Minutes of NCERA 217: *Drainage Design and Management Practices to Improve Water Quality* Annual Meeting and NCERA 217 Station Reports

Annual Meeting: 29-30 March 2017 at the Hilton Garden Inn, Champaign, Illinois

Contents

NCERA 217 Meeting Overview

The 2017 NCERA 217 Annual Meeting was held March 29-30, 2017, 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), Gary Sands (MN), Jeff Strock (MN), Matt Helmers (IA), Xinhua Jia (ND), Kelly Nelson (MO), Clarence Prestwich (Oregon), Laura Christianson (IL), and Gary Feyereisen (MN). Guests present: There were an additional guests present during the NCERA 217 Business and Research meetings including: Christopher Hay (IA), Jeppe Kjaersgaard (MN), Barry Allred (OH), and Lindsay Pease (OH). Many other additional guests were present for the ADMS-TF/ADMC and Transforming Drainage meetings (*total registration: 79*).

NCERA 217 2017 Business Meeting Minutes

The NCERA 217 business meeting was called to order at 7:50 AM on Thursday, 30 March 2017, at the Hilton Garden Inn (Champaign, Illinois) by Chair Gary Feyereisen.

- Welcome by NCERA 217 Chair Gary Feyereisen (Minnesota)
- Approval of minutes: Eileen Kladivko (Indiana) moved to accept the minutes from last year's meeting. The motion was seconded by Kelly Nelson (Missouri). There was no discussion, and the motion carried unanimously.
- Advisor's report: Ramesh Kanwar (Iowa): Dr. Kanwar was complimentary of how far the committee has come since he attended the meetings of the "*NC 175 Benefits of Drainage*" committee in the 1970s. The committee's good work is exemplified by substantial national funding (USDA NIFA Transforming Drainage project), and by the number of graduate students at this meeting.
    - Dr. Kanwar encouraged the committee to apply for the Experiment Station Section Award for Excellence in Multi-State Research ($15,000 from Hatch Multi-state). Five thousand dollars of the award can be used for travel and the remainder can be used as the committee sees fit. This application is due 28 February 2018.
    - The committee will also need to submit a new project for approval next year.
- Old business: Gary Feyereisen (Minnesota)
    - The committee's minutes are logged at the NIMSS website, and minutes are reviewed heavily. Ours have received favorable reviews in terms of coordination and linkages, but the committee has room to improve our understanding and demonstration of interactions of our work to other fields (e.g., linkages to energy, food, greenhouse gases).
    - Linkages:
        - Jane Frankenberger (Indiana) raised the issue that Clarence Prestwich (USDA NRCS, Oregon) inquired about joining NCERA 217, which would strengthen the committee's linkage with the NRCS. Eileen Kladivko (Indiana) noted other committees have generally voted on the acceptance of new members.
            - Jane Frankenberger (Indiana) moved to accept Clarence Prestwich as a member. Eileen Kladivko (Indiana) second the motion. The motion passed unanimously without further discussion.
        - Xinhua Jia (North Dakota), the current chair of the ASABE NRES 23 Drainage Committee, reported:
            - ASABE NRES 23 will be holding elections for chair (2 year term) this year. She is currently seeking nominations.
            - ASABE NRES 23 is leading the revision on the design standard EP 302.04 (*Design and Construction of Surface Drainage Systems on Agricultural Lands in Humid Areas*). Xinhua is leading the review.
            - 29 drainage-related abstracts have been submitted for the 2017 ASABE annual international meeting (Spokane, Washington; July 2017), and will be distributed over 3 sessions.
        - Gary Feyereisen (Minnesota): American Society of Agronomy Managing Denitrification in Agronomic Systems community (MDiAS)
            - The MDiAS community successfully hosted an invited symposium and a 5 minute rapid session at the 2016 ASA annual meeting (Phoenix, Arizona; Nov. 2016).

        - Laura Christianson (Illinois), current MDiAS chair, noted the community will be hosting an oral session, including a student oral competition with cash prizes, at the 2017 ASA annual meeting in Tampa, Florida (Oct. 2017).
    - Jeppe Kjaersgaard (Minnesota) noted:
        - The ASCE EWRI Irrigation and Drainage subcommittee was hosting a webinar this Friday (4/1/2017) by Jim Ayars on salinity management.
        - One of the major sections within ASA is the Environmental Quality section, and Jeppe is the current chair, while Gary Feyereisen was just elected incoming section chair.
- New Business:
    - Multi-state committee award: Dan Jaynes (Iowa) and Matt Helmers (Iowa) will lead the application (due February 2018).
    - Jane Frankenberger (Indiana) raised the issue of next year's NCERA 217 annual meeting. She suggested the meeting be in North Carolina, with a late Monday start, the Transforming Drainage project meeting Tuesday, Wednesday be a combined day for ADMS and NCERA meetings, and a field trip on Thursday.
        - 2018 NCERA 217 Annual Meeting: North Carolina at the end of March 2018 [*This has since been updated to the second week of April 2018 in North Carolina*].
    - Election of vice-chair: Based on a show of hands, the majority of attendees had served as NCERA 217 chair. Jane Frankenberger (Indiana) encouraged the group to consider electing a more senior person. Gary Sands and Jeff Strock (both Minnesota) were identified as potential chairs, and Gary Sands nominated Jeff Stock to be chair. Kelly Nelson (Missouri) seconded the nomination. Jeff Stock was elected unanimously without further discussion.
    - Welcome to Laura Christianson (Illinois) as incoming NCERA 217 chair.
- Motion to adjourn: Jane Frankenberger (Indiana) moved to adjourn, and the motion was seconded by Kelly Nelson (Missouri). There was no discussion, and the motion carried at 8:30 AM.

Minutes respectfully submitted,
Laura Christianson, 2017 NCERA 217 Chair

NCERA 217 2017 Research Meeting Summary

The research meeting began at 8:45 AM on Thursday, 30 March 2017, at the Hilton Garden Inn (Champaign, Illinois) and was moderated by Chair Gary Feyereisen.

Chris Hay (Iowa Soybean Association) presented an evaluation of the benefits of drainage water recycling for crop production in Iowa. Jeppe Kjaersgaard (Minnesota Department of Agriculture) continued this water-balance theme to discuss crop water needs for subirrigation in the Red River Valley, Minnesota. Xinhua Jia (North Dakota) discussed challenges with the practice of drainage water management in the Red River Valley where sodic and saline soils pose a problem. Moving south, Kelly Nelson (Missouri) provided an update on drainage research in Missouri that includes evaluating in-field practices (e.g., polymer coated urea), edge-of-field practices (i.e., going to be installing a saturated buffer and bioreactor this summer), and terrace-tile systems. Ehsan Ghane, a newly appointed assistant professor at Michigan State, discussed research from his post-doc in Minnesota comparing drainage water quality under two nutrient management practices (application of inorganic N fertilizer vs. none). Lindsay Pease (USDA ARS, Ohio) showed two interesting case studies of field-scale P-filters, and

reported they are encouraging farmers to delay when they pull their boards in the spring for drainage water management (suggest they wait until at least April 1st). Matt Helmers (Iowa) discussed an assessment of drainage main redesign considering many mains were installed in the early 1900s with original drainage design coefficients of 1/8th to 1/4th inch per day, and districts today want to upgrade to ½ to 1 inch per day. Barry Allred (USDA ARS, Ohio) discussed mapping subsurface drainage with airplane, drone, and satellite imagery (e.g., Are suspected drainage patterns in imagery consistent over time? Are the linear features related to field operations like field turn-arounds?). Eileen Kladivko and Laura Bowling (Indiana) presented an update on the long-term SEPAC drainage project, which has been in operation since 1983. Laura Christianson (Illinois) concluded the session with an update of new bioreactor, saturated buffer, and drainage water management research in Illinois that may eventually help update the Illinois Nutrient Loss Reduction Strategy.

The session concluded with lunch at 12:00 PM.

