Minutes of NCERA217: Drainage Design and Management Practices to Improve Water Quality Annual Meeting and NCERA217 Station Reports

Annual Meeting: March 29-30, 2016, at the Stewart Center on the Purdue University campus, West Lafayette, IN.

NCERA217 Meeting Overview

The 2016 NCERA217 Annual Meeting was held March 29-30, 2016, 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 Transforming Drainage project followed the NCERA217 and ADMS/ADMC meetings. The report below documents the NCERA217 annual business meeting, actual meeting presentations, and the accomplishments, impacts, and written/oral communications produced by committee members the past year.

Members Present: Ramesh Kanwar (IA; Advisor), Jane Frankenberger (IN), Eileen Kladivko (IN), Larry Goehring (NY), Tim Harrigan, (MI), Gary Sands (MN), Jeff Strock (MN), Matt Helmers (IA), Laurent Ahiablame (SD), Christopher Hay (SD), Xinhua Jia (ND), Dan Jaynes (IA), Kelly Nelson (MO), Laura Christianson (IL), Richard Cooke (IL), Jeppe Kjaersgaard (SD) , Mohamed Youssef (NC), Barry Alred (OH), Larry Brown (OH), and Gary Feyereisen (MN).

Guests present: There were an additional 58 guests present during the meeting.

NCERA 217 Business Meeting

The NCERA217 business meeting was called to order at 8:05 a.m. on Tuesday, March 29, 2016, by Chair Jeppe Kjaersgaard.

1. Chair Kjaersgaard welcomed the group and directed the meeting through the following planned agenda.
2. Approval of minutes from the 2015 minutes. Eileen Kladivko moved (Kelly Nelson second) that the 2015 minutes be approved as written and sent to members prior to this meeting. Motion carried.
3. Advisor's report – Ramesh Kanwar. Dr. Kanwar stated that minutes from this meeting are due May 29, 2016. Additionally, this year marks the mid-term review of NCERA217, which requires that another report be filed by December 15, 2016. The mid-term review is a USDA-NIFA requirement to ensure that its –ERA groups are meeting regularly and showing impact from their work. Dr. Kanwar mentioned that this group will have no problem demonstrating impact, listing key items such as organization of the 10th International Drainage Symposium, executing the multi-state Transforming Drainage project, completing the States' reports, and holding regular annual meetings in conjunction with the Agricultural Drainage Management Systems – Task Force. This strong list of accomplishments puts NCERA217 in the top few committees of its kind.
4. Old Business
    a. Follow up on 2015 item: Gary Sands and Dan Jaynes have been leading a small subcommittee to write a 2-page document for application for an Experiment Station Director's Award of Excellence. The work is in progress.

b. Impact Summary 2009 – 14. Last year a nice two-page brochure was written of the last 5 years of accomplishments of NCERA217. Documentation of accomplishments of all –ERA groups is required, but only a quarter or so of the projects are chosen for the complete write-up, which is done with the aid of a professional technical writer.
c. Chair Kjaersgaard recognized and thanked several NCERA217 members who spoke at last year's Agronomy Society of America annual meeting at a symposium organized by the Managing Denitrification in Agronomic Systems Community: Drs. Frankenberger, Nelson, Jia, and Helmers.

