Minutes of NCERA 217: *Drainage Design and Management Practices to Improve Water Quality* Annual Meeting and NCERA 217 Station Reports Annual Meeting: 11-12 April 2018 at the Hilton Double Tree Hotel, Raleigh North Carolina

Contents

NCERA 217 Meeting Overview

The 2018 NCERA 217 Annual Meeting was held March 11-12, 2018, in conjunction with the Agricultural Drainage Management Systems Task Force (ADMS-TF) – Agricultural Drainage Management Coalition (ADMC) meeting. Additionally, a project meeting for those involved in the USDA NIFA-funded Transforming Drainage project was incorporated into the meetings. The report below documents the NCERA 217 annual business meeting, actual research meeting presentations, and the accomplishments, impacts, and written/oral communications produced by committee members during the past year.

Members Present: Ramesh Kanwar (IA; Advisor), Jane Frankenberger (IN), Eileen Kladivko (IN), Ehsan Ghane (MI), Jeff Strock (MN), Matt Helmers (IA), Xinhua Jia (ND), Kelly Nelson (MO), Gary Feyereisen (MN), John McMaine (SD), Mohammed Youssef (NC), Larry Goehring (NY), Dan Jaynes (IA), and Gary Hawkins (GA).

Members Not Present: Gary Sands (MN), Laura Christianson (IL), William Ford (KY), Richard Cooke (IL), Zachary Easton (VA), Aaron Daigh (ND), Tim Harrigan (MI), Robert Evans (NC), Clarence Prestwich (Oregon),

Guests: Chad Poole (NC), Tom Scherer (ND), Christopher Hay (IA), Jeppe Kjaersgaard (MN), Ben Reinhart (IN) and James Dobrowolski (NIFA). Many other additional guests were present for the ADMS-TF/ADMC and Transforming Drainage meetings (*total registration: 79*).

NCERA 217 2018 Business Meeting Minutes

The annual business meeting of NCERA-217 was called to order by Vice-Chair Jeff Strock (MN) at 7:47 a.m. on Thursday, 12 April 2018, and the Hilton Double Tree Hotel in Raleigh, North Carolina. NCERA-217 Chair Laura Christianson (IL) was not able to attend this meeting and will Chair next year's meeting in place of Jeff.

- Welcome by NCERA 217 Vice-Chair Jeff Strock (MN) acting on behalf of Chair Laura Christianson (IL).
- Past-Chair (2017), Dr. Gary Feyereisen agreed to take meeting minutes.
- Approval of minutes: Eileen Kladivko (IN) moved to accept the minutes from last year's meeting. The motion was seconded by Dan Jaynes (IA). There was no discussion, and the motion carried unanimously.
- Advisor's report: Dr. Ramesh Kanwar (IA) presented the NCERA-217 Advisor's report. He congratulated the group on the good news that NCERA-217 has been selected for the North Central Region's Experiment Station Section Award for Excellence in Multistate Research and has been submitted for the national award. Dr. Kanwar mentioned the strong attributes of the group that make for its success: strong stakeholder support; well-attended meetings (e.g. this year again >60); success garnering large grants - $10M, and $2M with matching; leadership and organization of the highly successful International Drainage Symposium in 2016; role with ASABE in development and maintenance of drainage standards. Dr. Kanwar encouraged members to consider participating in ASABE's Global Water Security for Agriculture and Natural Resources Conference scheduled 3 – 6 October 2018, in Hyderabad, India. Dr. Kanwar ended his report with an encouragement to keep up the good work.
    - Dr. Kanwar reminded the committee that a report of this NCERA-217 meeting is due to be filed within 60 days.
    - The committee will also need to submit a new project for approval next year.

- Old business:
    - Dan Jaynes (IA), who nominated NCERA-217 for the Experiment Station Section Award, reported that the national nomination is due sometime in mid-May. The University of Illinois Crop and Soil Sciences Department has offered to enlist the aid of professional writers to strengthen the nomination prior to its submission for the national award. There are a number of publications that can be added yet. A group consisting of Dan Jaynes (IA), Laura Christianson (IL) and Jeff Strock (MN) will work together to get the National Award Nomination prepared for submission.

- New Business:
    - Vice-Chair: Ehsan Ghane (MI), was nominated by Jane Frankenberger (IN). Ehsan was elected unanimously without further discussion to serve as Vice Chair for 2019. He will assume the Chair in 2020.
    - The five-year renewal of NCERA217 project is due within the next year; a draft is due sometime in November. It was suggested that a team of three take the leadership in developing the renewal application, with the team leader having many years' experience with NCERA-217. Ehsan Ghane (MI) and Jeff Strock (MN), who wrote a previous renewal, volunteered for the team, which still needs a leader. A short discussion was held concerning the content of the renewal application. Dan Jaynes (IA) mentioned that the project name has remained the same, but that the objectives do change somewhat each time. Suggested emphases for the new project included water quantity as well as water quality, along with the recycling of water and nutrients. Soil health/resilience was mentioned, as it has a link to

drainage, but Eileen Kladivko (IN) cautioned against making it a major objective for this Regional project.

- Two locations were posited for next year's meeting location: Moorhead, MN and Dayton, OH. Moorhead, which was discussed last year, is near several research sites, is in an area with active installation of drainage, and is in a region of drainage industry expansion. An industry partner Trimbel offered Dayton,OH as a site, where historical advances of laser technology in the drainage industry occurred and in a state with major phosphorus-related water quality issues. After a lengthy discussion of the positives of the sites a non-binding vote was taken – 5 votes cast for each location with several abstentions. The matter was brought up to the larger group (including ADMS-Task Force, ADMC, and other attendees) after the NCERA-217 business meeting. [U*pdated: the location for 2019 Annual meeting has not been decided upon as of submission of this report. The committee was leaning toward Moorhead, MN*].
- The members were reminded to send annual reports to Jeff Strock (MN) within 60 days. He will send out periodic reminders to members.
- Linkages/Announcements
  - Xinhua Jia (ND) reported on related American Society of Agricultural and Biological Engineers (ASABE) activities; the NRES 23 Drainage Subcommittee meets Tuesday, July 31st, at 7 p.m. at the Annual International Meeting in Detroit, MI. She encouraged members to participate in review of an NRES 23 related standard by April 30th, this year.
  - Jeppe Kjaersgaard (SD/MN) reported on related American Society of Agronomy (ASA) activities associated with its International Annual Meeting November 4 – 7, 2018, in Baltimore, MD. Morgan Davis of Iowa State, Chair of the NCERA-217-pertinent Managing Denitrification in Agronomic Systems Community is organizing a session; abstracts are due May 22nd. Also of interest is a special symposium of invited speakers organized by the Environmental Quality Section, of which Jeppe is the current Chair.
- Welcome to Jeff Strock (MN) as incoming NCERA 217 chair.
- Motion to adjourn: Eileen Kladivko (IN) moved to adjourn, and the motion was seconded by Dan Jaynes (IA). There was no discussion, and the motion carried at 8:28 AM.

Minutes respectfully submitted,
Gary Feyereisen, Past-Chair (2017), acting on behalf of Vice-Chair Jeff Strock

NCERA 217 2018 Research Meeting Summary

The research meeting began at 8:00 AM on Wednesday, 11 April 2018, at the Hilton Double Tree Hotel (Raleigh, NC) and was moderated by Vice-Chair Jeff Strock.

The research meeting consisted of a morning and an afternoon session of oral presentations. The morning session included 10 presentations given by NCERA 217 committee members and invited guests. Dan Jaynes (IA) presented on the impacts the Ag Drainage Management Systems and NCERA-217 partnerships have had on agricultural drainage system design and management, water quality, and research. Teferi Tsegaye (USDA-ARS National Program Leader, Water Availability and Watershed Management), gave an overview presentation on the importance of water management. Ruth Book (NRCS, IL) gave a presentation on NRCS's perspectives and needs for drainage and drainage water management. Charlie Schafer [Agridrain and Ag Drainage Management Coalition, (ADMC)] gave and update on the activities of ADMC. Wayne Honeycutt (President and CEO, Soil Health Institute) was scheduled to give a presentation on the Soil Health Institute related to drainage an water but he had to cancel at the last minute. Alison Thompson (Field to Market) gave a presentation on the work being done by Field to Market in the area of water metrics for industry. Katie Flahive (US EPA) gave a brief update on EPA water directives, state programs and funding opportunities. A representative from the North Carolina Dept. of Agriculture gave a presentation on the NC Ag WRAP cost-share program with drainage water recycling. Jane Frankeberger (IN) concluded the session with an update of the Transforming Drainage project and revisited the ADMS taskforce goals and plans for the future.

The morning session concluded with lunch at 12:00 PM.

