce nitrogen loads from agricultural drainage. Further innovation in bioreactor design is required to increase effectiveness considering the scale of the nitrogen loss reduction goals. A standard bioreactor generally cannot treat 100% of the large nitrate loads associated with high drainage flows that occur during the spring. On the other hand, a given bioreactor may be vastly oversized for lower drainage flow periods in the summer. Adjustments in the design are needed to treat a greater proportion of drainage flow without oversizing the bioreactor for low flow times. In response, a two-trench bioreactor was designed and installed, with one main trench working under all flow conditions and a booster trench that comes on-line only during high flow events. This design was intended to treat large flow volumes with a smaller footprint than one large bioreactor. In the summer of 2017, this two-chamber bioreactor was installed at the Northwest Illinois Research and Demonstration Center (Monmouth, Illinois). Along with this novel design, the orientation of the flow direction within the bioreactor was shifted to increase the overall amount of flow treated. Flow and nitrate removal within the main chamber (L x W x D: 18 x 6.1 x 0.6 m) and booster chamber (12 x 6.1 x 0.6 m) have been monitored since summer 2017, although this initial monitoring period has been relatively dry. Flow and nitrogen removal data, along with details of this novel design will be presented.

## **Cover Crops: Impact on Sediment and Nutrient Export from a Corn-Soybean Rotation in a Paired Watershed Study**

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Department of Forestry, Southern Illinois University – Carbondale

Use of cover crops, to manage the loss of sediments and nutrients caused by surface and sub-surface flow is one of the best management practices in the Midwestern United States. Plot level small scale studies were the only source for evaluating the impact of cover crops. Recently, Singh., et. al (2018) carried out a watershed scale study to analyze water quality of a stream. The objective of the study is understanding the potential of cover crops in improving water quality at watershed scale which will focus on continuous monitoring of the watershed to analyze changes in the water quality from a no-till corn/soybean rotation with cereal rye (*Secale cereal*) and hairy vetch (*Vicia villosa*) as the winter cover crops in the treatment watershed located at Southern Illinois university, Carbondale, IL. The study will evaluate the sediment, phosphate, nitrate, ammonia, total N and dissolved organic carbon losses from the paired watershed. With the total area of 42 ha, watershed #1, the treatment watershed is under mixed land use of 66.4% crop land, 30.3% forested cover and 3.3% impervious surface. Watershed #2, the control watershed, has a total area of 27 ha with its area comprising 91% crop land, 6.6% forested cover, and 2.4% impervious surface. Calibration data of 3 years and treatment period of 2 years will be used as reference to carry out the study to check if the water quality results are unwavering or new patterns emerge. Data for plant (biomass of cover crop and cash crop, yield and N uptake by plants), soil (carbon accrual in different pools, soil quality parameters, soil moisture), and water quality (major anions including nitrate and phosphate) will be calculated from field sample collection and laboratory analysis while the regression equation from the calibration period will be in use to calculate the data in treatment watershed, if was left untreated for the next few years. The overall change in actual result and estimation will serve as base for realizing the impacts of treatment (cover crops) from stream discharge of the paired watershed study.

**Key words: Paired Watershed, cover crops**

# **A New Guide to Using the MRTN: Illinois On-Farm Research Supports Science Based Recommendations for Responsible, Reliable and Defensible Nitrogen Rates for Corn**

Jason Solberg

Illinois Fertilizer & Chemical Association

In September 2018, the Illinois Fertilizer & Chemical Association worked with the Illinois Nutrient Research & Education Council (NREC) and with the University of Illinois to produce a printed and digital publication entitled “Using the Maximum Return to Nitrogen (MRTN) Recommendation System in Illinois.” This new Guide is significant—it is the first thorough explanation of how scientific field trials are conducted in order to support the Nitrogen Rate Calculator, which is an on-line program supported by all Midwest Land Grant Universities and enables crop advisers and farmers to determine their state’s LGU recommended rate for nitrogen used in corn production: the Maximum Return to Nitrogen (MRTN) rate. Adopting the MRTN across all corn acres in Illinois is a recommended activity in the INLRS. The Strategy concludes that a nitrogen rate that is neither too high nor too low is protective of the environment (specifically water quality) and an economic benefit to the farmer. But despite the MRTN being listed in the INLRS as a vital activity to reduce nitrogen losses, the MRTN system is not widely understood throughout the ag industry, especially in relation to the previous LGU recommendation which was known as “1.2 lbs of N is the most you should do” meaning use 1.2 lbs of nitrogen per expected bushel of corn yield based on a five year field average and adjusting for a soybean nitrogen credit. If farmers are not truly transitioning to the MRTN and instead continue to use the old “1.2” nitrogen recommendation system they were familiar with, applied rates of nitrogen in today’s improved corn hybrid marketplace would exceed the ability of the crop to utilize that much nitrogen, and certainly result in potential loss of excess applied nitrogen to the environment, namely to water. The research that supports the MRTN recommendation system is based on on-farm research trials funded by NREC and performed extensively and primarily on farmer fields throughout Illinois, but also at UI Research Centers. IFCA works with NREC and UI to implement the N rate trials. Our presentation at the INLRS will explain the on-farm research that is underway, how it’s designed to produce data for analysis, the terminology used in the Nitrogen Rate Calculator System, and why nitrogen management based on the MRTN is vital to balance agronomic goals with environmental responsibilities. In our presentation we will also address common questions and misunderstanding about nitrogen use. Ultimately, assuring farmer understanding, adoption and confidence in using the MRTN is paramount to reducing nitrogen losses and also assuring farmers that they do have enough N to maximize corn yield potential on their farm. Our presentation will include posters that showcase example of on-farm MRTN research, important terminology associated with understanding the MRTN, and data that shows how corn response to different nitrogen rates from research conducted in 2014 – 2018.