5. Upcoming Activities
   a. A special section of peer-reviewed journal articles on bioreactors, "Moving denitrifying bioreactors beyond proof of concept," for which Laura Christianson served as editor, was just published in the Journal of Environmental Quality (JEQ), Volume 45 Issue 3: https://dl.sciencesocieties.org/publications/jeq/tocs/45/3#h1-SPECIAL SECTION: MOVING DENITRIFYING BIOREACTORS BEYOND PROOF OF CONCEPT
   b. International Drainage Symposium – September 7 – 9, 2016. Jane Frankenberger gave a brief overview of the agenda. Gary Sands reported there are 111 presentation submissions to date; approximately ¾ of them are from the U.S., but ≈12 countries are represented. Attendees will be able to select, for no additional cost, one of two exciting tours to be conducted the third day of the Symposium.
   c. Transforming Draining Project. Jane Frankenberger gave an update on this project, which involves a number of committee members. Ben Reinhardt was introduced to the group as the new Project Manager.
6. Other Items. A publication is in the ideation stage covering the topic of how to manage controlled drainage flashboards. Norm Fausey is looking for interested co-authors. A comment was made that special consideration needs to be made for cold regions, i.e. Minnesota and North Dakota, where deep frost can create problems with control structures.
7. Election of Vice Chair. Chair Kjaersgaard opened nominations. Eileen Kladivko nominated Laura Christianson. Nominations were closed. Laura Christianson was elected Vice Chair. She will serve as Secretary for 2016 and assume the Chair at the conclusion of her Secretary duties after the 2017 Annual Meeting.
8. After a brief discussion of a meeting location and date for next year's Annual Meeting, Illinois was put forth as a best place given its central location and the fact that it has been several years since the meeting was held there. The decision was made to hold the 2017 NCERA217 Annual Meeting in Illinois. The dates established were Tuesday and Wednesday, March 28 – 29, 2017. The meeting will likely include the ADMS/ADMC meeting and an extra day for a Transforming Drainage project meeting.

The business meeting was adjourned at 8:40 a.m.

Respectfully submitted,

Gary Feyereisen, Secretary

NCERA217 Meeting Presentations

Chair Jeppe Kjaersgaard opened the NCERA217 Annual Meeting at 9:00 a.m. on Tuesday, March 29, 2016. Members and attendees introduced themselves. Chair Kjaersgaard moderated the morning session devoted to drainage research and the afternoon session on drainage management implementation. Chris Hay gave an overview of the extensive Iowa Soybean Association 2015 tile monitoring program. Jeppe Kjaersgaard presented a drainage water management and water storage project in the south end of the Red River Valley. Xinhua Jia talked about the challenges of optimizing water management, including drainage and subirrigation, in the Red River Valley. Laura Bowling discussed various drainage conservation practices installed in Indiana at field and small watershed scales. Kelly Nelson gave an update on the progress of drainage research sites in Missouri. Dan Jaynes reported results from cover crop, bioreactor, and saturated buffer research at the National Lab for Agriculture and Environment. Larry Geohring discussed bioreactor research in progress in New York. Laura Christianson summarized and explained the meta-analysis completed for bioreactors, which was published in the JEQ special section on bioreactors.

The afternoon session, planned in collaboration with ADMS, began shortly after 1:00 p.m. with a review of NRCS drainage activities and standards development, given by Rob Sampson, NRCS. Dan Jaynes briefed the attendees on the progress and findings of the saturated buffer CIG project and how these findings are informing NRCS saturated buffer standard development. Norm Fausey moderated a couple of talks given by Mark Seger and Justin McBride (drainage practices in Ohio) and Ramesh Kanwar (corn response to excessive wetness) and then discussed the objectives of and recommendations for drainage water table management. Barry Allred, USDA-ARS, spoke of the benefits of recycling agricultural water through subirrigation under future climate scenarios. Rob Sampson talked about practice standards with respect to storage. Four NRCS State Engineers, Bruce Atherton, Beth Clarizia, Anna Bramblett, and Ruth Book, gave updates on funding policies in their states for storage ponds. Charlie Schafer and Steve Baker gave an update of ADMC activities. Katie Flahive summarized USEPA goals and priorities. Eileen Kladivko led a brief discussion of experiences with roots growing into drains. Jane Frankenberger and Chris Hay reported on progress of the Transforming Drainage Project. Gary Sands briefed the group on the International Drainage Symposium, which is being held in Minneapolis, MN, September 7 – 9, 2016. Jane Frankenberger mentioned the place and date for next year's NCERA217, ADMS/ADMC, and Transforming Drainage Project meetings: Illinois, March 28 – 29, 2017.

The meeting adjourned at 5:00 p.m. to a reception and poster session (12) held in the adjacent Purdue Memorial Union.