Accomplishments --- Station Reports

Georgia - *University of Georgia, Gary Hawkins*

Over the past year (2016) we received 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. A few samples have been collected and the samples run in the UGA Water Lab running an expanded profile of compounds. The only things that were shown to be high were Iron and Aluminum. With the low pH of the water both Iron and Aluminum are expected to be the result of the soil type and the lower pH.

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 this drainage research. We are also continuing our work on P-sorbing media. Our recently completed column study pairing woodchips and P-sorbing filters led to the recommendation that the P-filter should be placed downstream of the woodchips (Christianson et al., In revision). We also co-guest-edited a special issue of fourteen bioreactors articles in the Journal of Environmental Quality (May 2016 issue) (Christianson and Schipper, 2016; Addy et al., 2016; Feyereisen et al., 2016; David et al., 2016). Notable findings from a bioreactor meta-analysis in the special issue were that temperature and hydraulic retention time are strong influencers of bioreactor nitrate removal, and there is no significant difference between hardwood and softwood woodchips in a bioreactor application (Addy et al., 2016).

In addition to edge-of-field drainage water quality practices, we are also engaged in the study of the effects of climate change on the performance of drainage systems (Resende et al., 2016). Additionally, new replicated drainage plot infrastructure was installed at the Univ. of Illinois ACES Dudley Smith Farm (Pana, Illinois) in the fall of 2016. These 16 x 2-acre individually drained plots will allow replication of four treatments: (1) “conventional” farming nitrogen management, (2) improved “4Rs” nitrogen management, (3) 4Rs nitrogen management plus a winter cover crop, and (4) a zero nitrogen application rate control. This new drainage system also routes drainage into a novel bioreactor that was designed with two internal baffles. Preliminary results show nearly 100% nitrate load reduction by this bioreactor.

Outreach activities in 2016 have included continued partnership with the Metropolitan Water Reclamation District of Greater Chicago to establish a research/demonstration site for several drainage-related practices, and designing and installing a combination drainage/subirrigation system on an urban farm in the Chicago suburb of Skokie. We also worked with Illinois Corn Growers Association and the Illinois Land Improvement Contractors Association (ILICA) in the design and installation of a field-scale drainage lab consisting of 37 instrumented drainage plots on a 160-acre university farm near Blue Mound, Illinois. Other extension activities include the development of new interactive applications for the Illinois Drainage Guide, engagement with ILICA via their annual Drainage School (see the figure in our Impacts section below) and through the "Extension Connection" article in the ILICA bi-monthly newsletter.

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

We completed eleven years of monitoring drain flow, soil moisture at five depths, water table depth, and tile flow nitrate concentrations at the Davis Purdue Agricultural Center. Our analysis of results from the two free draining and two controlled drainage quadrants of the field shows that controlled drainage reduced drain flow by 14% to 49%, with similar reductions in nitrate load. In addition to publishing the results, the data have been provided to the shared database managed by the Transforming Drainage team at Iowa State University.

These data were also used to address the management of controlled drainage. We examined whether the outlet should be lowered prior to or directly after a rainfall event to reduce the amount of time that the water table is at a level that would be detrimental to either trafficability or crop yield. We determined water table recession rates from two pairs of controlled and free-draining fields located at the Davis Purdue Agricultural Center in Indiana over a period of 9 years from 2006 to 2014. For each pair, comparison of mean recession rate from the two fields indicated that controlled drainage reduced recession rate. Raising the outlet of the subsurface drainage system decreased the mean rate of water table recession by 29% to 62%, increasing the time needed for the water table level to fall from the surface to 60 cm depth by approximately 24 to 53 hours. Based on these results, lowering the outlet before storm events would reduce the amount of time that the water table is at a detrimental level for either crop growth or trafficability. However, the trade-off between costs and benefits of active management depends on the sensitivity of the crop and probability of a severe storm.

Collaborations and information sharing are important in seeking solutions to drainage issues and water quality problems related to drainage. We are leading a team of researchers and educators across nine academic institutions and agencies in the Midwest to advance and coordinate research, extension, and implementation of drainage water storage systems through the Transforming Drainage project. We also provided leadership to Agricultural Drainage Management Systems Task Force, which includes representatives from ARS, NRCS, land-grant universities, NIFA, USGS, State Departments of Agriculture, and the drainage industry. We co-led the International Drainage Symposium, held in Minneapolis, MN in September 2016.

Jane Frankenberger presented information on drainage management to 655 people in nine Extension presentations. Audience members included staff from federal, state, and local agencies; commodity groups; drainage contractors; crop advisors, seed dealers; and producers. She also spoke to 4,567 students at 61 schools from 13 states through a Purdue University "zip trip" virtual field trip for high school students about practices that store drainage water to increase resilience of drained agriculture.

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 2016 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 2016 looking at the impact of nitrogen application timing on nitrate-N loss. In addition, we began work 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 began work examining whether use of gypsum as a soil amendment can reduce dissolved phosphorus loss in subsurface drainage.

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 2016, an Iowa Drainage School was held near Nashua, IA that focused on hands-on design of drainage systems. Approximately 45 individuals participated in this event.

Iowa - *USDA ARS, Dan Jaynes*

Saturated Riparian Buffers: 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.

We currently have 10 saturated buffers installed that we are monitoring for performance across Iowa. We are also monitoring several saturated buffers as a continuation of the Saturated Buffer CIG grant. Some results for these sites are shown in Fig. 1. Averaged across the sites years, we are diverting 50% of the tile discharge at the outlet into the saturated buffers. Annual nitrate removal in the buffers has ranged from 35 to 290 kg-N and has averaged 105 kg/yr across the IA sites. We will continue to monitor these sites plus potentially new sites installed as part of the Iowa Water Quality Initiative.

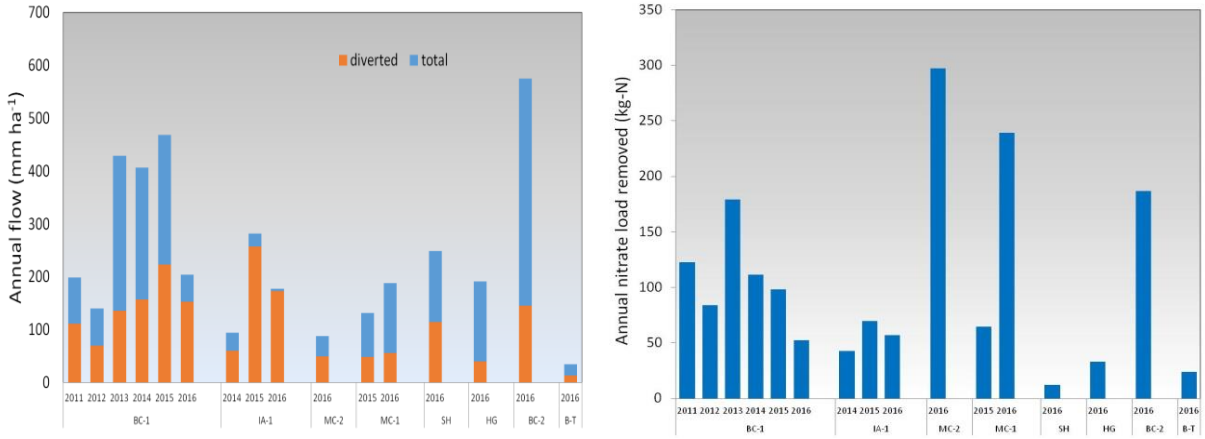

Fig. 1. Flow into (left) and nitrate removed (right) at saturated buffers sites in IA 2011 – 2016.

Kentucky - *University of Kentucky, Bill Ford*

Kentucky's involvement in NCERA 217 is just beginning. Funding has been received from the NSF EPSCOR RII-2 program to monitor and model nutrient source fate and transport in agroecosystems as a

part of a multi-state project involving Kentucky and West Virginia. Further, collaboration with researchers at the USDA-ARS to modify the Agricultural Policy Environmental eXtender (APEX) model to include macropore P contributions to tile drains resulted in a publication in a special issue of the J. of Environmental Quality (Issue: The evolving science of phosphorus site assessment). On-going work on a decadal water quality time-series in nested tile-drained watersheds is being conducted and is being presented at the ASABE annual meeting in Spokane, Washington this summer.