## **Effect of Cover Crops and Tillage on Nitrate Leaching in the Vadose Zone**

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College of Agricultural Sciences, Southern Illinois University Carbondale

Cover crops (CCs) have been promoted as a practice to limit nutrient leaching, especially during the dormant season. However, there is little field research data quantifying nutrient leaching in the vadose zone. The winter fallow period is a critical time for leaching of nutrients, since winter precipitation has a great potential to flush nutrients from the soil profile. A replicated plot study was established in 2014 to monitor nutrient leaching loss through pan lysimeters in different CCs and tillage rotations at the Southern Illinois University Carbondale research farm. The layout of research had complete randomized design with three different rotation treatments with two tillage practices, conventional tillage (CT) and No tillage (NT). The rotation treatments were corn-noCC-soybean-noCC (CncSnc), corn-cereal rye-soybean-hairy vetch (CcrShv) and corn-cereal rye-soybean-oats+radish (CcrSor). Pan Lysimeters were installed in each plot below the A horizon which varied around 22-30 cm in depth. Soil solution samples were collected weekly or biweekly depending on the precipitation and analyzed for nitrate and dissolved reactive phosphate. In the NT system, corn yield was 14% greater with CcrShv compared to CncSnc, whereas no significant difference existed in corn yield due to CC treatments within CT. Both CC treatments under NT reduced soybean yield by 24 to 27% compared to noCC. The rotations CcrShv and CcrSor with hairy vetch and oats+radish as preceding CCs resulted in 89% (37.73 vs 19.96 kg ha<sup>-1</sup>) and 68% (33.46 vs 19.96 kg ha<sup>-1</sup>) more nitrate-N leaching than the CncSnc during cash crop season 2015. This was likely due to the mineralized N from the cover crop biomass being available prior to the primary N demands by the cash crop and significant precipitation events that flushed the soil profile in the spring. During the CC season in spring 2016, cereal rye CC in CcrShv and CcrSor reduced the nitrate-N leaching by 84% (0.68 kg ha<sup>-1</sup>) and 78% (0.63 kg ha<sup>-1</sup>) compared to the CncSnc, respectively, under the CT system. Our study highlights the role of different cover crops species in limiting nutrient leaching and the importance of timing the release of nitrogen from cover crop biomass to meet N demands of subsequent cash crops. This research has been supported by the Illinois Nutrient Research and Education Council.

## Denitrifying Bioreactor Woodchip Chemical and Biological Properties Variation over Time

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Denitrifying bioreactors have successfully decreased NO<sub>3</sub>-N loads in agricultural drainage water across the US Midwest. A novel two-chamber bioreactor installed at the Northwest Illinois Research and Demonstration Center (Monmouth, Illinois) in summer 2017 is being used to study differences in woodchip longevity under differing flow and moisture regimes. This two-chamber configuration consists of a low-flow bioreactor (LWD: 6.1 x 18 x 0.6 m) intended to remain nearly always flowing during times of drainage flow, and a “high-flow booster” bioreactor (6.1x12x0.6 m) intended to only receive drainage water during high flow events and when conditions are the wettest. Forty-eight mesh bags (25 cm x 25 cm) were each filled with 155 g of woodchips (air-dried weight), and deployed at two levels (“bottom” within 30 cm from the bioreactor bottom; “top” within 65 cm from the bioreactor top) inside three 15 cm diameter ports within each of the two bioreactors in early November 2017. The first two sets of bags were harvested approximately 6 months and one year later, with future bag harvests planned for three and five years. For the initial bags harvested, the woodchips were analyzed for changes in mass and carbon (C), nitrogen (N), and fiber content, as well as for the development of biological material using DNA extraction followed by Quantitative Polymerase Chain Reaction and Scanning Electron microscopy. The initial mean C:N ratio was 135 in the low flow bioreactor chips and 224 in the high flow booster bioreactor. The mean C:N ratio after 6 months were 170, 142, 195 and 156 in low flow top, low flow bottom, high flow top and high flow bottom respectively bioreactors. Expected results will likely show more denitrifiers in the more consistently saturated bags (“bottom” bags and low-flow bioreactor bags).