Accomplishments – Station Reports

Georgia – Gary Hawkins, University of Georgia: Georgia's involvement in NCERA217 is just beginning. Funding has been received to install and gather initial data on tile drain water from blueberry production. Flumes have been ordered and will be installed and samples collected. A few proposals have been submitted to obtain additional fund for water sample analysis.

Illinois – Richard Cooke and Laura Christianson, University of Illinois: The release of the Illinois Nutrient Loss Reduction Strategy in the summer of 2015 created an opportunity for research and outreach about the drainage practices that reduce transport of nitrogen and phosphorus from Illinois fields. During 2015, University of Illinois research evaluated watershed-scale drainage water quality impacts (David et al., 2015; Li et al., 2015; Verma et al., 2015), and the university continued to be a leader in woodchip bioreactor research (Bell et al., 2015; Goodwin et al., 2015; Feyereisen and Christianson, 2015).

The David et al. (2015) study included a survey of farmers' perception of potential sources of water quality problems. Only a small proportion of respondents rated nitrogen (18.4%) or phosphorus (15.6%) as a problem (4 or 5 on a scale of 1 to 5). Two potential sources of problems, sediments (23.4%) and municipal discharge (22.4%), were rated higher. Approximately 16 to 20% of respondents indicated they did not know if the above sources were a problem for water quality. Neither drainage water management nor bioreactors were prominent on the list of water quality amelioration practices that the participants knew about or would try.

Illinois continues to push the envelope with woodchip bioreactor design and application, for example, by pairing P sorbing media in-line with woodchip bioreactors for removal of both P and N from drainage waters (Goodwin et al., 2015). We confirmed previous research findings that temperature and retention time are important for woodchip bioreactor nitrate removal (Bell et al., 2015). However, though we were able to increase the bioreactor temperature by 2^{o}C through passive solar heating, we were unable to determine the significance to bioreactor nitrate removal, because of errors introduced by nitrate stratification in control structures (Rendall, 2015).

The timing of Illinois' 2015 strategy release coincided with new research and extension capacity at the university with the hiring of Dr. Laura Christianson in the Crop Sciences Department. Her recent work has focused on understanding drainage water quality through large-scale data syntheses (Christianson and Harmel, 2015a and 2015b), as well as woodchip bioreactors, including where Feyereisen and Christianson (2015) updated the hydraulic conductivity of woodchips which is a critical design parameter.

Outreach activities in 2015 have included working with the Metropolitan Water Reclamation District of Greater Chicago to establish a research/demonstration site for several drainage-related BMPs, and designing and installing a combination drainage/subirrigation system on an urban farm in the Chicago suburb of Skokie.

Indiana – Jane Frankenberger and Eileen Kladivko, Purdue University: as Purdue University research is assessing the impact of tile drains of nitrate export at the field and watershed levels, and the potential impact of storing drainage water in the landscape through drainage water management and drainage water recycling. At our drainage water management research site at Davis Purdue Agricultural Center (DPAC), we collected continuous drain flow, soil moisture at five depths, water table depth measurements, and tile flow nitrate concentration, and found that drainage water management reduced flow and nitrate loads by approximately 30%.

We compared yield and soil moisture conditions in controlled and free-draining plots to gain a better understanding of the effect of drainage water management on crop yield. We found that late-season

soil moisture deficit and early-season excess soil moisture were indicators of yield reductions. Soil moisture excess that occurred early in the season, and deficit that occurred late in the season, had the highest correlation with yield. However, few significant differences were found in excess stress between free and controlled drainage, which explains the inconsistent yield benefits often found with controlled drainage.

A potential cause of yield reductions from drainage water management is excess water after rain events. We analyzed 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 used 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. At each pair, comparison of mean recession rate from the two fields indicated that controlled drainage reduced recession rate. The significance of the relationship between paired observations and the effect of controlled drainage was determined by paired watershed approach using the analysis of variance (ANOVA) and covariance (ANCOVA). 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.