Michigan - *Michigan State University, Ehsan Ghane*

In Michigan, reducing phosphorus transport from agricultural fields is of high importance due to the presence of freshwater bodies surrounding the state. We plan to conduct research in the area of drainage water management and water quality, and educate farmers and agency personnel in that area. Two practices that we plan to investigate are controlled drainage and drainage water recycling in Michigan.

Minnesota - *University of Minnesota, Gary Sands*

Hosted the 10th International Drainage Symposium: Minnesota (specifically, Minneapolis) hosted the 10th International Drainage Symposium in September 2016. Success of the symposium was due in large part to collaboration among NCERA 217 members. The 10th IDS by the numbers:

- 250 Attendees representing the U.S., Denmark (14), Canada, Ireland, Finland, Norway, Sweden, Latvia, Lithuania, Netherlands
- 134 Presentations/Abstracts (20 posters/59 tech papers)
- 61 Participant Evaluations
- 22 Papers submitted for a special collection in an ASABE journal
- 15 Sponsors (8) & exhibitors (7)
- 4 Keynote Presentations (2 luncheon talks)
- 3-hr Dinner Cruise (100+ attendees)
- 2 Field Tours (~60 attendees)

Graduate education: Four graduate students are working in the area of agricultural drainage in the Department of Bioproducts and Biosystems Engineering at the University of Minnesota. Mike Talbot continues his M.S. research on ET methods as related to predicting water balances and hydrology of subsurface drainage systems. Mr. Nathan Utt began his doctoral program and will be undertaking dissertation research on saturated buffers.

Extension Activities: The annual University of Minnesota Extension Drainage Design and Water Management Workshop was offered in partnership with NDSU Extension. Approximately 50 drainage practitioners and stakeholders participated in the the 2-day workshop.

Minnesota - *USDA ARS, Gary Feyereisen*

Drainage research at USDA-ARS Minnesota is highly collaborative with the University of Minnesota. The past year, efforts have continued to be concentrated on reduction of nutrient losses from agricultural landscapes through deployment of denitrifying bioreactor technology. Laboratory research was completed that demonstrated significantly greater nitrate-N reduction through the use of corn cob media versus woodchips and through biostimulation with acetate (Fig. 2 left). The biostimulation strategy was successful at 5°C. These, and previous laboratory results, informed a pilot bioreactor installation during the year on a U of MN Research and Outreach Center. Initial results indicate phosphorus (P) reductions were realized as well as nitrate-N reductions. Another field pilot

installation was operated to test the hypotheses that biostimulation and bioaugmentation, the addition of microbes selected for cold temperature performance, would improve nitrate-N removal rates.

In addition to the emphasis on improving nutrient removal efficiency, work focused on treating a greater percentage of drainage system flow began with the instrumentation of a unique three-cell cascading woodchip bioreactor design in southern Minnesota. The bioreactor system is at the outlet of a 266-ha watershed, a uniquely large scale. First-year flow data (Fig. 2 right) highlight the challenges of draining crop land without overwhelming the conservation practices designed to prevent rapid loss of nutrients, and to treat the water before it enters surface waters. Positive relationships with the local SWCD, Drainage Authority, and producers, provide opportunity to work at water quantity and quality improvements over time at a manageable, realistic scale.

The past year provided numerous opportunities to inform producers, agency/policy personnel, and researchers about treatment of drainage waters. Five formal field day or tour events were held at two of the above-named sites with several informal field visits also conducted. The two sites were included in both the "West" and "South" tours held in conjunction with the 10th International Drainage Symposium in September 2016.

A symposium was organized and conducted at the Annual Meeting of the American Society of Agronomy, "Exchanging Waterway Nutrient Abundance for Scarcity," which explored four technologies to capture and reclaim nutrients from agricultural effluents.

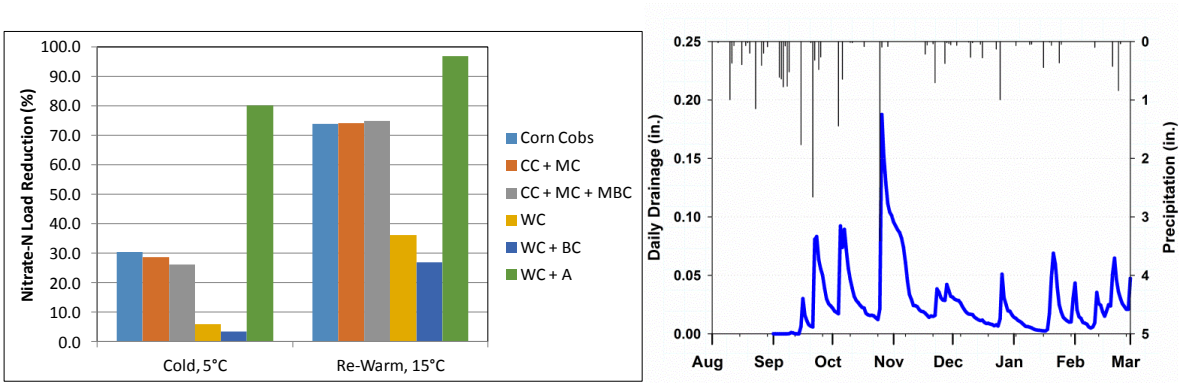

Fig. 2. (*left*) Nitrate-N load reduction in lab columns at 5 and 15°C for various media combinations: CC, Corn Cobs; MC, modified coconut coir; M/BC, modified/biochar; WC, wood chips; A, acetate. From: Roser, M. 2106. Using unique carbon source combinations to increase nitrate and phosphate removal in bioreactors. M.S. Thesis. Univ. of Minn., St. Paul. (*right*) Precipitation and drainage outflow from a 266-ha watershed.

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). Research has also evaluated the impact of N source and corn hybrid under saturated soil conditions at V3 and V6 (2011-2015). Saturated claypan soils commonly result in gaseous N loss. Research on urea placement and corn response to saturated poorly-drained claypan soils and an extension guide on questions and answers on drainage water recycling was completed during the period.

Practices to increase nitrogen (N) use efficiency (NUE) include selecting appropriate N fertilizer sources and application methods, but minimal research has focused on these practices in poorly-drained claypan soils which are prone to N loss. This research assessed the impact of different urea fertilizer placement practices on corn (Zea mays L.) production and N utilization in a poorly-drained claypan soil. Field trials were conducted in 2014 and 2015 in Missouri. Treatments consisted of pre-plant deep banding (20 cm) urea at 202 kg N ha-1 or urea plus a nitrification inhibitor (NI) (nitrapyrin) compared to pre-plant urea broadcast surface-applied or incorporated to a depth of 8 cm. In 2014, incorporating urea, deep banding urea, and deep banding urea plus NI had higher yields (> 10%) of corn compared to the control with grain yields ranging from 13.73 to 14.05 Mg ha-1. In 2015, grain yields were lower than in 2014, ranging from 4.1 to 7.9 Mg ha-1. Deep placing banded urea with a NI yielded an increase in grain yield up to 48% compared to the other treatments. Rainfall amounts were higher in 2015, which could have resulted in poorer root growth and greater N loss in deep banded treatments. In 2014, deep banding urea with a NI produced the highest NUE. Similar to NUE, silage tissue N concentrations in 2014 were greater with deep banded urea plus NI, while in 2015 silage tissue N concentrations were higher with surface applied urea. The results suggest that urea fertilizer incorporation including deep banding may improve corn grain production, N uptake, and NUE, but response was affected by climatic conditions. The addition of an NI may be an important safeguard when deep banding urea in years with excessive precipitation.