The afternoon session consisted of 11 oral presentations followed by a poster session which included 15 posters. The session started with a presentation by R. Wayne Skaggs (NCSU) on the production and availability of DRAINMOD modules for educational purposes. The modules consisted of YouTube video lectures and demonstrations on using the model. A presentation was given by Lamyaa Negm (graduate student, NCSU) on the results of a modeling study comparing the effect of water stress on crop yield. Jeff Frey (USGS) gave a presentation on delineating tile drainage systems using thermal and multispectral imagery. Barry Allred (USDA-ARS, OH) also gave a presentation on the field application of using UAV's and thermal imaging to detect drainage systems in the field. The work showed promise. Chris Hay (IA soybean Assn) gave a presentation on conservation drainage education tools the Association is developing in IA. Matt Helmers (IA) gave a presentation on a large multi-state project looking 4R nutrient strategies and drainage water quality. Jeff Strock (MN) gave a presentation on a new small watershed project integrating in-field (cover crops), edge-of-field (bioreactors and constructed wetlands) and in-stream (ditch management) on water quality. Tiequan Zhang (Agriculture and Agri-Food Canada) was scheduled to give a presentation on reducing phosphorus loss from tile drainage using cover crops, but he was unable to attend the meeting. Ben Reinhart (IN) gave a presentation on the development of a tool to evaluate the benefits of drainage water recycling in the Midwest. Jeppe Kjaersgaard (SD/MN) gave a presentation on results from a field scale controlled drainage, conventional drainage and subirrigation project in northwest MN. Finally, Laura Bowling (IN) gave an overview presentation on drainage research in Indiana.

Accomplishments --- Station Reports

Georgia - *University of Georgia, Gary Hawkins*

Since receiving a grant from the Georgia Department of Agriculture (Specialty Crop Program) to investigate the movement of nutrients from Blueberry beds as drained by tile drains (2016) we have worked with farmers to collect some drainage water samples and had those samples analyzed for nutrients, pH, and minerals.

In May 2018, we established some bench scale blueberry plots (in a hoop house) to mimic and better collect representative samples and manage the addition of fertilizer to conduct research on different ways to potentially reduce nutrient losses. This was accomplished by bringing soil from the Blueberry growing area of Georgia to Watkinsville, GA (location of water resources lab of Dr. Hawkins) and building blueberry beds in 250 gallon cattle troughs. In the troughs, a drainage systems was installed using well screen and soil from blueberry growing area was placed in trough (6 inches) and then 6 inches of soil was mixed with 300 cubic yards per acre equilivant of pine bark (the amount mixed into 6 inches of soil in the blueberry field) and placed in the troughs. Irrigation system was installed and set to irrigate daily for 30 minutes initially to establish blueberry plants. Electronic rain gauges have been installed to measure the volume of water draining from the bench scale plots after each irrigation event. Water samples have been collected from the bench scale plots to compare to water samples collected in the field. The samples collected from the blueberry field are still showing high (as measured by MCL values) Iron and Aluminum concentrations. These samples are being analyzed in the UGA water lab. Nitrate has not been an issue during the sampling events.

Currently, blueberries are being harvested on the field being monitored. This field uses overhead irrigation and will receive the Fall fertilization application in July/August timeframe. Prior to and after fertilization, sampling will be more frequent (monthly during growing season) to try and capture movement of nitrogen through the soil and into (and out) of tile drains.

Illinois - *University of Illinois at Urbana-Champaign, Richard Cooke and Laura Christianson*

Agricultural drainage research and extension efforts at the University of Illinois continue to focus on proper drainage design and practices that reduce nutrient transport through tile drainage systems.

Denitrifying woodchip bioreactors continue to be a cornerstone of our drainage research and outreach. Work in this area is facilitating cross-county and international collaborations as we are moving the design science forward with modifications to “standard” tile drainage bioreactor designs by newly trialing in-ditch bioreactors, ditch-diversion bioreactors and sawdust denitrifying walls. Christianson et al. (2017a) and Rosen and Christianson (2017) showed several types of bioreactors trialed in the Mid-Atlantic region now show promise for helping clean the Chesapeake Bay. We’ve also evaluated design modifications to improve N-removal performance (e.g., addition of a post-bioreactor polishing chamber; Feyereisen et al., 2017) and the application of bioreactor technology for treatment of other types of agricultural water pollution (i.e., manure effluents, Christianson et al., 2017c; aquaculture wastewater Christianson et al., 2017b).

Beyond bioreactors and N pollution, we’re engaged in research on phosphorus (P) removal technologies for ag drainage. Christianson et al. (2017b) recommended that a P-sorbing filter be located downstream of a bioreactor if the two are paired. Work in this area continues with small P-filter cartridges that can be installed in standard drainage control structures. Li et al. (2017a) have

evaluated the use of fly-ash ceramic pellets as a short contact time medium for P removal in these structures. Results are pending on other media.

In the field, we evaluated the performance of new surface inlet designs (Li et al., 2017b). We also continue to study cover crops and the 4Rs approach to nutrient management to better evaluate the impact of these practices on drainage nutrient loss. We recently collaborated with Eagle et al. (2017) to encourage others to do similar field studies. 2017 was our baseline data collection year at the Illinois ACES Dudley Smith Farm replicated drainage plot infrastructure (Pana, Illinois) where we are using 16 x 2-acre individually drained plots to evaluate four treatments: (1) "conventional" farming nitrogen management, (2) improved "4Rs" nitrogen management, (3) 4Rs nitrogen management plus a winter cover crop, and (4) zero nitrogen application rate control.

We provided articles for the bi-monthly Illinois Land Improvement Association (ILICA) Newsletter. Topics covered in 2017 include

- Designing Combination Drainage/Sub-irrigation Systems
- A QGIS Plugin for Thinning and Extracting Elevation Data from LiDAR Maps
- An Excel Worksheet for Sizing Drainage Mains
- The Bolilands of Sierra Leone: A new frontier for tile drainage
- Online Tools for Watershed-scale Drainage Design

Dr. Reid Christianson, PE, was hired in the Department of Crop Sciences at the University of Illinois in May 2017, and one of his major efforts is to develop the tracking and reporting system for the implementation of conservation practices for the Hypoxia Task Force.

Indiana - *Purdue University, Jane Frankenberger and Eileen Kladivko*

We completed a 10-year evaluation of the potential of controlled drainage to reduce drain flow and improve water quality at Davis Purdue Agricultural Center. To construct a complete drain flow data record to use in statistical analysis, a method was developed to use water table depth data to fill missing values in the drain flow record (Saadat et al., 2018a). The method uses the Hooghoudt equation with a layered saturated hydraulic conductivity profile to estimate drain flow. Drain flow estimated using this method compared well to observed flow in both calibration and validation periods, Using this method, together with linear regression for the remaining gaps, a long-term drain flow record for a controlled drainage experiment at the Davis Purdue Agriculture Center was used to evaluate the impacts on drain flow.

The nitrate and phosphorus load evaluation was completed using two different statistical methods (Saadat et al., 2018b). The first method was a cumulative annual analysis that avoids the difficulty of accounting for the transition times as well as the potential lateral seepage between the neighboring fields. The second was a rigorous statistical method that accounts for the pre-treatment relationship between the fields and explicitly models dependence in the data, allowing daily data to be used in the analysis. Both methods indicate that controlled drainage significantly decreased drain flow (by 25% to 39%) and nitrate load (by 26% to 43%) through subsurface drainage. The impacts on phosphorus (P) loads were more complex and inconsistent over years and across plots but overall during 5 years, controlled drainage decreased P loads slightly. The higher level of outlet control during the non-growing season (winter) provided about 70% of annual water quality benefits while the lower level used during the growing season (summer) provided about 30%. By quantifying the magnitude of the increased impact, this study clarifies the added water quality benefit of controlling drainage at a higher level, especially during the non-

growing season.

Increasing collaboration to understand and implement storage of drainage water in the environment continues to be a priority. The Transforming Drainage project, led by Purdue University, has brought together researchers and educators across nine universities, USDA-ARS, and other organizations in the Midwest to advance and coordinate research, extension, and implementation of drainage water storage systems. This year, three new collaborators joined the network and 10 new sites were added (8 saturated buffers, 1 controlled drainage, 1 drainage water recycling.) **)**. These sites and collaborators strengthen the growing Transforming Drainage network. Collaborators will work with team members to advance the awareness and understanding of drainage water storage practices through project synthesis, modeling, and extension activities.

We also coordinate the national Agricultural Drainage Management Systems (ADMS) Task Force, which includes representatives from ARS, NRCS, land-grant universities, NIFA, USGS, State Departments of Agriculture, and the Drainage Industry. These collaborations increase the potential to address nutrient issues from drainage and accomplish the NCERA-217 goals.
Jane Frankenberger made presentations to more than 900 producers and drainage contractors at 15 workshops and field days. A field day at Davis Purdue Agricultural Center highlighting the controlled drainage project was attended by more than 200 people including farmers and drainage contractors who make decisions about drainage system design and installation.

Iowa - *Iowa State University, Matthew Helmers*

Research and extension efforts at Iowa State University relative to drainage design and management practices to improve water quality continue to center on nutrient export from tile drainage systems and nutrient management practices to minimize this export of nutrients, specifically nitrate-nitrogen. Work is also continuing that is evaluating drainage water management and cropping practice impacts on drainage volume and drainage water quality. Water quality and water quantity are being monitoring from seven drainage water quality research sites.