We worked with researchers at Ohio State University, Michigan State University, and USDA-ARS to analyze the potential for increasing water storage on farm as a climate change adaptation strategy. We used historic yield data together with climate projections to estimate potential yield benefits that could be achieved by the Ohio WRSIS water recycling systems under expected future climate conditions. Growing season crop water deficit was quantified and categorized based on the 30-year record in the three locations, then used to assess the additional benefit under future climate conditions. We found that as growing season drought becomes more frequent, the crop yield benefits with agricultural water capture and subirrigation systems will improve, and these systems therefore provide a viable climate adaptation strategy for agricultural production. To gain understanding of the opportunities and barriers to on-farm water recycling in the Great Lakes region, we talked with drainage contractors, agency staff, farmers, Extension specialists, irrigation dealers, and farmers who have and have not installed on-farm water recycling. We have shared this information at drainage workshops and scientific conferences, and meetings, and are developing fact sheets describing these systems that provide information that will benefit producer and agency decision-making about this new and promising practice.

We led a team of researchers and educators across 9 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.

Iowa – Matt Helmers, Iowa State University: 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 2015 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 began new monitoring work in 2015 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 collaboration with colleagues at the University of Minnesota, the 16th IA-MN-SD Drainage Research Forum was held in November 2015 and was attended by approximately 85 stakeholders. In August 2015, 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 – Dan Jaynes, USDA-ARS-NLAE, Ames, IA: 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 distribution tile installed along the top of the buffer, we are diverting a fraction of the tile water into shallow ground water flow through the buffer. We hypothesis that both denitrification and sequestration processes known to be active in buffers will remove nitrate before it can enter the adjacent stream.

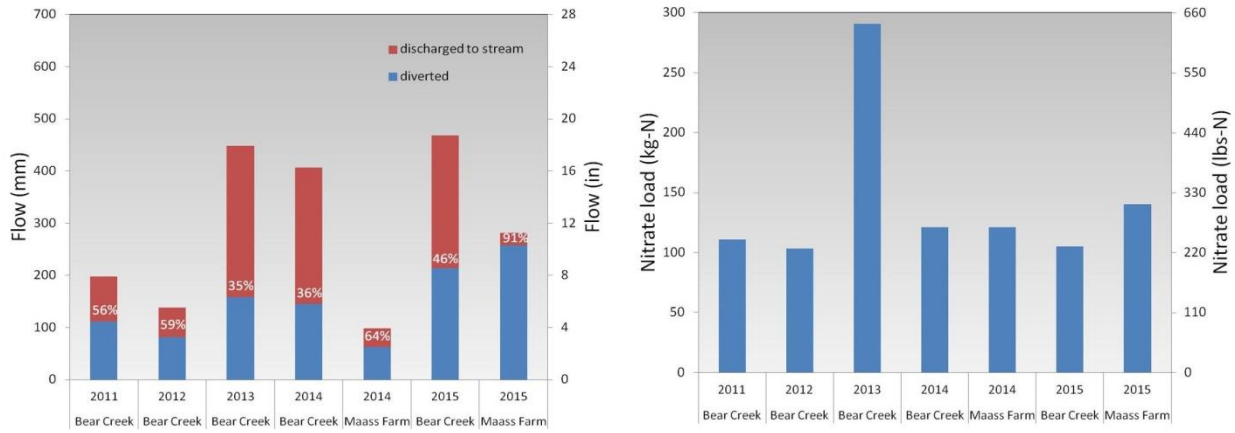

Figure 1. Flow into and nitrate removed at Bear Creek and Maass farm buffer from 2011 – 2015.

We have monitored performance of saturated buffers installed at Bear Creek and the Maass farm over the past year. These results, plus results from Bear Creek in previous years are shown above. We assume the nitrate loss is due to denitrification and are testing this assumption at several sites. Annual flow diversion into the buffers has ranged from 35 to 91% of the total tile-outlet discharge. Annual nitrate removal in the buffers has ranged from 100 to 290 kg-N. We will continue to monitor these sites plus new sites installed as part of the Iowa Water Quality Initiative. Final results from the Saturated Buffer CIG grant with ADMC have also been published. Major findings from this study were that: the

flow to buffer is difficult to measure; most sites appeared to be removing nitrate; saturated buffers do not consistently remove P; and proper siting of the saturated buffers is required for good performance.