In the Midwestern United States, excessive soil moisture resulting from extreme precipitation events during early spring can often cause decreases in corn (Zea mays L.) grain yields and escalate N loss. A field trial was conducted from 2013 to 2015 to determine the effects of soil waterlogging duration, pre-plant N and rescue N fertilizer applications on corn and succeeding soybean [Glycine max (L.) Merr] production. Plots were either non-flooded or flooded for durations of 1, 3, or 7 d when corn was at V6 growth stage. Pre-plant N fertilizer treatments included non-treated control (CO), urea (NCU), urea plus nitrapyrin (NCU+NI), and polymer coated urea (PCU) applied at 168 kg N ha–1. A rescue N fertilizer application of 0 or 84 kg N ha–1 of urea plus N-(n-butyl) thiophosphoric triamide (NBPT) (NCU+UI) was applied at V10 growth stage. Each day of waterlogging resulted in an average corn grain yield loss of 0.42 and 0.72 Mg ha–1 in 2013 and 2014, respectively. Pre-plant N fertilizer applications of NCU, PCU, and NCU+NI resulted in 19% higher yields compared to CO in 2014. Effects of rescue N fertilizer were seen on soybean yields in the succeeding year after corn, while rescue N positively affected corn yields only in 2014. These results indicated that rescue N fertilizer applications are not effective if drought conditions occur after its application in corn. Climatic conditions including rainfall and air temperature had a significant role in crop response to waterlogging and N fertilizer treatments.

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

1. We have completed a study to develop DRAINMOD-based tools for quantifying reductions in annual drainage flow and nitrate losses caused by implementation of controlled drainage on artificially cropland in North Carolina and the U.S. Midwest. These tools utilize regression equations that are easy-to-use and require readily available input data.
2. We have completed modeling study on the Tar-Pamlico River Basin, North Carolina to identify cropland suitable for controlled drainage and estimate the edge-of-field reduction in nitrogen loss that would be expected if controlled drainage is implemented on this cropland within the river basin.
3. We have completed a study assessing nitrogen export from an agricultural watershed and an urban watershed in the Upper Midwest.
4. Experimental research is underway to assess the effectiveness of controlled drainage and bioreactor systems in reducing N export to surface waters from land application of liquid animal waste to subsurface drained fields.

5. Experimental research is underway to investigate managing drainage water for more resilient crop production on drained agricultural landscapes. The effects of controlled drainage and drainage water recycling on crop yield are currently being investigated.
6. 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, Thomas Scherer, Dean Steele, and Hans Kandel

North Dakota State University research is assessing the impact of tile drainage on soil salinity and sodicity at the field scale, and impact of tile drainage on snow hydrology and snowmelt runoff through measurements of soil moisture, temperature, salinity, water quality and quantity, water table, infiltration, and snowfall and snow equivalent water contents. Detailed soil physical and chemical analysis showed that tile drainage and subirrigation can affect the soil properties in a healthy way. Water quality sampling for the last seven years at a ND field showed that both drainage flow and nitrate-nitrogen load were lowered in 2012-2016 compared with 2008-2010, mainly due to reduced flow volume. However, the nitrate-nitrogen concentration stayed relative constant. Field data at five locations with two fields with tile drainage and three without were used to map soil moisture and snow equivalent water contents for the entire Red River Valley. The maps clearly showed a lower soil moisture for tile drained fields.

We developed and published an NDSU Extension bulletin SF1809 Soil Testing Unproductive Areas available online at https://www.ag.ndsu.edu/publications/crops/soil-fertilizer. We partnered with Gary Sands and Brad Carlson from the University of Minnesota Extension Service to conduct a 2-day tile drainage design workshop attended by 45 farmers and industry personnel. Presented the sessions on lift stations and subirrigation design. At the request of the Saskatchewan Ministry of Agriculture, Tom Scherer partnered with Gary Sands to conduct a 2-day tile drainage design workshop in Outlook, Saskatchewan. Hans Kandel developed and made presentations on the agronomics of subsurface water management at 13 locations in North Dakota where attendance was over 925 people. Some of those presentations were tours of his subsurface drainage research site. Naeem Kalwar has given many local presentations on subsurface drainage and sodic/saline soils in addition to several tours of his research plots along with farm visits. Soil Health field days were conducted by Abbey Wick and others at sites in eastern North Dakota where subsurface drainage is one option for controlling soil salinity. Tom Scherer developed and made 12 presentations on subsurface drainage and/or subirrigation at several locations and venues in North Dakota where the combined attendance was over 600 people. Several county agents have sodicity control and amendment demonstration projects initiated by local farmers and crop improvement associations.

New York - *Cornell University, Larry Geohring*

The research at Cornell University continues to evaluate the effectiveness of using denitrifying bioreactors to reduce nitrate and phosphorus export from tile drained fields. Two more denitrification bioreactors were installed during the summer of 2016 on two farms in the Finger Lakes region, so now there are nine bioreactors installed on six farms in different watersheds. The monitoring at three of the farms continues to evaluate paired bioreactors, one containing woodchips and one containing woodchips amended with biochar, to determine if the biochar amendment provides any additional benefit (Hassanpour et al., 2016 and 2017). Experiments using lab-scale denitrifying bioreactors with and without biochar are being done also to determine their effectiveness to remove atrazine.

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, agri-business consultants, drainage

contractors, extension agents and Soil and Water Conservation District and NRCS professionals. A total of 76 people attended the 2016 Skaneateles Lake Watershed Agricultural Program annual meeting, which also included Town Supervisors and other general public. We collaborated with a USDA-NRCS standard's workgroup to revise the national Denitrifying Bioreactor Conservation Practice Standard (Code 605) for adoption in New York.

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

South Dakota State University (SDSU) has a continuing project to demonstrate and evaluate the performance of edge of field practices to reduce nitrate and phosphorus loading from subsurface drainage systems. Three practices including denitrifying bioreactors, phosphorous adsorption media, and saturated buffers are being evaluated. The bioreactor project is also assessing the production of nitrous oxide, an intermediate product of the denitrification process and a greenhouse gas. Four bioreactors have been installed and are being monitored. The bioreactors were installed near Baltic, SD (July 2012), Montrose, SD (December 2012), Arlington, SD (July 2013), and Hartford, SD (November 2014). A phosphorous adsorption bed made of steel chips was installed downstream of the bioreactor at the Baltic site in October 2015 and is being monitored.

Field monitoring indicates good performance of the practices with nitrate reduction ranging from 7 to 100% across the four bioreactors. Phosphorus reduction ranges from 10 to 96% by the adsorption media.

Saturated buffers were installed at two cooperative sites in partnership with corn producers, near Flandreau and Baltic, SD. The Baltic site has two additional practices as mentioned above. Limited data were collected from the sites (only four samples) and preliminary results show an average of approximately 85% reduction in nitrate concentrations.

SDSU also has a continuing a project with plot-scale research at the SDSU Southeast Research Farm near Beresford, SD to demonstrate the benefits of subsurface drainage for crop production and water quality. The study, set up in a split-plot design with drainage as the whole-plot treatment and nitrogen as the split-plot treatment (regular Urea and Super U), is comparing conventional drainage and no drainage practices. The plots were in corn in 2016 and the benefits of tile drainage were reflected in yield data, which were slightly higher on plots with drainage treatments, although there was no statistical significant difference in crop yield between drained and undrained plots. Shallow ground water quality showed less nitrate leached in drained plots compared to undrained plots, suggesting that tile drainage contributed to nitrate exports to receiving waters.

Demonstration plots to compare controlled and conventional drainage (one plot for each) were also installed at the SDSU SERF since September 2013. The tiles were installed at 4-ft deep with 40-ft spacing. Monitoring of the plots started last year (i.e. 2016) with corn-soybean rotation to match the other plots discussed above. Corn was planted last year. The conventional drainage plot operates with an estimated drainage coefficient (design capacity of the drainage system) of ⅜ inches per day. Based on the data collected so far nitrate concentration in drain flow are slightly lower in controlled drainage plots compared to conventional drainage plots.