Work continued in 2017 examining the impacts of manure (poultry and liquid swine) on drainage water quality. This work is continuing to examine nutrient loss as well as bacteria and antibiotic resistant bacteria assessments. We continued monitoring work in 2017 looking at the impact of nitrogen application timing on nitrate-N loss along with examining timing of liquid swine manure application on N loss and whether cereal rye crops can mitigate N loss with early swine manure application. We also continued work examining whether use of gypsum as a soil amendment can reduce dissolved phosphorus loss in subsurface drainage.

Began regional drainage water quality project studying the impacts of 4R nitrogen management on crop yield, soil health, nutrient losses with water, and gaseous emissions. This work is being conducted across seven sites in the Upper Midwest US cornbelt and one site in Ontario, CA. The project is funded by the Foundation for Food and Agriculture Research and 4R Research Fund.

Extension work has focused on disseminating information relative to drainage water quality and economic design of drainage systems. This has included statewide, regional, and local programming events. In August 2017, an Iowa Drainage School was held near Nashua, IA that focused on hands-on design of drainage systems. Approximately 35 individuals participated in this event. In December 2017, a drainage water quality practice design workshop was held with

watershed coordinators and drainage engineers. The design of saturated buffers, controlled drainage, bioreactors and wetlands was discussed.

Iowa - *USDA ARS, Dan Jaynes*

Saturated Riparian Buffers. **Accomplishment.** In this project we are investigating the efficacy of reconnecting tile drainage to shallow ground water flow through riparian buffers for removing nitrate. By diverting a fraction of the tile discharge through a distributary tile installed along the top of the buffer, we are diverting a fraction of the tile water as shallow ground water flow through the buffer. We hypothesize that both denitrification and sequestration processes known to be active in buffers will remove a fraction of the nitrate before it can enter the adjacent stream.

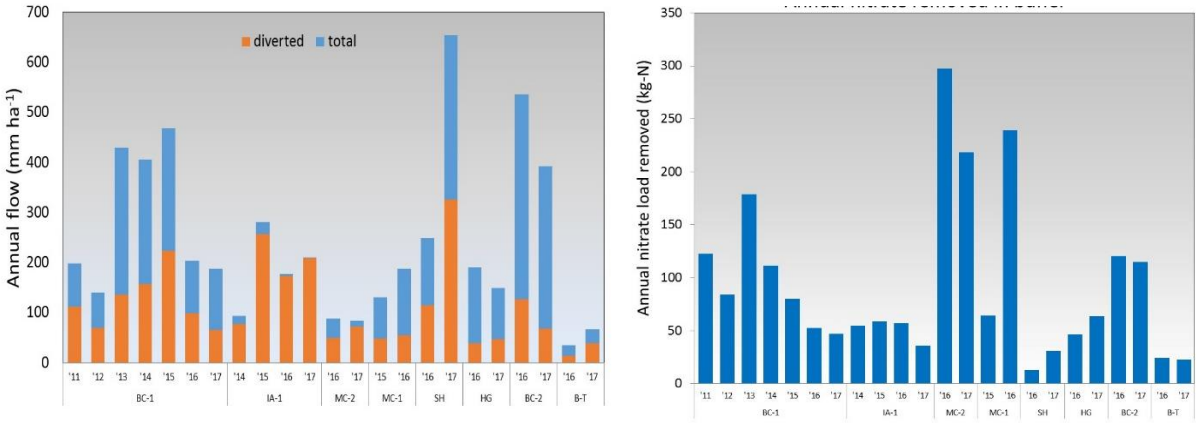

Figure 1. Flow into and nitrate removed at Saturated Buffers sites in IA 2011 – 2017.

Kentucky - *University of Kentucky, Bill Ford*

A subaward from the USDA-ARS SDRU has been awarded to the University of Kentucky to support edge-of-field water quality monitoring and modeling in tile-drained midwestern landscapes. The funding is being used to support a PhD student and undergraduate research assistant to implement modifications into APEX to simulate the effects of controlled drainage on water quality in surface and subsurface runoff. Funding is also being utilized to obtain high resolution water quality sensors and supplemental drainage samples for stable isotope analysis of N and O for nitrate (both) and phosphate (O). Work from this research will be presented by the PhD student at the 2018 ASABE Annual international meeting in Detroit.

Ford has been working on a preliminary assessment of the oxygen isotope of phosphate as a tracer and indicator of intra-event variability of P dynamics in tile-drainage. The study was recently accepted in Transactions of the ASABE. Results of this study will also be presented by Ford at the ASABE AIM 2018 in Detroit.

Michigan - *Michigan State University, Ehsan Ghane*

Reducing phosphorus transport from agricultural fields in Michigan is of great importance due to the presence of the Great Lakes. We acquired $1.5M for an edge-of-field research proposal submitted to Michigan Department of Agriculture and Rural Development (MDARD) and Michigan Department of Environmental Quality (MDEQ). The edge-of-field research evaluates the effectiveness of controlled drainage and a saturated buffer at on-farm sites in southeast Michigan. In Michigan, there is a need to determine the effectiveness of these conservation practices in reducing nutrient load, especially phosphorus, to show stakeholders and farmers the extent of

nutrient reduction of these practices under local conditions. This project will quantify the nitrate, total phosphorus and dissolved reactive phosphorus loads reduction under controlled drainage and a saturated buffer. There are two on-farm sites for evaluating controlled drainage under commercial and manure application, and one site for evaluating a saturated buffer in a no-till field under manure application. We have hired a technician to help instrument the on-farm sites and a Ph.D. student to conduct the research.

During the summer 2017, an undergraduate student worked on determining the hydraulic property of agricultural drain pipes from different manufacturers across the Midwest. He estimated the effective radius of different pipes in the market based on empirical relationships in the literature. Using the effective radius data, he designed a drainage system for a field in Michigan. His preliminary work identified those pipes that provide the cheapest installation of subsurface drainage systems as well as providing optimal water removal from the field to meet the crop production requirement. In Michigan, the optimal lateral spacing is selected rather than calculated. This research will help set the foundation for an upcoming research project that will lead to the improved design method of subsurface drainage systems. As a result, optimal lateral spacing will be calculated and used in a design of a drainage system.

Minnesota - *USDA ARS, Gary Feyereisen*

Drainage research at USDA-ARS Minnesota was focused in two areas this past year: tile drainage in dairy systems and removal of nitrate-N from tile drainage using denitrifying bioreactors. Extensive soil, water and atmospheric measurements amassed on-farm for a manured corn silage – alfalfa crop rotation were used to show that reducing manure application rates and applying manure via center pivot irrigation during the growing season reduced tile drainage nitrate-N losses by ≈20%. Work is in progress to validate the Integrated Farming System Model (IFSM) for tile drainage and then through modeling identify management practices that contribute the economic and environmental health of the US dairy industry. This work is part of USDA-ARS Dairy Agroecosystems Working Group (DAWG) Grand Challenge initiative.

In collaborative research with the University of Minnesota, the strategies of biostimulation (carbon dosing with acetate) and bioaugmentation (inoculation with cold-adapted denitrifiers) to improve woodchip bioreactor nitrate removal performance are being tested in a replicated field experiment on a farm. Field performance has been promising although inconsistent, and challenges have been uncovered. In a related approach, uniquely designed vertical bioreactors with carbon dosing are also being field tested. It appears that nitrate-N removal rates can be increased two to three times over standard woodchip design.

Work continues on increasing the percentage of drainage system flow using a unique three-cell cascading design woodchip bioreactor in southern

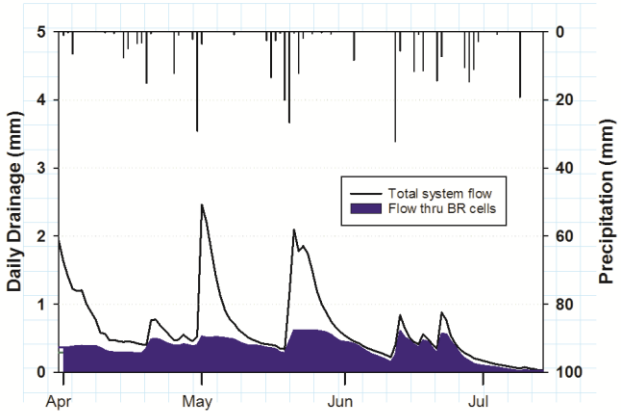

Fig. 1. Precipitation, total system drainage flow, and cumulative flow through three woodchip bioreactor cells from 266-ha watershed near Blue Earth, MN, from May through July, 2017.

Minnesota. The system treated ≈60% of flow from a 266-ha agricultural watershed from April to July 2017 (Fig. 1).