Bioreactors. There is a general understanding in the scientific community as to how denitrifying bioreactors operate, but we lack a quantitative understanding of the details of the denitrification process acting within them and comprehensive models for simulating their performance. We hypothesized that nitrate transport through woodchip bioreactors would be best described by a dual porosity transport model where the bioreactor water is divided into a mobile domain (i.e., the water between the woodchips where it is free to flow and solute movement is by advection and dispersion) and an immobile domain of water (i.e., the water mostly within the woodchips that is stagnant and where solute movement is by diffusion alone).

We calibrated the dual-porosity model contained in the HYDRUS model for a woodchip bioreactor using the results of a Br breakthrough experiment where we treated Br as a conservative nonadsorbing tracer. We then used the resulting model parameters to describe 2 yr of NO3 transport and denitrification within a bioreactor supplied by tile drainage. The only model parameters fitted to the NO_3 data were either the zero- or first-order denitrification rate and its temperature dependence. The bioreactor denitrified 2.23 kg N (38%) of the NO_3 entering it in 2013 and 3.73 kg N (49%) of the NO_3 that entered it in 2014. The dual-porosity model fit the NO_3 data very well, with fitted zero-order reaction rates of 8.7 and 6.8 mg N L^{-1} d^{-1} in 2013 and 2014, respectively, and corresponding first-order reaction rates of 0.99 and 1.02 d^{-1}. For the 2-yr data set, both reaction rate models fit the data equally well. Consistent model parameters fitted for the 2 yr indicated that the model used was robust and a promising approach for modeling fate and transport of NO_3 in woodchip bioreactors.

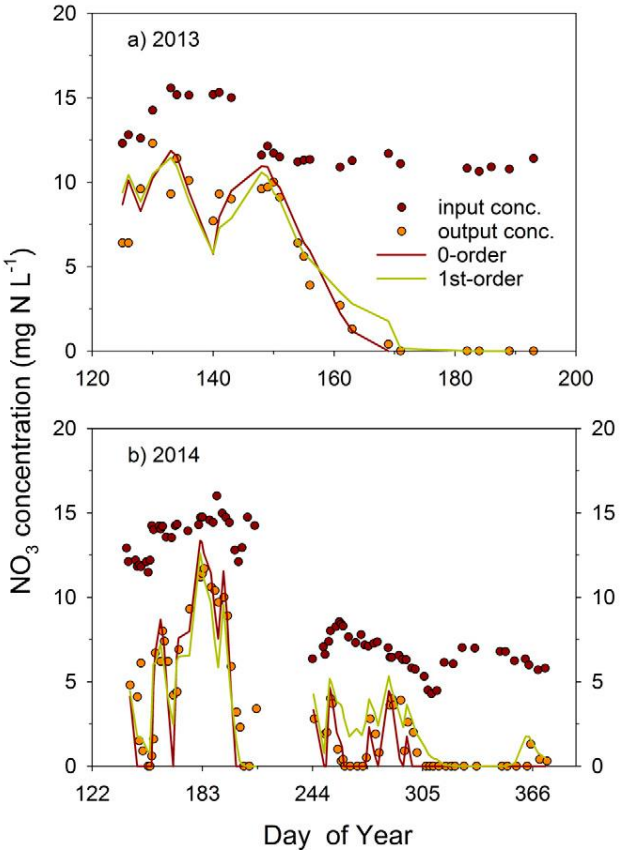

Figure 2. Measured NO3 concentration in input and output flow of bioreactor and best fitted zero- and first-order denitrification kinetics for HYDRUS simulations for (a) 2013 and (b) 2014.