Virginia - *Virginia Tech, Zach Easton*

Virginia Tech continued in lead research efforts to develop, demonstrate, and test a comprehensive approach to drainage management for the Atlantic Coastal Plain to address water quality concerns. Collaborators on this project include the USDA Agricultural Research Service, University of Maryland Eastern Shore, University of Delaware, Penn State University, and the Midshore Riverkeepers Conservancy. Ongoing work includes field research, evaluation of cost-effectiveness, education and outreach, and developing regionally-specific design standards for edge-of-field practices. Field monitoring of previously installed edge-of-field practices (3 denitrifying bioreactors in tile systems,

2 receiving water diverted from drainage ditches, one in-ditch bioreactor, and 2 sites with sawdust walls and gypsum curtains used in combination), used in conjunction with conventional drainage water management, provided data to calculate nutrient removal efficiency and assess variability in practice performance across the region; the latest information from these studies has been presented at conferences, field days targeted toward producers, site demonstrations targeted toward conservation personnel, and published in academic journals.

A workshop on a comprehensive drainage management approach was presented at the Mid-Atlantic Crop School in two one-hour long sessions which trained 130 extension agents, soil and water conservation district personnel and ag service providers about nutrient reduction in drainage ditches. At the 2016 Resilient Virginia Conference, conservation personnel were educated about the potential impacts of climate change on agricultural drainage and crop management and how to mitigate these impacts, including drainage and drainage water management. Additionally, two extension publications detailing the underlying principles of drainage and drainage water management, topics much less prominent in the Mid-Atlantic than the Midwest, expanded resources available through the Virginia Cooperative Extension.

Two journal articles reporting denitrifying bioreactor performance in the Atlantic Coastal Plain were published in the past year (Bock et al., 2016; Rosen and Christianson, 2017). An economic analysis assessing the cost of nitrogen remediation with bioreactors in context of a suite of nutrient-removing best management practices water quality challenges in the Chesapeake Bay watershed showed that bioreactors are a competitive option relative to other practices but that a lack of incentive to install them remains an obstacle (Rees et al., 2017). Analysis of data collected from the coupled sawdust wall/gypsum curtain and in-ditch stepped bioreactor nears completion and we anticipate publishing several journal articles to disseminate the findings in the coming year. Adaptation of woodchip bioreactors designed for use in conjunction with subsurface drainage (e.g. NRCS code 605) to the ditch drainage systems that dominate the region remains a challenge, but we have been testing design modifications and working toward design recommendations for ditch systems.

Impact Statements --- Station Reports

Georgia - *University of Georgia, Gary Hawkins*
Since this is a new project, there are no impacts to date.

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

At the ILICA Drainage School in fall 2016, Dr. Christianson presented a seminar on a variety of practices shown in Fig. 3, and an additional in-depth seminar on bioreactors. While there was a general improvement in knowledge for most practices we discussed, the additional education for bioreactors provided the most notable change in knowledge (Fig. 3). Our program is looking forward to new funding which will expand our capacity to do field studies on and outreach about bioreactors, controlled drainage, and saturated buffers starting in 2017.

Another impact of our Extension efforts is the recent release of the "*Ten Ways to Reduce Nitrogen Loads from Drained Cropland in the Midwest*" booklet (freely downloadable: http://go.aces.illinois.edu/TenWays). This regional collaboration booklet has been electronically accessed more than 1,300 times since its release in September 2016, and has been widely distributed to Extension educators, conservation professionals, state and federal agency staff, and Hypoxia Task Force members.

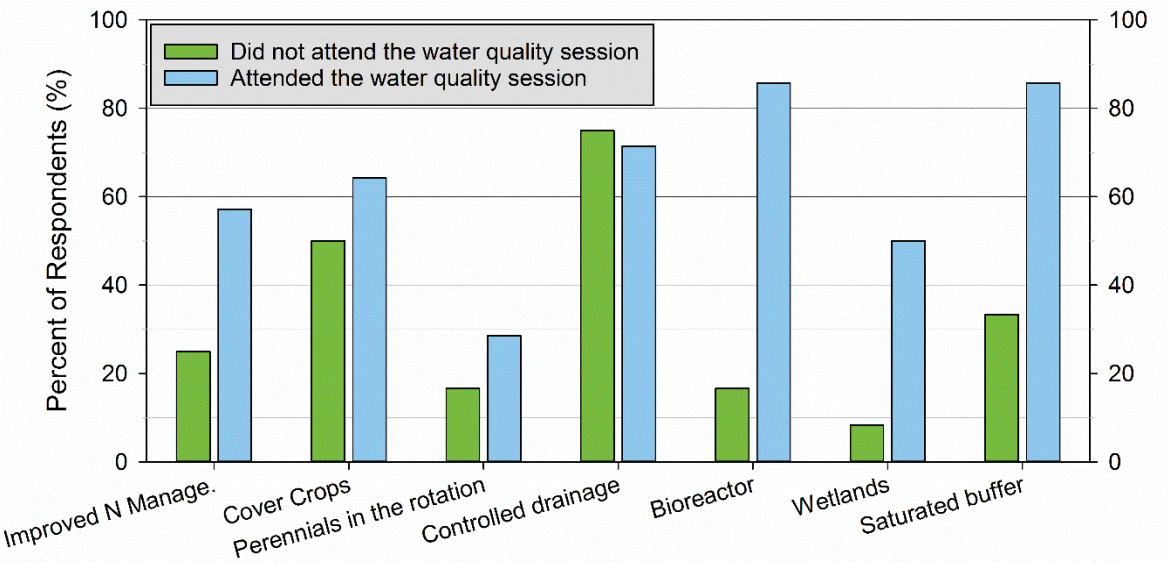

Fig. 3. Illinois Land Improvement Contractors Association Drainage School attendees' survey results for: "*Check the practices which you think have the most potential to improve water quality (check all that apply)".* Dr. L. Christianson presented a 1 h overview on these practices and others plus an additional 1 h seminar focused on bioreactors.

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

The Transforming Drainage team, which includes numerous NCERA-217 participants, has brought together agronomic, soil, hydrologic, water quality, and weather data at 16 experimental sites in 8 states, to quantify the impacts of the three drainage storage practices addressed in the project (controlled drainage, saturated buffers, and drainage water recycling). The database framework that has been developed for managing experimental data will support coordinated synthesis and modeling of drainage storage approaches. It includes 34 experimental drainage sites across 8 states representing 186 site-years of data and containing 85 field measurement, 91 field management, and 25 weather data types to allow for characterization of production and water quality impacts across drainage water storage practices. We launched the website, http://transformingdrainage.org, to serve as portal for drainage stakeholders and the general public to access project updates and information and interact with products and materials.

The 10th International Drainage Symposium, led by numerous NCERA 217 members, brought together 249 attendees from 10 countries to advance drainage innovations. The broad international participation generated renewed recognition of the similarities of drainage issues around the world, and new insight into potential solutions being developed. Of those who filled out the post-Symposium survey, 100% agreed or strongly agreed that "*The Symposium was a valuable experience for me*." and "*Interactions with others at the Symposium will benefit me*." The record-setting attendance and high-quality presentations have led to new knowledge and collaborations, both within the U.S. and internationally.

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 results from Iowa is important for gaining confidence of these stakeholders. We continue to assist with subsurface drainage bioreactor design throughout Iowa.

In 2016, we completed the 10th Iowa Drainage School. This program is a collaboration of Greg Brenneman, Kapil Arora, and myself (Matt Helmers). Three hundred thirty-five participants, consisting of contractors, engineers, drainage planners, landowners, farmers, agency staff, and drainage district supervisors, have attended the school. These individuals have come from all over the Midwest along with participants from Canada and Mexico. In 2016, Kapil Arora led the development of a Qualtrics survey to determine what students learned in the school, how they have used this knowledge, and how they have applied what they learned in the drainage school. As a result of the training in the school, 45% of the respondents indicated an increase in number of clients they served, 35% of the respondents indicated hiring additional staff, and 39% indicated purchasing additional equipment to manage the additional work acquired. Respondents reported developing a per year average of 373 drainage designs with an average project size of 312 acres and subsequently making improved drainage decisions on approximately 51,000 acres annually. Sixty-three percent of the designs developed by the respondents used knowledge gained from the school in including sizing of laterals and mains, depths of installation, outlet sizing, inclusion of a drainage coefficient, and use of lateral spacing taught in the school. Respondents reported that approximately two-thirds of the designs they developed actually are implemented, indicating that the operationalization of the research results is improving the conditions of drainage in Iowa.