Missouri - *University of Missouri, Kelly Nelson*

Long-term crop production research evaluating drainage water recycling systems (2001-present) as well as corn and soybean response to drainage water management on claypan (2010-present) and river bottom (2010-present) soils. Field research was initiated on claypan and silty clay (river bottom) soils to evaluate the impacts of controlled drainage on crop production and water quality from 2009 to 2013. In addition, demonstration sites on drainage water management in Northwest Missouri near Oregon and Albany are ongoing (2013-present). Annual forage research was conducted from 2010 to 2013 and research was published. In addition, a synthesis of soybean response to drainage water recycling on a claypan soil was completed during 2017, and research evaluating a new formulation of nitrapyrin on a poorly drained claypan soil was completed in 2017.

As livestock demand and production continue to rise in the United States, there is a greater need for increased forage production and improved forage quality. Forage production will need to expand to soils with production restrictions, such as poorly drained floodplain soils, in order to meet future demands. The objectives of the study were to evaluate the impact of free drainage (FD), managed drainage systems (MD), and no drainage (ND) on forage production, nitrogen (N) uptake, and nitrate (NO_3) concentration in rye (*Secale cereale* L.) and forage sorghum (*Sorghum bicolor* [L.] Moench). On average across years, MD did not increase forage production compared to FD, but the presence of subsurface drainage (both FD and MD) increased total forage biomass production by 27% to 32% compared to ND. Annual plant N uptake increased 30% with MD and 41% with FD compared to ND when averaged across the four-year study. Nitrate concentration in rye mass never reached a concentration that could impact cattle grazing the forage over the four-year study. Regardless of subsurface drainage system, NO_3 concentration in forage sorghum in two study years ranged from 1,310 to 4,520 mg kg^{-1}, which corresponded to toxic to extremely toxic levels. Dry summer months may have contributed to the high NO_3 concentrations observed in forage sorghum. Subsurface drainage may provide farmers with an opportunity to increase annual forage production from rye and forage sorghum, but farmers should have forage sorghum tested for NO_3 concentrations before feeding.

Claypan soils with less than 1% slope are poorly drained because of an argillic claypan layer 45 to 60 cm below the soil surface. Field research conducted near Bethel, Missouri, evaluated soybean (*Glycine max* [L.] Merr.) grain yields and plant populations above subsurface drain tile lines and 3.1 m distances from the tile lines of laterals installed at 6.1 and 12.2 m wide spacings for drainage (DO) or drainage plus subirrigation (DSI). The site was arranged as a split-plot design with four replications. In some years, sub-sub-plots included multiple cultivars or fungicide/insecticide management systems. This resulted in 30 year-cultivar-management (YCM) treatments from 2002 to 2015. Averaged over all of the 30 YCM systems, the highest yields (4,050 kg ha^{-1}) were observed above the 6.1 m DSI drainage tile line. Subsurface drainage tile spacings (6.1 and 12.2 m) and distances from the tile lines for DO or DSI yielded 11% to 21% greater than the ND control. Due to extreme weather events among YCM systems, data were separated into low (LYE, <3,360 kg ha^{-1}) and high (HYE, >3,360 kg ha^{-1}) yield environments. In LYEs, yields were more variable above the tile line and generally decreased as the distance from the subsurface tile lines increased for DSI, but yields were greater and more variable between the tile lines for DO. In HYEs, yields were greatest and more variable between the 6.1 or 12.2 m spaced DO treatments, while yields were greatest above the drain tiles with lower variability compared to between the tile lines with DSI. A narrower

drain tile spacing may be needed to reduce yield variability in LYEs, but this was less evident in HYEs.

Use of nitrification inhibitors (NI) in agricultural production systems is considered a risk management strategy for both agricultural and environmental considerations. It can be utilized when risk of reduced nitrogen (N) fertilizer use efficiency or yield, and risk of pollution from mineral N is high which can occur in poorly-drained soils that are vulnerable to waterlogging and runoff. Field research was conducted on corn (*Zea mays* L.) from 2012 to 2015 in Missouri, USA on a poorly-drained claypan soil. Treatments consisted of two application timings of urea ammonium nitrate (UAN) fertilizer solution [pre-emergence (PRE) and V3 growth stage], two application rates (143 and 168 kg N ha^{-1}) in the presence or absence of nitrapyrin, and a non-treated control. UAN at 143 kg ha^{-1} with nitrapyrin at the V3 growth stage resulted in the highest yield (8.6 Mg ha^{-1}). Similarly, pre-emergence application of UAN 168 kg ha^{-1} with nitrapyrin resulted in greater yields (7.7 Mg ha^{-1}). UAN application rates and timings affected soil NO3-N and NH4-N concentrations more than the presence or absence of nitrapyrin during the growing season. A side-dress application of a lower rate of UAN with nitrapyrin at V3 was effective in poorly-drained soils when risk of N losses during the growing season due to unfavorable precipitation events and other environmental variables was high. A pre-emergence application of UAN with nitrapyrin was also effective and it may eliminate the need for split-application of N fertilizer later in the season thereby reducing the workload on growers during the growing season.

North Carolina - *North Carolina State University, Mohamed Youssef*

1. A new generation of drainage water control structures have been designed for open ditch drains to minimize the time and cost of drainage water management. These structures can be adjusted to automatically open and close according to a preset schedule.

2. A smart water management system has been designed to manage the outlets of the drainage systems depending on the soil water conditions in the field. The new structures are being demonstrated in two demonstration sites.

3. Continued to experimentally investigate the effects of drainage water management on crop yield and N export to surface waters. We collect and analyze hydrologic, water quality and yield data for two artificially drained agricultural sites in eastern North Carolina;

4. Experimental research is underway to assess the effectiveness of controlled drainage and bioreactor systems for reducing N export to surface waters from land application of liquid animal waste to subsurface drained fields.

5. Experimental research has been initiated to assess the agricultural drainage water reuse. In this system, agricultural drainage water is stored in an in-field pond for subsequent use as a source of irrigation in dry periods during the growing season.

6. The DRAINMOD-DSSAT model has been developed and field tested. DRAINMOD-DSSAT is a field scale, process based model that simulates the hydrology, soil carbon and nitrogen dynamics, and crop growth for agricultural lands.

7. A new version of DRAINMOD is currently being developed to simulate the fate of phosphorus in drained agricultural land.

North Dakota - *North Dakota State University, Xinhua Jia*

Prepared by Xinhua Jia and Thomas Scherer

North Dakota State University research focused on evaluating the drainage water management on soil quality, water budget and quality, and crop yield. Various instruments were used to measure the soil moisture, temperature, and salinity, water quality and quantity, water table, infiltration, snowfall and snow equivalent water contents. The results showed tile drainage and subirrigation can affect the soil properties in a healthy way. Water quality sampling for the last eight years at a ND field showed that both drainage flow and nitrate-nitrogen load were lowered in 2012-2017 than in 2008-2010, mainly due to controlled drainage flow as well as reduced precipitation amount. In the spring time before subirrigation starts, all salt related parameters (%Na, Na^+, SAR, SO_4^{2-}, Ca^{2+} and Mg^{2+}) increased over time in the surface water downstream of the field, but stayed constant in the surface water upstream of the field. This indicated that tile drainage affected the surface water quality for salt related parameters. However, the nitrate-nitrogen concentration in the drainage outlet decreased overtime with a mean of 13.51 mg/L for the nine years in 2008 – 2017. In the fall after the subirrigation ceased, all salt related parameters (%Na, Na^+, SAR, TDS, EC, SO_4^{2-} and Mg^{2+}) increased in the surface water. Soybean yield was 40.1 bu/ac, only 14.56% higher than that of the county average, but 36% lower than the soybean yield (54.7 bu/ac) at in the undrained control field. Soil sampling and analysis indicated that the yield reduction was due to waterlogging along the main tile and some laterals. Further analysis will be conducted in 2018.

Since 2012, the precipitation pattern has been drier in North Dakota and northwestern Minnesota but there is still educational interest in subsurface drainage. A subsurface drainage research forum was planned for March 6, 2018 but was cancelled due to a snowstorm and power loss in the building where it was to be held. In March 2018, 2-tile drainage design workshops were held with a total attendance of 72 and 12 of those were from Manitoba. Tom Scherer and Hans Kandel were invited to present a session on subsurface drainage in Winnipeg Manitoba to the Legislative Council; an organization of elected legislators from ND, SD, MN, Saskatchewan and Manitoba. The ND law pertaining to tile drainage was revised during the last legislative session and Tom Scherer provided neutral testimony to the Senate Agriculture Committee on the revisions.