**Key words:** Woodchips, Organic matter, Nutrients, Denitrifying bioreactor,



## **Charactering the influence of pH and Calcium Chloride on the Phosphorus Precipitation Process**

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The main products produced during corn-ethanol processes are distiller's grain and corn gluten feed – both of which release soluble phosphorous (P) in the form of phytate (inositol hexakisphosphate) during sidestream processing. These sidestreams are referred to as light steep water (LS) and thin stillage (TS) when generated during the production of corn gluten feed and distiller's grain respectively. Eventually, this P is returned to the mainline products after evaporation processes which concentrates P further.

Distiller's grain and corn gluten feed are both used as animal feed. However, phytate cannot be digested by non-ruminant animals. This results in the release of P into the environment. Therefore, there exists a need to develop methods which can reduce sidestream P produced during corn-ethanol processing. In turn this could lead to decreases in the magnitude of P runoff related to animal feeding operations that use distiller's grain and corn gluten feed.

In this work, a method is developed to reduce P in corn-ethanol sidestreams based on the precipitation of a calcium-protein-phytate solid. A wide array of pH and Ca:P molar ratios were tested to determine the optimal solution chemistry defined as the highest reductions in soluble P. Our study indicates that pH ~8 for TS and pH ~6 for LS with a Ca:P molar ratio of 2 for both cases are ideal conditions for the removal of phosphorus by precipitation. Additional experiments in dilute TS and LS give preliminary results for the kinetics of the precipitation process.

These findings work to reduce the amount of P released into the environment related to the use of distiller's grain and corn gluten feed produced from current corn-ethanol processes. If used in sidestream treatment before reintroduction to the mainline products, substantial reductions in P are possible.

This work will be presented as a traditional research poster. Our intent is to inform other Illinois NLRs workshop attendees of the work performed by the Cusick research group at the University of Illinois at Urbana-Champaign.

## **Identifying Strategies for Increasing Use of Best Management Practices**

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Nutrient pollution has a major impact on the environment in the watersheds all around the globe. The increased levels of nitrogen and phosphorus have resulted in algal blooms and hypoxia within these water bodies, impacting local aquatic life, industries, and the health and safety of people. The Mississippi watershed and the Gulf of Mexico near the mouth of the river are one instance where this is a particular problem. Agriculture is attributed as a major non-point source contributor to these issues in many of these cases. The implementation of best management practices by farmers could greatly reduce the amount of nutrients released from farms into the surrounding watershed. In order for this to be effective, however, farmers must implement these practices. Determining which practices are the most effective in a given area and what motivations farmers need in order to implement them is a necessary but challenging step in reducing nutrient pollution. A computer model, NitroShed, was created to model the environmental and human factors that result in nitrogen pollution into the environment. The model was developed using MATLAB and SWAT to simulate the human and environmental factors involved in agricultural runoff. The development of an improved farmer decision-making algorithm was added to better simulate the behavior of farmers making choices on investments in environmental infrastructure and management practices. The updated model includes a farmer typology based on the factors farmers consider when they are making decisions. Some examples of these typologies include: Business Oriented, Environmentally Oriented, Innovators, Traditionalists, and Supplemental. Each group of farmers is unique in the way that they consider factors such as risk, change, identity, social expectations, profit, and the environment. The model is then run under conditions to test adoption rates of best management practices through the use of policy changes and financial influences. Typologies can then be calibrated to accurately represent the behavior of farmers in a region. This will help policy-makers and extension services determine the most effective action plan in increasing farmer adoption of best management practices.

## **Impact of Shrub Willow Buffers in an Agricultural Landscape**

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Perennial bioenergy crop production in agricultural landscapes can serve the dual purpose of producing feedstock for bioenergy and potentially addressing environmental problems including water quality. A field study in Fairbury, IL evaluates the production of short-rotation shrub willow strategically placed within a corn-soybean field to reduce nitrate leaching and provide other ecosystem services including greenhouse gas reduction, soil quality improvement, and habitat provision for pollinators and pest control species. Willow biomass production after the first harvest cycle (3-yr harvest cycle) was about 5.5 Mg ha<sup>-1</sup> in both landscape positions assessed (northern plots placed on the footslope with lower nitrate leaching from surrounding grain crop, and southern plots placed on marginal soil within the backslope where nitrate leaching is higher). The more comparative biomass production between the two landscape positions (even with southern plots planted on marginal soils) can be partially contributed to the greater stem number, larger stem diameters, and higher chlorophyll leaf content at the end of the season in the southern plots where nitrogen availability is expected to be higher (due to higher leaching) than in the northern plots. However, regardless of landscape position, willow plots – in comparison with corn or soy – were found to have significantly lower nitrate leaching, lower nitrous oxide emissions, and had potential improvements in soil health. Preliminary insect diversity sampling also indicates that the willow's presence can provide habitat to a variety of insect species including those of important functional groups such as pollinators and pest control.