Iowa - *USDA ARS, Dan Jaynes*

This saturated buffer 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” for the practice. A new initiative was also signed by Secretary Vilsack this past fall allowing saturated buffers to be installed on CRP buffers.

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. Following broad scale validation across landscapes the tool could help inform user-friendly tools such as the P-index and nutrient tracking tool (NTT).

Michigan - *Michigan State University, Ehsan Ghane*

We have educated farmers and agency personnel on how to use controlled drainage to improve water quality at county level and statewide workshops. The first workshop took place in Clinton County, and the second one was a statewide workshop as part of the Michigan Chapter of Soil and Water Conservation Society. The drainage water management workshop in Clinton County has led to potential partnership between MSU and a farmer who is interested in implementing the practice. We have visited the farmer’ field, and we are currently evaluating the suitability of his farm for monitoring.

Minnesota - *University of Minnesota, Gary Sands*

- International collaboration resulting from the 10th International Drainage Symposium (IDS). Many spin-off conversations, ideas, and initiatives were reported.
- 2 full-day field tours as part of the 10th IDS brought international participants together with regional and local stakeholders and practitioners
- Approximately 50 drainage practitioners were exposed to conservation drainage design through University of Minnesota’s annual Extension Drainage Design Workshop.

Minnesota - *USDA ARS, Gary Feyereisen*

The laboratory denitrifying bioreactor research results have informed the hypotheses being tested at the field scale. The publicity the field sites have generated is increasing awareness among the various stakeholder groups about treatment options for drainage effluent.

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

1. The development of the DRAINMOD-based tools for estimating the annual reductions in flow and nitrogen losses resulting from the implementation of drainage water management is a very important accomplishment since these tools are easy to use and do not require inputs that are difficult to obtain. These tools were developed for use with nitrogen credit trading that involves drainage water management. The tool, however, can have other uses. Testing of these tools by comparing their estimates of annual drainage flow and N losses to field measured data at several locations within the U.S. Midwest is needed before using the tools to make predictions.
2. 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.
3. The results of our research have shown that both controlled drainage and bioreactor 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.
4. Our research on the effect of controlled drainage and drainage water recycling on crop yield could lead to large-scale adoption of these practices.

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

NDSU is part of the large USDA NIFA 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 ND Soybean Grower Association supported this project with focus on water quality assessment. A NASA Water Program funded project is focusing on soil moisture and snow runoff difference for fields with and without tile drainage. All these projects will improve our overall understanding of tile drainage impacts on our environment.

Contributed to two listening sessions organized and attended by Representatives Colin Peterson (MN) and Kevin Cramer (ND) to examine drainage issues in the Red River Valley. South Dakota Representative, Kristi Noem, and Glenn Thompson (PA), chair of the house Conservation and Forestry subcommittee, also attended the first listening session. Contributed to an educational meeting for ND legislators on the topic of subsurface drainage. Contributed to changes made to ND drainage law regarding the permitting and installation of tile systems.

New York - *Cornell University, Larry Geohring*

Stakeholders have become more aware of the benefits of utilizing denitrifying bioreactors and drainage water management to reduce water quality impacts to receiving watersheds. The applied research and demonstrations on farms and the adoption of a Conservation Practice Standard by NY-NRCS has generated more interest by farmers to evaluate their drainage water quality and what practices they may need to use to address nutrient loss concerns.

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

The different field demonstration studies being conducted continue to:

- Inform producers for potential implementation in their operations on selection of drainage conservation practices (i.e. saturated buffers, woodchip bioreactors, phosphorus adsorption bed, controlled drainage, and nitrogen stabilizer) that can be used to reduce nutrient losses without sacrificing yield,
- Provide drainage design recommendations for South Dakota producers to help maximize the economic benefits of production while decreasing potential negative environmental impacts,
- Improve stakeholder understanding of drainage and associated conservation practices to support qualified assessment of the effects of subsurface drainage on water quality in the state.

Virginia - *Virginia Tech, Zach Easton*

Working closely with conservation personnel and producers, we have demonstrated the effectiveness of comprehensive drainage and ditch management systems on the Coastal Plain of Virginia and Maryland and closely coupled this research to educational activities, described above, aimed at producers, drainage districts, and conservation personnel. Through these educational activities, we have raised the prominence of drainage management as an important consideration/strategy for meeting water quality goals in the region and emphasized that climate change is expected to both increase the need for drainage and exacerbate the impact of drainage on water quality. Our economic analysis of denitrifying bioreactors provides a basis for drainage managers to evaluate the comparative merits to conventional alternatives.

Publications --- Station Reports

Peer-reviewed publications

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3. Basche, A.D., T.C. Kaspar, S. Archontoulis, D.B. Jaynes, T.J. Sauer, T.B. Parkin, and F. Miguez. 2016. Soil water improvements with the long-term use of a winter rye cover crop. *Ag. Water Management* 172:40-50. doi: 10.1016/j.agwat.2016.04.006.
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13. Ghane, E., G.W. Feyereisen, and C.J. Rosen. 2016. Non-linear hydraulic properties of woodchips necessary to design denitrification beds. *J. Hydrol*. 542:463-473.
14. Golmohammadi, G., S.O. Prasher, A. Madani, R. P. Rudra, M.A. Youssef. 2016. SWATDRAIN, a new model to simulate the hydrology of agricultural lands, model development and evaluation. *Biosystems Eng.* 141:31-47.
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Non-peer-reviewed publications and conference presentations/abstracts

1. Allen, A., A. Collick, E. Bock, L. Christianson, R. Bryant, P. Kleinman, A. Buda, E. May, T. Rosen, F. Hashem, and Z. Easton. 2016. Evaluating edge-of-field and in-ditch stratagems to reduce nutrient losses in the Mid-Atlantic Region. ASA, CSSA, & SSSA International Annual Meetings. Phoenix, Arizona. 6-9 November 2016.

2. Bailey, S. Bianca, L. Christianson, and R. Cooke. 2016. Mitigating phosphorus loss with drainage control structure sorption filters. International Drainage Symposium. Minneapolis, Minnesota. 9-11 September 2016.
3. Bock, E., G. DeBoe, K. Stephenson, and Z. Easton. Opportunities and challenges for denitrifying bioreactors in the Mid-Atlantic. 2017. Poster presentation delivered at NCERA-217 and ADMS Task Force Annual Meeting, Champaign, IL, 28-29 March.
4. Bock, E., J. Faulkner, and Z.M. Easton. Climate change adaptation for agriculture: Mitigating short- and long-term impacts of climate on crop production. 2016. Resilient Virginia Conference. Richmond, VA, 22-23 Aug.
5. Boler, J.L., C. Yang, C. Xie, and Sands G.R. 2016. Measuring crop response to subsurface drainage with satellite remote sensing. Presented at the ASABE 10th International Drainage Symposium, Minneapolis, September 7-9, 2016.
6. Bowling, L.C., and E.J. Kladivko. 2016. Trend analysis of the SEPAC 30 year drainage climatology. Proc. 10th International Drainage Symp., Sept. 7-9, 2016, Minneapolis, MN. doi:10.13031/ids.20162515027.
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8. Christianson, L., R. Bryant, P. Kleinman, A. Allen, A. Collick, A. Buda, E. May, E. Bock, and Z. Easton. 2016. In-ditch, stepped denitrifying bioreactor for treatment of agricultural ditch drainage. ASABE Annual International Meeting. Orlando, Florida. 17-20 July 2016. Paper #162458188.
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23. Tahmasebi, M., X. Jia, and X. Chu. 2016. Modeling of subsurface drainage under varying micro-topographic, soil and rainfall conditions. 10th International Drainage Symposium. Minneapolis, MN. September 7-9, 2016. Paper No. 162499952.
24. Talbot, M.T. and G.R. Sands. 2016. Predictions of evapotranspiration for corn as impacted by the effective rooting depth in DRAINMOD. Presented at the ASABE 10th International Drainage Symposium, Minneapolis, September 7-9, 2016.
25. Tuttle, S., E. Cho, C. Vuyovich, X. Jia, P. Restrepo, B. Connelly, M. DeWeese, S. Buan, M. Cosh, and J. Jacobs. 2016. Satellite enhanced snowmelt flood prediction in the Red River of the North Basin. Town hall meeting with landowners along the Grand Forks flight line. Grand Forks, ND. December 5, 2016. Presentation by Jia.
26. Wesslak, R.,K.A. Nelson, P. Motavalli, and C. Dudenhoeffer. 2016. Subsurface drain tile spacing affects yield variability of corn in a claypan soil. Abstract ASA-CSSA-SSSA. Online.
27. Wesslak, R.N., K.A. Nelson, and C.J. Dudenhoeffer. 2016. Spatial response of corn yields to drainage and subirrigation tile spacings in a claypan soil. Presented at the ASABE 10th International Drainage Symposium, Minneapolis, September 7-9, 2016.