New York - *Cornell University, Larry Geohring*

The research at Cornell University has focused on evaluating the effectiveness of using denitrifying bioreactors to reduce nitrate and phosphorus export from tile drained fields, roadside ditches, and stormwater retention/detention ponds. Although the monitoring period varied from 1 year to 4 years for the 9 different denitrifying bioreactor sites on 6 farms, in summary for all the bioreactors, the tile drains produced a total nitrate + nitrite-Nitrogen load of around 4100 kg during this period. Of this, a load of 3000 kg was diverted into the 9 bioreactors and they removed 980 kg. This represents an average 33% removal of the N input load to the bioreactors, or about a 24% removal of the total N load from the tile flows. The N load removal ranged from 20 to 46% of the N input to the different bioreactors, or from 15 to 40% removal of the total N in the tile flows. Depending on the site characteristics, most of the bioreactors had some bypass flow during larger storm events. The bed of woodchips in the roadside ditch or submerged in the stormwater retention pond also removed some nitrogen, suggesting there may be some alternative engineering applications for using denitrifying bioreactors to remove excess nitrates from surface drainage waters. Experiments with both lab and field-scale denitrifying bioreactors are evaluating their effectiveness to remove atrazine also.

Presentations were made at several meetings regarding the use and effectiveness of using denitrifying bioreactors, and about other drainage water management strategies to improve water quality. These presentations were primarily targeted to farmers, drainage contractors,

and Soil and Water Conservation District professionals. A course was taught at the Conservation Skills Workshop on denitrifying bioreactor design procedures as per the USDA-NRCS Denitrifying Bioreactor Conservation Practice Standard (Code 605) which was adopted in New York.

South Dakota - *South Dakota State University, John McMaine*

Research activities broadened the focus from edge-of-field practices such as woodchip bioreactors, saturated buffers, and controlled drainage to in-field practices such as cover crops. A project was funded by the South Dakota NRCS and initiated in Fall 2017 that looks at the impact of a winter rye cover crop on nitrate loss through tile drained fields. The project will measure nitrate in soil, plant tissue, and subsurface drainage over a three year period. The project was also leveraged to receive funding from two SD water development districts to purchase sensor technology to achieve high frequency nitrate concentration measurements in the subsurface drains in the study. Monitoring continued at the saturated buffer, bioreactor, and controlled drainage sites located throughout eastern South Dakota.

Extension activities focused educating producers, drainage professionals, and the public on drainage best management practices and drainage design. Project investigator McMaine presented over the winter of 2017-2018 at multiple farm shows on drainage best management practices. McMaine also assisted with a drainage workshop in Fargo, North Dakota in March, 2018. Approximately 90 stakeholders were served by these activities. Emphasis was also placed on strengthening and expanding industry and producer relationships for future project opportunities. This has led to representatives from Prinsco assisting with sample collection and the planning of a series of workshops on drainage best management practices to be held in 2018-2019 with industry and producer collaboration.

Virginia - *Virginia Tech, Zach Easton*

Concluded three-year project funded by NRCS CIG #69-3A75-13-232, entitled “Comprehensive drainage management to decrease agricultural nutrient export,” findings from which were disseminated at the NCERA217 2018 meeting, in peer-reviewed scientific journals, and Virginia Cooperative Extension Publications. This project aimed to integrate field and drainage management practices to develop, demonstrate and test a comprehensive approach to drainage management that can be readily adopted by producers on the Coastal Plain. Work included field installations and monitoring, laboratory experiments, and collaborative evaluations of the outlook for denitrifying bioreactors in the Mid-Atlantic and their potential utility in meeting Chesapeake Bay water quality improvement goals. Specifically, nutrient removal and greenhouse gas emissions from a denitrifying bioreactor installed in a tile drained farm on the Virginia Coastal Plain were for over two years (Bock et al., 2018). Controlled laboratory experiments testing the effect of biochar on nutrient removal and greenhouse gas emissions in woodchip bioreactors were also conducted (Bock et al., in press; Coleman et al., in prep). Finally, we collaborated on both technical and economic assessments of the opportunities and challenges for bioreactors in the Mid-Atlantic. The technical assessment was based on early performance data from the region, including our VA Coastal Plain installation (Christianson et al., 2017). The economic assessment focused on the viability bioreactor use in the Mid-Atlantic to reduce nonpoint source nitrogen pollution (DeBoe et al., 2017). We also continue to collaborate with the University of Maryland Eastern Shore to assess the paired usage of sawdust walls and gypsum curtains intercepting shallow groundwater before it reaches drainage ditches. However, the discontinuity in hydraulic conductivity created by the sawdust walls has proven to be a challenge in treating passive flow to ditches. Of the adaptations to the NRCS tile-drain bioreactor design standard (CPS 605), simply following the design guidelines but diverting ditch flow with drainage control structures through an adjacent woodchip bed before

returning it to the ditch seems to hold the most promise (Christianson et al., 2017).

Impact Statements --- Station Reports

Georgia - *University of Georgia, Gary Hawkins*

a. We are still collecting initial data from the project so no Impacts to report so far as it relates to data collection.
b. We have submitted a proposal to the Georgia State Environmental Protection Division that includes continuing the monitoring of the blueberry (both field and bench scale) plots to quantify and develop ways to reduce nutrient movement. Notification of the grant being awarded has been received, but the final contract has not been finalized.

Illinois - *University of Illinois at Urbana-Champaign, Richard Cooke and Laura Christianson*

The "Ten Ways to Reduce Nitrogen Loads from Drained Cropland in the Midwest" program, a regional collaboration including a booklet, factsheet, slide decks, and online content, continues to be very popular (>2,000 web hits; >3,000 hard copies distributed). More than 30 conservation professionals and Extension educators from 10 states and 2 countries, have requested our Ten Ways PowerPoint slide decks.

Dr. Laura Christianson presented on conservation drainage, bioreactors, and nutrient loss issues to more than 1,100 attendees at events in 2017 (including invited in-state and out-of-state conferences; field events; the Farm Progress Show, etc.)

Dr. Richard Cooke conducted the annual two-day Drainage Workshop for drainage contractors. The attendance exceeded 40 on each day.

Indiana - *Purdue University, Jane Frankenberger and Eileen Kladivko*

The nitrate load reduction findings of the 10-year controlled drainage study in Indiana are statistically robust, and enhance our knowledge about water quality impacts of controlled drainage systems. They support this management practice as a reliable system for reducing nitrate loss through subsurface drains, mainly caused by flow reduction.
The Transforming Drainage team, which includes numerous NCERA-217 participants, has brought together agronomic, soil, hydrologic, water quality, and weather data at 34 experimental to quantify the impacts of the three drainage storage practices addressed in the project (controlled drainage, saturated buffers, and drainage water recycling). The regional database now contains 161 site-years of yield data (59% increase from year 2), 166 site-years of tile flow (71% increase), 72 site-years of water table (67% increase), 122 site-years of tile water nitrate-nitrogen concentration (25% increase), and 170 site-years of weather (21% increase). The database can support coordinated synthesis and modeling of drainage storage approaches. The website, http://transformingdrainage.org is widely used by drainage stakeholders and the general public to access project updates and information and interact with products and materials.

Iowa - *Iowa State University, Matthew Helmers*

The research information generated on drainage water quality has continued to be shared in support of implementation of the Iowa Nutrient Reduction Strategy. Being able to report on results from Iowa is important for gaining confidence of these stakeholders. We continue to assist with subsurface drainage bioreactor design throughout Iowa.

Iowa - *USDA ARS, Dan Jaynes*

This research has quantified the potential nitrate removal capacity and water quality benefits from reconnecting a portion of field tile flow to riparian buffers. The research has led to a completed CIG grant from NRCS, an AFRI grant from NIFA, and a final NRCS Conservation Standard Practice # 604 "Saturated Buffers" describing the practice.

Kentucky - *University of Kentucky, Bill Ford*

The improvement of widely used agronomic and water quality models, such as APEX, to more accurately reflect hydrologic pathways of nutrients to tile-drains will ultimately help inform sustainable management strategies. Further, new novel measurement techniques (such as oxygen isotopes of phosphate and N/O isotopes of nitrate) will allow advancement of our perceptual model of field-scale nutrient dynamics and will provide unique datasets to test and improve numerical models

Michigan - *Michigan State University, Ehsan Ghane*

We raised awareness of farmers about the dynamics of phosphorus in drainage water and how it can affect water quality. We educated farmers and agency personnel about conservation practices that can improve drainage water quality at the county level and statewide during 9 field days/workshops. The conservation practices included controlled drainage and saturated buffers. We also provided education about the economics of subsurface drainage. Our education has resulted in farmers expressing interest in collaborating with MSU related to drainage conservation research. Our published interviews with news agencies has heightened interest from state agencies and farmers about our edge-of-field research.

Minnesota - *USDA ARS, Gary Feyereisen*

The cooperating producer involved in the dairy research estimates that the findings of the work have resulted in manure application rates being lowered by 15% on 60,000 acres in Minnesota and neighboring states. The bioreactor research continues to move the science forward and to increase awareness among various stakeholder groups about treatment options for drainage effluent.

North Carolina - *North Carolina State University, Mohamed Youssef*

1. The development of the smart agricultural water management system including the automated drainage water control structure will lead to the revitalization of controlled drainage in eastern NC where large areas of agricultural lands are artificially drained. This will result in a potential increase in crop production, reduction in production cost, conservation of water, and substantial improvement in surface water quality.