Kelly Nelson – University of Missouri: Field research was initiated on claypan and silty clay (river bottom) soils to evaluate the impacts of managed drainage systems 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). Long-term crop production research is still evaluating integrated water management systems (2001-present) as well as corn response to drainage water management on claypan (2010-present) and river bottom (2010-present) soils. 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. Studies of N_2O loss due to water logged soil conditions, corn yield response in a river bottom soil, and N_2O and NH_3 loss from a subsurface drained claypan soil were completed during the period.

Poorly-drained claypan soils in the Midwestern United States experience periods of short-term soil saturation shortly after pre-plant N fertilization, which may result in relatively large amounts of soil surface N_2O emissions. Slowing the release or conversion of N fertilizer to soil NO_3 early in the growing season through the use of enhanced efficiency fertilizers (EEF) could be an effective strategy for reducing soil N_2O emissions and gaseous N loss during a period of relatively low plant N demand. This research determined the effects of short-term soil waterlogging and pre-plant applications of conventional and EEF on soil inorganic N and N_2O emissions during and up to four days following a waterlogging event during the dry down period. Waterlogging treatments were initiated at V6 corn. Main plots consisted of no waterlogging or water ponded 7 to 13 cm above the soil surface for three days, and sub-plot N fertilizer treatments [non-treated control (CO), or preplant broadcast applications of 168 kg N ha^{-1} of urea (NCU), urea plus nitrapyrin nitrification inhibitor (NCU+NI), and polymer coated urea (PCU)]. In 2012, greater cumulative soil N_2O-N emissions of 2.8 kg N_2O-N ha^{-1} were observed with PCU in comparison to NCU over the entire seven-day sampling period. A significant portion of cumulative soil N_2O emissions were associated with the four-day soil drying phase, where PCU and NCU+NI had greater emissions (1.9 and 1.2 kg N_2O-N ha-1) compared to NCU. The proportion of N fertilizer lost as N_2O-N averaged over all pre-plant N treatments during the 2012 and 2013 sampling periods in the non-waterlogged soils were 0.04% and 0.03%, and 1.1% and 2.6% in the waterlogged soils, respectively. This research suggests that a large proportion of the cumulative soil surface N_2O emissions typically observed in these poorly-drained soils over a growing season may occur during and shortly after soil waterlogging events.

Gaseous nitrogen (N) loss from denitrification and ammonia (NH_3) volatilization from poorly drained soils in corn production can be significant, diminish production, and lead farmers to apply a high rate of N. Nitrous oxide (N_2O), a greenhouse gas that is emitted during denitrification, has a high global warming potential that contributes to climate change. Reducing gaseous N loss from poorly drained soils through drainage and N management in corn production is essential to minimizing the environmental impact and maintaining high yields. This research determined how subsurface tile drainage and applications of polymer-coated urea (PCU) affected soil N_2O emissions and N fertilizer-induced NH_3 volatilization loss from a claypan soil. Drainage water management treatments consisted of conventional subsurface tile drainage, managed subsurface tile drainage, and no-drainage in combination with N fertilizer source (noncoated urea [NCU] and PCU). Subsurface drainage treatments did not affect cumulative soil N_2O emissions and NH_3 volatilization loss compared to no-drainage. Averaged over 2010 to 2013, cumulative soil N_2O emissions from PCU was 2% of applied N, and NCU was 4% of applied N. Yield-scaled soil N_2O emissions were reduced 53% with PCU compared to NCU. The percentage fertilizer loss from NH_3 volatilization was significantly ($p \leq 0.05$) reduced from 2.8% with NCU to 0.8% with PCU. These results suggest that use of PCU may assist in reducing cumulative losses of N_2O and NH_3 from poorly drained claypan soils, but drainage systems operating under this study's environmental conditions did not affect gaseous N losses.