Extension and outreach presentations and publications

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

1. Christianson, L and H. Dougherty. 2016. The Extension Connection: Your perceptions of nitrate loss reduction practices for drainage – Results from the 2016 ILICA Drainage Workshop Survey. Illinois Land Improvement Contractors Association (IL LICA) bi-monthly newsletter (Nov/Dec 2016 issue).
2. Christianson, L. 2016. North Central Region Water Network Leadership Column (September 2016 Newsletter): Nitrogen in tile drainage: No silver bullets, but perhaps some silver buckshot.

http://campaign.r20.constantcontact.com/render?m=1108940524026&ca=a4d4fa9b-f3a4-4ee8-82cc-8d114f15c12b.

3. *FACTSHEET*: Christianson, L. 2016. Nutrient loss reduction: Using science to find the right practices for your field. Illinois Extension and Illinois Water Resources Center (4-pg factsheet). Available at: http://go.illinois.edu/UseScience.
4. *REGIONAL BOOKLET*: Christianson, L., J. Frankenberger, C. Hay, M. Helmers, and G. Sands (Eds.). 2016. Ten ways to reduce nitrogen loads from drained cropland in the Midwest. Urbana, IL: Illinois Extension. (Open peer review). Available electronically: http://go.aces.illinois.edu/TenWays
5. Christianson, L. 2016. The Extension Connection: New Multi-State "Transforming Drainage" Project Envisions the Future of Drainage. Illinois Land Improvement Contractors Association (IL LICA) bi-monthly newsletter (Sept/Oct 2016 issue).
6. Christianson, L. 2016. Woodchip bioreactors: Biological nitrogen removal for cleaning agricultural runoff. Engineers Ireland ejournal. Published online 26 July 2016. Available at: http://www.engineersjournal.ie/2016/07/26/woodchip-bioreactor-biological-nitrogen-removal/.
7. Christianson, L. 2016. Reducing water pollution with microbes and wood chips. The Conversation: Online publication for scientists (06 July 2016). Available at: https://theconversation.com/reducing-water-pollution-with-microbes-and-wood-chips-58852.
8. Christianson, L. 2016. Bioreactors: Science, not magic. Wallace's Farmer of Iowa (June 2016 issue). Available at: http://magissues.farmprogress.com/WAL/WF06Jun16/wal029.pdf.
9. Christianson, L. 2016. The Extension Connection: Evaluating 50+ years of drainage research: Looking backward can help point the way forward. Illinois Land Improvement Contractors Association (IL LICA) bi-monthly newsletter (Jan/Feb 2016 issue).
10. Cooke, R. A. C. 2016. The Extension Connection: LiDAR and the Design of Drainage Systems. Illinois Land Improvement Contractors Association (IL LICA) bi-monthly newsletter (May/June 2016 issue).
11. Cooke, R. A. C. 2016. The Extension Connection: A Procedure for Thinning and Extracting Elevation Data from LiDAR Maps. Illinois Land Improvement Contractors Association (IL LICA) bi-monthly newsletter (July/Aug 2016 issue).
12. Christianson, Laura. 2016. Choose your own adventure: 10 ways to reduce nitrate loss in tile drainage. Bradley University Osher Lifelong Learning Institute. Peoria, Illinois. 19 October 2016. ≈15 in attendance.
13. Christianson, Laura. 2016. Selecting nitrate loss reduction practices. 2016 Iowa Watershed Academy. Ames, Iowa. 23-24 May 2016. ≈30 in attendance.
14. Christianson, L. 2016. Reducing tile drainage nutrient loss: Using science to clean up our water. 'Raise the Grade" 2016 Upper Mississippi River Conference. Moline, IL. 13-14 October 2016. ≈50 in attendance.
15. Davidson, P., J. Coppess, and L. Christianson. 2016. #AskACES live Twitter chat and Podcast. 27 September 2016.
16. Christianson, L. 2016. Drainage Water Management. Illinois Nutrient Strategy Ag Water Quality Partnerships Committee. Springfield, IL.17 May 2016. ≈30 in attendance.
17. Christianson, L. 2016. Bioreactors. Illinois Farm Bureau Annual Governmental Affairs Leadership Conference. Springfield, IL.06 April 2016. ≈60 in attendance.
18. Christianson, L. 2016. Energy and Environment, Local Food and Small Farms, and Commercial Ag Teams In-Service Training: Water Quality and Illinois Agriculture. Urbana, IL 15 November 2016. ≈30 in attendance.

19. Christianson, L. 2016. IL Nutrient Loss Reduction Strategy. Cover Crops and Nutrient Management Field Day. Stockton, IL 16 September 2016. ≈23 in attendance.
20. Christianson, L. 2016. IL Nutrient Loss Reduction Strategy (Phosphorus loss). Apple Canyon Lake watershed group dinner. Apple River, Illinois. 15 September 2016. ≈23 in attendance.
21. Christianson, L. 2016. Illinois Nutrient Loss Reduction Strategy. Illinois State Fair Illinois Department of Agriculture tent. Springfield, Illinois. 21 August 2016. ≈50 present.
22. Pittelkow, C. L. Christianson, and R. Bhattarai. Project Update. Dudley Smith Farm Field Day. Pana, Illinois. 19 August 2016. ≈30 in attendance.
23. Christianson, L. 2016. Nutrient Loss Reduction Strategy. ILICA Drainage Contractors School. Decatur, IL. 2-4 August 2016. ≈30 in attendance.
24. Christianson, L. 2016. Bioreactors. Drainage Contractors School. Decatur, IL. 2-4 August 2016. ≈30 in attendance.
25. Christianson, L. Monmouth Research Farm 35th Annual Field Day. Illinois Nutrient Loss Reduction Strategy Practices: Every field needs at least one! 15 July 2016. ≈50 in attendance.
26. Pittelkow, C. L. Christianson, and R. Bhattarai. Dudley Smith Farm Field Day. Pana, Illinois. 15 June 2016. ≈50 in attendance.
27. Christianson, Laura. 2016. Don't be a Black-Eyed P: How to Reduce P Loss from Fields. Illinois Soybean Association Webinar Series. Urbana, IL.15 March 2016. Live participants: 63.