2. The results of our research have shown that both controlled drainage and bio-reactor systems have the potential to be used as BMPs for reducing nutrient export from drained spray fields. Our research could lead to the adoption of these two practices by the state of North Carolina to reduce nitrogen losses to surface waters from land application of animal waste to drained fields.

3. The DRAINMOD suite of models are being used by many researchers in the U.S. and abroad to assess the long term effects of emerging changes in land uses and management practices on the hydrology and biogeochemistry of agricultural and forested lands with improved drainage. Models such as DRAINMOD are particularly essential at this time for predicting the response of agricultural

and forest ecosystems to potential changes in the climate and assessing strategies for adapting agricultural and forest production systems on drained land to these changes in the climate

4. The continued advancements in the DRAINMOD suite of models will enhance the field of agricultural drainage research since these models are widely used by the drainage research community.

North Dakota - *North Dakota State University, Xinhua Jia*

NDSU is part of the large USDA NIFA in the Water for Agriculture program project, with our focus on subirrigation and education. A senior design team redesigned the subirrigation system at one of the sites to optimize the water table and management zones for best crop yield potential. The senior design project result was shared with the landowner, who adopted our plan and planted different corn varieties in different zones. A NASA Water Program funded project are focusing on remote sensing soil moisture and snow water equivalent for fields with and without tile drainage. All these projects will improve our overall understanding of tile drainage impact on our environment.

The attendees of the two tile drainage design workshops were asked to evaluate the effectiveness of the training they had received. Overall rating of workshop one was a 3.45 out of 4 and for workshop 2, it was 3.9 out of 4. The reason for the difference was that changes suggested by the attendees to the first workshop were incorporated into the second workshop.

New York - *Cornell University, Larry Geohring*

The applied research and demonstration on farms, and the adoption of a Conservation Practice Standard by NY-NRCS has generated more interest by conservation district technicians, agricultural consultants, contractors, and farmers to consider utilizing denitrifying bioreactors and drainage water management to address drainage water quality and nutrient loss concerns.

South Dakota - *South Dakota State University, Laurent Ahiablame*

As drainage implementation continues to grow in South Dakota, questions about drainage and drainage best management practices also continue to increase. The general public, producers, and industry professionals attended and benefitted from extension activities. Comments voiced appreciation for learning about solutions to problems (ie – controlled drainage and saturated buffers). As results are learned from research into the success of integrating cover crops with tile drainage, producers can continue to improve management practices to reduce impact to water quality.

Virginia - *Virginia Tech, Zach Easton*

Outcomes, apart from the generation of publications listed below, include developing working relationships with cooperating farm managers that supported the concluded project and hold the potential to support future work on managing agricultural drainage in the Mid-Atlantic. Preliminary data were also generated to support continuation of research on denitrifying bioreactors focused on the treatment of legacy nutrients of agricultural origin present in groundwater. In addition, we leveraged our work on agricultural drainage management to submit a proposal for an EPA environmental education grant focusing on empowering producers on the Eastern Shore of Virginia as environmental stewards. A unifying aim in this proposal was to equip producers with the tools to evaluate the potential impact of their specific land and management practices on local water quality, and management of drainage waters provided a central theme around

which to present information on nutrient transport processes and a comparative assessment of management options.

Publications --- Station Reports

Peer-reviewed publications

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54. Soupir M.L., Hoover N.L., Moorman T.B., Law J.Y., Bearson B.L. (2018) Impact of temperature and hydraulic retention time on pathogen and nutrient removal in woodchip bioreactors. Ecological Engineering 112:153-157. DOI: 10.1016/j.ecoleng.2017.12.005.
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Non-peer reviewed publications and conference abstracts

1. Adler, R., and K. Nelson. 2017. Effect of Cover Crops On Nutrient Loss In A Terraced Field In Upstate Missouri. Greenley Memorial Research Center Report. pp. 7-10.
2. Bock, E.M., Collick, A.S., and Z.M. Easton. Managing Drainage from Agricultural Lands with Denitrifying Bioreactors in the Mid-Atlantic. 2018. (in review)
3. Easton, Z.M. How Do Stream Buffers Reduce the Offsite Impact of Pollution? 2017. BSE-38NP.
4. Easton, Z.M., Bock, E.M**.**, and A.S. Collick. Factors when Considering an Agricultural Drainage System. 2017. BSE-208P.
5. Frankenberger, J., B. Reinhart, K. Nelson, L. Bowling, C. Hay, M. Youssef, J. Strock, **X. Jia**, M. Helmers, and B. Allred. 2017. Questions and answers about drainage water recycling for the Midwest. Purdue Extension, ABE-156-W. March 2017. https://www.extension.purdue.edu/extmedia/ABE/ABE-156-W.pdf
6. Helmers, M, L. Christianson, and R. Christianson. July/August 2017. Reducing nitrate-N losses to achieve water quality goals. Resource: Engineering and technology for a sustainable world (ASABE magazine) 24(4): 22-24.
7. Kaur, G., K. Nelson, and P. Motavalli. 2017. Early-Season Soil Waterlogging, Hybrids and N Fertilizer Sources Affects Corn Production. Greenley Memorial Research Center Report. pp. 98-99.
8. Kaur, G., B. Zurweller, K. Nelson, P. Motavalli, and C. Dudenhoeffer. 2017. Soil Waterlogging and Nitrogen Fertilizer Management Effects on Corn and Soybean Yields. Greenley Memorial Research Center Report. pp. 96-98.
9. McMaine, J., D. Kringen, T. Trooien. January, 2018, General Impacts of Tile Drainage on Hydrology and Water Quality in South Dakota. White Paper for SD Legislature (not publicly available)
10. McMaine, J. March, 2018. Nutrients in water – Why does it matter and what can we do?. Guest Column for *Emerge* South Dakota Corn Growers' Association Quarterly Industry Publication
11. Nash, P., K. Nelson, P. Motavalli, and S. Anderson. 2017. Corn Yield Response to Managed Drainage and Polymer-Coated Urea. Greenley Memorial Research Center Report. pp. 134-135.
12. Nash, P., K. Nelson, P. Motavalli, M. Nathan, and C. Dudenhoeffer. 2017. Reducing Phosphorus Loss in Tile Water with Managed Drainage in a Claypan Soil. Greenley Memorial Research Center Report. pp. 136.
13. Nash, P., K. Nelson, and P. Motavalli. 2017. Reducing Nitrogen Loss with Managed Drainage and Polymer-Coated Urea. Greenley Memorial Research Center Report. pp. 139.
14. Nash, P., K. Nelson, and P. Motavalli. 2017. Corn Response to Drainage and Fertilizer on a Poorly-Drained River Bottom Soil. Greenley Memorial Research Center Report. pp. 140.
15. Nash, P., K. Nelson, and P. Motavalli. 2017. Reducing Nitrogen Loss in a Subsurface Tile Drainage Water with Managed Drainage and Polymer-Coated Urea in a River Bottom Soil. Greenley Memorial Research Center Report. pp. 141.
16. Nash, P., and K. Nelson. 2017. Maximizing Forage Production in a Poorly-Drained, Blackoar Soil with Subsurface Drainage Systems. Greenley Memorial Research Center Report. pp. 142-149.
17. Nelson, K., and R. Smoot. 2017. Corn Hybrid Response to Drainage, Drainage Plus Subirrigaton and Non-Drained Overhead Irrigation. Greenley Memorial Research Center Report. pp. 132-133.
18. Nelson, K., and P. Motavalli. 2017. Nitrogen Source and Drain Tile Spacing Affects Corn Yield Response in a Claypan Soil. Greenley Memorial Research Center Report. pp. 130-131.
19. Nelson, K., D. Harder, and M. Mungyeko-Mayola. 2017. Corn Response to Drainage Water Recycling in a Blackoar Silt Loam. Greenley Memorial Research Center Report. pp. 150-151.
20. Nelson, K.A. 2017. Corn Yield Variability of Drainage and Subirrigation Systems in a Claypan Soil. Greenley Memorial Research Center Report. pp. 125-128.