Iowa - *Iowa State University, Matthew Helmers*

28. Iowa Drainage School: August 23-25, 2016 – Coordinated with Kapil Arora and Greg Brenneman. There were 45 attendees consisting of drainage contractors, drainage sales people, and county agency representatives from Iowa, South Dakota, North Dakota, Wisconsin, and Minnesota.
29. December 15, 2016 – Presentation on “Bioreactor design” at Drainage Design Workshop near Fort Dodge, IA (35 attendees)
30. December 9, 2016 – Presentation on “Extending field-scale 4R nutrient management and wetland performance to watershed scale outcomes” at the Iowa Drainage District Association Annual Meeting in Fort Dodge, IA (85 attendees)
31. December 1, 2016 – Presentation on “Drainage design for improved profits and water quality” at the Integrated Crop Management Conference in Ames, IA (155 attendees)
32. November 30, 2016 – Presentation on “Extending field-scale 4R nutrient management and wetland performance to watershed scale outcomes” at the Integrated Crop Management Conference in Ames, IA (145 attendees)
33. November 3, 2016 – Presentation on “Reducing nitrate loss: Scale of practice implementation needed” at North Central Soil Fertility Conference Ames, IA (135 attendees)
34. November 1, 2016 – Presentation on “Soil Loss and Drainage” at the Water Rocks! Multi-state Summit in Ames, IA (60 attendees)
35. October 19, 2016 _Presentation on “Myths and misconceptions of drainage” Iowa Learning Farm webinar (40 live attendees)
36. August 26, 2016 – Presentation on “Practices for nitrate-N reduction” at Northeast Research and Demonstration Farm 40th Anniversary Field Day near Nashua, IA (85 attendees)
37. August 15, 2016 – Presentation on “Nutrient reduction of perennial biomass crops” to Biofuels group near Ames, IA (20 attendees)
38. August 8, 2016 – Presentation on “Practices for nitrate-N reduction” at Agribusiness Association of Iowa summer field day near Ames, IA (45 attendees)
39. July 29, 2016 – Rainfall simulator demonstration for Ragbrai near Washington, IA (50 attendees)
40. July 28, 2016 – Presentation on “Scale of implementation for Iowa Nutrient Reduction Strategy” at Iowa Learning Farm Field Day near Fort Dodge, IA (35 attendees)

41. July 26, 2016 – Presentation on "Nitrate-N reduction practices" to Agronomy Distance Masters Program (35 attendees)
42. July 14, 2016 – Presentation on "In-field nitrogen management" at ISG Group Drainage Water Quality Workshop in Clear Lake, IA (25 attendees)
43. July 13, 2016 – Presentation on "Practices for nitrate-N reduction" at Northwest Research and Demonstration Farm Summer Field Day near Sutherland, IA (75 attendees)
44. June 29, 2016 – Presentation on "Practices for nitrate-N reduction" at Northeast Research and Demonstration Farm Legislature Tour near Nashua, IA (35 attendees)
45. June 28, 2016 – Presentation on "Practices for nitrate-N reduction" at Northeast Research and Demonstration Farm summer field day near Nashua, IA (85 attendees)
46. June 24, 2016 – Presentation on "Prairie strips for water quality protection" to Heartland Cooperative Young Leaders in Prairie City, IA (25 attendees)
47. June 14 and 21, 2016 – Presentation on "Soil Loss and Drainage" at the Water Rocks! Teacher Summit in Ames, IA (60 attendees)
48. June 14, 2016 – Presentation on "Nitrate-N reduction practices in the drained landscape" at the Ag Credit School in Ames, IA (55 attendees)
49. June 8, 2016 – Presentation on "Scale of implementation for Iowa Nutrient Reduction Strategy" at Iowa Learning Farm Field Day in Gilmore City, IA (35 attendees)
50. May 17, 2016 – Presentation on "Reducing nitrate loss: Scale of practice implementation needed" at McClure Engineering meetings in Sheldon and Sioux City, IA (25 attendees)
51. April 17, 2016 – Presentation on "Nutrient Reduction in Iowa" at League of Women's Voters meeting in Sioux City, IA (20 attendees)
52. November 2, 2016 – Panel presentation on state level nutrient reduction strategies at ANPC summit in Bentonville, AR (35 attendees)

Iowa - *USDA ARS, Dan Jaynes*

53. Toured the members of the National Association of State Conservation Agencies around a potential new saturated buffer site in Polk Co., IA on Apr., 27, 2016. 30 in attendance.
54. Consulted with representatives of NRCS and FSA on Saturated Buffers as a nitrate removal practice, 20 May, 2016.
55. Consulted with representatives of Deere Company on improving fertilizer use efforts and discussion on regulatory expectations, 19 July, 2016.
56. Conducted field day on saturated buffers, Oelwein, IA, on 4 Aug., 2016, 45 in attendance.
57. Attended and gave presentation on Saturated Buffers at the 10th International Drainage Symposium, Minneapolis, MN, 6-8 Sept. 2016.
58. Gave tour of Saturated Buffer in North Field, MN, 9 Sept., 2016, 50 scientists and agency representatives from the US, Canada, and Europe.
59. Article on our work with Saturated Buffers highlighted in an article by Donnelle Eller in the Des Moines Register, 14 Sept., 2016.
60. Interviewed on our work with Saturated Buffers for an article by Sherry Shifflet in the Farm Journal, 3 Oct., 2016
61. Presented "Designing Saturated Buffers" at the Drainage Water Quality Practices Design Workshop. Ft. Dodge, IA. December 15, 2016, 30 NRCS, watershed coordinators, and land improvement contractors in attendance.

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

62. *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*

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

Minnesota - *USDA ARS, Gary Feyereisen*

64. Presentation: Feyereisen, G., S. Matteson, and W. VanRyswyk. 2016. Faribault County Ditch 62 Bioreactor: A monitoring and research plan. Faribault County Drainage Authority Board Meeting. 5 April 2016.
65. Co-organized and conducted tour of Gorans Farm bioreactor installation for state agency personnel, producers, and researchers. Willmar, MN, 2 June 2016.
66. Participated in field tour of Faribault County bioreactors held for local producers, district and state agency personnel. Blue Earth, MN, 10 August 2016.
67. Interviewed and filmed for University of Minnesota: Field-scale bioreactors for the remediation of agricultural runoff. Posted 31 August 2016. https://mndrive.umn.edu/environment/news/mndrive-bioremediation-initiative-supports-field-scale-demonstration-projects
68. Co-organized field tour of Faribault County bioreactors held in conjunction with the 10th International Drainage Symposium for international and U.S. researchers, state, regional and local agency personnel. Blue Earth, MN, 9 September 2016.
69. Co-organized and led "Where City Meets the Farm" field tour of flood peak control, urban and agricultural drainage, and bioreactor research sites held in conjunction with the 10th International Drainage Symposium for international and U.S. researchers, state, regional and local agency personnel. Willmar, MN, 9 August 2016.
70. Interviewed and filmed (November 2016) for TV Documentary: Plunging through the ice to clear water. Broadcast 9 April 2017. http://www.pioneer.org/season-8.html.

Virginia - *Virginia Tech, Zach Easton*

71. Easton, Z.M., A.S. Collick and E.M. Bock. 2017. What to consider when considering an agricultural drainage system. BSE-208.
72. Easton, Z.M. and E.M. Bock. 2016. Soil and Soil Water Relationships. BSE-194P.
73. Easton, Z.M. and J.W. Faulkner. 2014. Climate change adaptation: Mitigating short and long-term impacts of climate on agriculture. BSE-109P.
74. Faulkner, J.W. and Z.M. Easton. 2014. Agricultural adaptation to climate change: improving resilience in row crop production. University of Vermont Extension.
75. Easton, Z.M., E.M. Bock, A.S. Collick, A. Allen, P. Kleinman, R. Bryant. NRCS Ag Water Management and Drainage Mid Atlantic Tour. June 2016. Tour of 7 current ag water management installation in DE, MD and VA developed under the CIG project. 29 participants over a 3-day period.
76. Collick, A.S., E. Bock, Z.M. Easton, A. Allen, R. Bryant, T. Rosen, L. Christianson, P. Kleinman. Comprehensive drainage management approach to reduce nutrients in agricultural drainage ditches: Mid-Atlantic Region. 2016. Mid Atlantic Crop School, Ocean City, MD. Nov 2016.
77. Collick, A.S., A. Allen, R. Bryant. How to reduce nutrient loss from tile and ditch drained agricultural fields. 2016. Agriculture Field Days at University of Maryland Eastern Shore (UMES), Princess Anne, MD. Sept. 2016.