21. Nelson, K., S. Paniagua, and P. Motavalli. 2017. Effect of Polymer Coated Urea, Irrigation and Drainage on Nitrogen Utilization and Yield of Corn in a Claypan Soil. Greenley Memorial Research Center Report. pp. 129.
22. Nelson, K.A., and C. Meinhardt. 2017. Drainage Water Management and Headline Fungicide Effects on Soybean Yield. Greenley Memorial Research Center Report. pp. 123-124. [Geographic Scope: State] [Peer Reviewed / Juried?: No] [Publication Type: Field Day Report]
23. Nelson, K.A., R. Smoot, and C. Meinhardt. 2017. Yield Response of Soybean Cultivars to Subsurface Drainage and Subirrigation in Northeast Missouri. Greenley Memorial Research Center Report. pp. 121-122.
24. Nelson, K.A., R. Smoot, and C. Meinhardt. 2017. Soybean Yield Response to Drainage and Subirrigation of a Claypan Soil in Northeast Missouri. Greenley Memorial Research Center Report. pp. 118-120.
25. Nelson, K.A. 2017. Soybean Yield Variability of Drainage and Subirrigation Systems in a Claypan Soil. Greenley Memorial Research Center Report. pp. 113-117.
26. Nelson, K., and D. Harder. 2017. MU Drainage and Subirrigation (MUDS) Research Update For Claypan Soils (2002-2016). Greenley Memorial Research Center Report. pp. 100-112.
27. Niaghi, A. R., **X. Jia.,** and T. F. Scherer. 2017. Impact of accurate evapotranspiration estimates on DRAINMOD simulation in North Dakota. ASABE Annual International Meeting, July 16-19, 2017. Spokane, WA. Paper No. 1701500. Nash, P., P. Motavalli, K. Nelson, and R. Kremer. 2017. Ammonia and Nitrous Oxide Gas Loss with Subsurface Drainage and Polymer-Coated Urea Fertilizer in a Poorly-Drained Soil. Greenley Memorial Research Center Report. pp. 137-138.

Extension and outreach presentations

Iowa - *Iowa State University, Matthew Helmers*

1. 17th Annual IA-MN Drainage Research Forum
    a. November 15, 2017 – Coordinated with Dr. Gary Sands from the University of Minnesota and Chris Hay from the Iowa Soybean Association the forum in Ames, IA. There were 85 attendees consisting of producers, contractors, and agency
2. Drainage Water Quality Field Tour
    a. September 5, 2017 – Organized a field tour at the Gilmore City Drainage Research and Demonstration project site and wetlands in Pocahontas and Palo Alto County for NRCS and FSA staff. There were 15 attendees.
3. Drainage Water Quality Field Day
    a. August 30, 2017 – Organized a field day at the Gilmore City Drainage Research and Demonstration project site. There were 45 attendees consisting of producers and agency representatives.
4. Iowa Drainage School
    a. August 22-24, 2017 – Coordinated with Kapil Arora and Greg Brenneman. There were 35 attendees consisting of drainage contractors, drainage sales people, and county agency representatives from Iowa, South Dakota, North Dakota, Wisconsin, and Minnesota.
    b. March 29, 2018 – Presentation on "Impacts of 4R nitrogen management on drainage water quality" as Iowa Farm Bureau Federation webinar (18 live attendees)
5. March 9, 2018 – Presentation on "Impacts of 4R nitrogen management on drainage water quality" at Farmers Coop Elevator in Sioux Center, IA (15 attendees)
6. February 19, 2018 – Presentation on "Iowa Nutrient Reduction Strategy and a Resilient Iowa" at Iowa Poultry Association annual meeting (55 attendees)
7. February 13, 2018 – Presentation on "Impacts of 4R nitrogen management on drainage water quality" at AAI Showcase in Des Moines, IA (45 attendees)
8. February 10, 2018 – Presentation on "Impacts of 4R nitrogen management on drainage water quality" at Beginning Farmer Network Conference in Ames, IA (65 attendees)
9. February 8, 2018 – Presentation on "Impacts of 4R nitrogen management on drainage water quality" at Growmark meeting in Des Moines, IA (75 attendees)
10. January 26, 2018 – Presentation on "Impacts of 4R nitrogen management on drainage water quality" at Crop Advantage Series meeting in Davenport, IA (45 attendees)
11. January 25, 2018 – Presentation on "Manure and cover crops" at Crop Advantage Series meeting in Denison, IA (45 attendees)
12. January 24, 2018 – Presentation on "Manure and cover crops" at Pork Congress in Des Moines, IA (45 attendees)
13. January 10, 2018 – Presentation on "Impacts of 4R nitrogen management on drainage water quality" at Crop Advantage Series meeting in Ames, IA (45 attendees)
14. January 9, 2018 – Presentation on "Impacts of integrated in-field management on drainage water quality" at Crop Advantage Series meeting in Storm Lake, IA (50 attendees)
15. January 5, 2018 – Presentation on "Impacts of 4R nitrogen management on drainage water quality: at Crop Advantage Series meeting in Burlington, IA (45 attendees)
16. January 4, 2018 – Presentation on "Impacts of integrated in-field management on drainage water quality" at Crop Advantage Series meeting in Okoboji, IA (35 attendees)
17. January 2, 2018 – Presentation on "Prairie strips in tiled fields" at North Central Crop Clinic in Iowa Falls, IA (35 attendees)
18. December 15, 2017 – Presentation on "Bioreactor design" at Drainage Design Workshop near Fort Dodge, IA (35 attendees)

19. December 11, 2017 – Presentation on “Water quality, soil health, and nutrient transport: An Iowa perspective” at the Water Rocks Summit in Ames (15 attendees)
20. December 6, 2017 – Presentation on “Challenges and opportunities of the Iowa Nutrient Reduction Strategy” at the Farm News meeting in Fort Dodge, IA (45 attendees)
21. December 1, 2017 – Presentation on “Past and future research on drainage in Iowa” at the Iowa Drainage District Association Annual meeting in Fort Dodge, IA (85 attendees)
22. November 30, 2017 – Presentation on “Practices to consider for the Iowa Nutrient Reduction Strategy” at Iowa Learning Farms Field Day in Roland, IA (25 attendees)
23. November 29, 2017 – Presentation on “Impacts of 4R Nitrogen Management on drainage water quality” at Integrated Crop Management Conference in Ames, IA (225 attendees)
24. November 16, 2017 – Presentation on “Practices to consider for the Iowa Nutrient Reduction Strategy” at Iowa Learning Farms Field Day in Floyd, IA (40 attendees)
25. November 2, 2017 – Presentation on “Financial aspects of prairie strips” at Prairie Strips Consultant Training near Ankeny, IA (20 attendees)
26. November 2, 2017 – Presentation on “Iowa Nutrient Reduction Strategy: Scale of implementation needed” at Iowa Association of Extension Agriculture Annual meeting in Altoona, IA (25 attendees)
27. November 1, 2017 – Presentation on “Drainage Water Quality studies at Iowa State University” as part of 4R Plus meeting in Des Moines, IA (35 attendees)
28. October 23, 2017 – Presentation on “Iowa Nutrient Reduction Strategy: Scale of implementation needed” at ISU Agriculture Think Tank in Ames, IA (12 attendees)
29. September 21, 2017 – Presentation on “Iowa Nutrient Reduction Strategy: Scale of implementation needed” at Iowa Ideas Conference in Cedar Rapids, IA (25 attendees)
30. September 20, 2017 – Presentation “Edge-of-field practices: What is needed and what will it take” as part of Iowa Learning Farms Webinar Series (25 on-line live attendees)
31. September 11, 2017 – Presentation on “Financial aspects of prairie strips” at Prairie Strips Consultant Training in Dubuque, IA (20 attendees)
32. August 3, 2017 – Presentation on “Research results of prairie strips” at Prairie Strips Consultant Training near Calmar, IA (25 attendees)
33. August 1, 2017 – Presentation on “Iowa Nutrient Reduction Strategy: Scale of implementation needed” at local meeting organized by state senator near Dewitt, IA (45 attendees)
34. July 26, 2017 – Presentation on “Water quality practices” as part of Agronomy Distance Education Program near Ames, IA (25 attendees)
35. June 29, 2017 – Presentation on “Cover crops and nitrogen loss” at Beginning Farmer meeting near Washington, IA (15 attendees)
36. June 29, 2017 – Presentation on “Drainage Water Quality studies at Iowa State University” as part of N week in Crawfordsville, IA (35 attendees)
37. June 27, 2017 – Presentation on “Drainage Water Quality studies at Iowa State University” as part of N week in Ames, IA (35 attendees)
38. June 22, 2017 – Presentation on “Iowa Nutrient Reduction Strategy: Scale of implementation needed” at Southeast Research Farm CCA meeting in Crawfordsville, IA (35 attendees)
39. June 21, 2017 – Presentation on “Water quality, soil health, and nutrient transport: An Iowa perspective” at the Water Rocks Teacher Summit in Ames (25 attendees)
40. June 15, 2017 – Presentation on “Iowa Nutrient Reduction Strategy: Challenges and opportunities” at Iowa Farm Business Association Annual Meeting in Des Moines, IA (155 attendees)
41. June 9, 2017 – Presentation on “Iowa Nutrient Reduction Strategy: Challenges and opportunities” at Rotary Club Meeting in West Des Moines, IA (225 attendees)

42. June 6, 2017 – Presentation on “Water quality in Iowa” at Agronomy in the Field near Ames (12 attendees)
43. April 6, 2017 – Presentation on “Iowa Nutrient Reduction Strategy: Challenges and opportunities” at ASCE Annual Meeting in Cedar Rapids, IA (45 attendees)
44.
45. May 28, 2018 – Presentation on “Lessons learned from the Iowa nutrient reduction strategy and application to Nebraska’s nitrate challenges” to Nitrogen team with University of Nebraska Extension (on-line webinar, 15 attendees)
46. April 3 and 5, 2018 – Presentation on “Nutrient reduction in the Mississippi River: From regional to farm scale” at Upper Midwest Dairy Industry Association Spring meetings in St. Cloud and Rochester, MN (75 attendees)
47. February 20, 2018 – Presentation on “State of the Science” Nutrient Management and Impacts on Water Resources” at the Great Lakes to Gulf Watershed Leadership Summit (40 attendees)
48. December 15, 2017 – Presentation on “Next generation strategies for managing edge of field nutrient losses” for LPELC webinar (~20 on-line attendees)
49. December 13, 2017 – Presentation on “Impacts of 4R Nitrogen Management on Drainage Water Quality” at the South Dakota Agronomy Conference (200 attendees) [Invited]
50. June 13, 2017 – Presentation on “Impacts of 4R Nitrogen Management on Drainage Water Quality” at 4R Summit in Minneapolis, MN (125 attendees)

Iowa - *USDA ARS, Dan Jaynes*

1. Gave webinar “Saturated Buffers and the Conservation Reserve Program Nutrient Reduction Effectiveness” to FSA and other interested parties, 25 Apr., 2017. 37 in attendance.
2. Gave presentation at the Soil and Water Week Declaration and Saturated Buffer field day. Fifty in attendance including the Governor and Secretary of Agriculture of IA. 4 May, 2017.
3. Gave presentation on siting and design of Saturated Buffers at the 2017 Iowa Watershed Academy, Boone, IA, 10 May, 2017. 60 in attendance.
4. Research was reported on in the Corn and Soybean Digest in article “Iowa State scientists add to knowledge of phosphorus dynamics” 21 June, 2017 http://www.cornandsoybeandigest.com/soil-health/iowa-state-scientists-add-knowledge-phosphorus-dynamics .
5. Attended 2017 Iowa LICA Midwest Expo and Field Day in Melbourne, IA and described design and function of saturated buffers and answered questions during installation of a demo saturated buffer, 26 July, 2017, 200 attendees.
6. Interviewed on saturated buffers by Amy Petherick for an article in the fall 2017 addition of Drainage Contractor Magazine
7. Attended Greenley Research Center field day in Novelty, MO and presented information regarding saturated buffers and denitrification bioreactors, 7-8 Aug, 2017, 300 attendees.
8. Attended Drainage Water Quality Practices Design Workshop and gave unit on “Siting and Designing Saturated Buffers”, 14 Dec, 2017, 20 NRCS, watershed coordinators, and land improvement contractors in attendance.

Indiana - *Purdue University, Jane Frankenberger and Eileen Kladivko*

1. *REGIONAL BOOKLET*: Frankenberger, J., B. Reinhart, K. Nelson, L. Bowling, C. Hay, M. Youssef, J. Strock, X. Jia, M. Helmers, B. Allred, 2017. Questions and Answers about Drainage Water

Recycling for the Midwest. Purdue Extension Publication ABE-156. Online at http://www.extension.purdue.edu/extmedia/ABE/ABE-156-W.pdf.

Michigan - *Michigan State University, Ehsan Ghane*

1. Wrote an article on MSU Extension: http://msue.anr.msu.edu/news/why_water_control_structures_should_be_considered

Minnesota - *USDA ARS, Gary Feyereisen*

1. Feyereisen, G., J. Baker, J. Gamble, and K. Spokas. 2018. ARS-MN drainage research update. NCERA-217 committee: Drainage Design and Management Practices to Improve Water Quality – Annual Meeting. 11 – 12 April 2018. Raleigh, NC.
2. Rosen, C., G.W. Feyereisen, S. Ishii, P. Wang, J. Jang, E. Anderson, M. Sadowsky, E. Dorsey, and S. Schumacher. Optimizing bioreactors to reduce nitrate losses from tile drainage water. MnDRIVE Environment Research Symposium. 11 April 2018. University of Minnesota, St. Paul, MN.
3. Feyereisen, G.W. Bioreactor research in Minnesota: An update. Water Resources Center Seminar Series. 9 March 2018. University of Minnesota, St. Paul, MN.
4. Feyereisen, G.W. Bioreactor Research Review. Minnesota Interagency Drainage Management Team Meeting. 18 January 2018. St. Paul, MN.
5. Feyereisen, G. 2017. Increasing tile drainage nitrate removal in bioreactors by treating more water. ASA-CSSA-SSSA-IAM, Tampa, FL. 22 – 25 October, 2017.
6. Reed, K., J.D. Gamble, P.A. Vadas, and G.W. Feyereisen. 2017. Assessment of the Integrated Farm System Model for predicting nitrate-nitrogen losses in drainage water from manured cropping systems. ASA-CSSA-SSSA-IAM, Tampa, FL. 22 – 25 October, 2017.
7. Ranaivoson, A., J.S. Strock, G.W. Feyereisen, K.A. Spokas, D. Mulla, and M. Roser. 2017. Novel design and field performance of phosphorus-sorbing and denitrifying bioreactors. ASA-CSSA-SSSA-IAM, Tampa, FL. 22 – 25 October, 2017.
8. Feyereisen, G.W., J. Gamble, and M. Soupir. Land-applied manures and residues: Water and soil quality considerations. RAMIRAN 2017. 5 September 2017. Wexford, Ireland. All conference expenses were paid by Agriculture and Food Development Authority of Ireland.
9. Reed, K., P.A. Vadas, C.A. Rotz, G.W. Feyereisen, and J.D. Gamble. 2017. Assessing regional differences in nitrogen losses from U.S. dairy farms using the integrated farm systems model. ADSA Annual Meeting. 25 – 28 June 2017. Pittsburgh, PA.
10. Feyereisen, G.W., E. Ghane, M.J. Sadowsky, P. Wang, C.J. Rosen, E.C. Dorsey, and S. Schumacher. 2017. Optimizing denitrification beds to reduce nitrogen and phosphorus in subsurface drainage water. MnDRIVE-Barr Mini-Symposium Lightning Talk. 25 April 2017. Bloomington, MN.

Extension Activities.

1. Presentation: Feyereisen, G., M. Lore, M. Stindtman, C. Viland, and S. Matteson. 2017. Faribault County Ditch 62 bioreactor: Monitoring and research update. Faribault County Drainage Authority Board Meeting. 1 August 2017.
2. Co-organized and led field day of Gorans Farm bioreactor installation for state agency producer, and research personnel. Willmar, MN, 11 November 2017.

3. Coauthor: 7-part blog series (1,215 views first seven months), 2017: Gorans Discovery Farm. http://agwaterexchange.com/2017/07/24/welcome-to-gorans-discovery-farm-blog-series/

North Dakota – *North Dakota State University, Xinhua Jia*

1. Niaghi, A. R., and **X. Jia.** 2017. Determination of grass evapotranspiration rates and crop coefficients using eddy covariance method in eastern North Dakota. ASCE World Environmental & Water Resources Congress (EWRI) Annual Meeting, May 21-25, 2017, Sacramento, CA.
2. Cho, E., J.M. Jacobs, and **X. Jia**. 2017. Tile Drainage Expansion Detection using Satellite Soil Moisture Dynamics. 2017 AGU Fall Meeting, December 11-15, 2017. New Orleans, Louisiana. Presentation by Cho.
3. Niaghi, R. A., **X. Jia.,** and T. F. Scherer. 2017. Impact of accurate evapotranspiration estimates on DRAINMOD simulation in North Dakota. ASABE Annual International Meeting, July 16-19, 2017. Spokane, WA. Presentation by Niaghi.
4. **Jia, X.** 2017. Best water management for a healthy environment and a profitable crop production. Xinjiang Agricultural Vocational and Technical College, Changji, Urumqi, Xiniiang, China, June 8, 2017. Presentation by Jia.
5. **Jia, X.** 2017. Best water management for a healthy environment and a profitable crop production. Xinjiang Agricultural University, Urumqi, Xiniiang, China, June 7, 2017. Presentation by Jia.
6. **Jia, X.** 2017. Best water management for a healthy environment and a profitable crop production. Xinjiang Academy of Agricultural Sciences, Urumqi, Xiniiang, China, June 6, 2017. Presentation by Jia.
7. **Jia, X.** 2017. Advanced evapotranspiration measurement. Xinjiang Academy of Forest Sciences, Urumqi, Xinjiang, China, June 5, 2017. Presentation by Jia.
8. **Jia, X.** 2017. Challenges in drainage water management. NCERA 217 Annual Meeting, Champaign, IL. March 30, 3017.

2. Frankenberger, J. E. Kladivko, L., Bowling, B. Engel, L. Prokopy, M. Helmers, L. Abendroth, G. Chigladze, J. Strock, D. Jaynes, K. Nelson, M. Youssef, L. Brown, B. Sohngen, L. Ahiablame, and **X. Jia**. 2017. Managing water for increased resilience of drained agricultural landscapes. Red River Basin Commission Annual Meeting. Fargo, ND. January 17-19, 2017. Presentation by Jia.