Poorly drained soils located in Missouri river bottoms have not traditionally been tile drained due to high clay content in the surface soil layers and low overall soil hydraulic conductivity. A combination of increased land and corn grain prices along with increased variability and intensity of rainfall have stimulated interest in the region to utilize managed subsurface drainage (MD) to increase yields. This research evaluated the effect of subsurface tile drainage systems [no drainage (ND), free drainage (FD), and MD] and N fertilizer source (polymer-coated urea [PCU] or non-coated urea [NCU]) on corn yield in a poorly drained river bottom soil. Abnormally dry growing seasons in 2011 to 2013 likely limited N loss, plant N uptake, and the subsequent yield response to PCU and drainage. Applications of PCU did not impact corn yield regardless of the presence or absence of drainage. Increased corn yields with MD compared to FD were not observed over the 3-yr study. Subsurface drainage (FD or MD) increased yields up to 13% compared to ND in 2012. Poorly-drained river bottom soils in the Midwest typically have saturated soil conditions for an extended period of time after corn emergence regardless of whether high amounts of rainfall were received due to the low landscape position and temperature. The presence of drainage may have promoted deeper root development compared to ND and improved water use efficiency during the dry summer months which may explain the increased yield production with drainage in 2012.

Larry Geohring, Cornell University: Cornell University research is evaluating the effectiveness of using denitrifying bioreactors to reduce nitrate and phosphorus export from tile drained fields. Field research is currently being conducted on three dairy farms and one vegetable farm. Paired bioreactors, one containing woodchips and one containing woodchips amended with biochar, are being monitored on three of the farms. During the past year, we evaluated nine more potential locations for the construction of denitrifying bioreactors and have selected and surveyed two sites and developed preliminary bioreactor designs to implement at these sites. Experiments using lab-scale denitrifying bioreactors is also being done to determine and better understand the factors that control denitrification within the bioreactors (Pluer et al., 2016).

We made presentations and conducted training at several local, statewide, and regional meetings and workshops about the use and effectiveness of using denitrifying bioreactors, and about other drainage water management strategies to improve water quality. We collaborated with USDA-NRCS to review the draft denitrifying bioreactor standard for New York and have worked with the local Soil and Water Conservation Districts to further implement these practices on farms.

Mohamed Youssef, North Carolina State University: We have developed DRAINMOD-based tools for quantifying reductions in annual drainage flow and nitrate losses resulting from drainage water management on croplands in North Carolina and the U.S. Midwest. These tools utilize regression equations that are easy to use and require readily available input data. The tools can be used with nutrient credit trading markets that involve nitrogen reduction caused by implementing controlled drainage.

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

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.

Work has 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.

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.

We are currently participating in a multi-state NIFA grant to investigate managing drainage water for more resilient crop production on drained agricultural landscapes.

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

Xinhua Jia, North Dakota State University: 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, and salinity, water quality and quantity, water table, infiltration, 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 2012-2015 compared to 2008-2010, mainly due to reduced flow volume. However, the nitrate-nitrogen concentration stayed relatively constant. Field data at five locations, 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 AE1747 Tile Drainage Pump Stations for Farm Fields available online at: https://www.ag.ndsu.edu/publications/crops/irrigation-and-drainage. We partnered with Gary Sands and Brad Carlson from the University of Minnesota Extension Service to conduct a 2-day tile drainage design workshop. I helped with the design sessions and presented on lift stations and subirrigation design. We completed analysis and published the final reports on a 4-year tile water monitoring project. Over 500 water samples were collected from 8 farm fields in the Red River Valley during the course of the project. Each water sample was analyzed for 40 constituents. Flow rate and volume was measured at 7 of the 8 sites. Copies of the reports can be found at: https://www.ag.ndsu.edu/tiledrainage/. Hans Kandel developed and made presentations on the agronomics of subsurface water management at 16 locations in North Dakota with total attendance of over 800 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 3 different sites in eastern North Dakota where subsurface drainage is one option for controlling soil salinity. I 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. I had several consultations about water management tools with farmers that are irrigating tile drained field with center pivots. Over 20 acres of subsurface drainage research plots were established at the Langdon Experiments Station to study the effects of subsurface drainage on saline and sodium affected soils. More details can be found in the Spotlight leadership article authored by Naeem Kalwar in the North Central Region Water Network February 2016 newsletter (http://northcentralwater.org/ncrwn-newsletters-2/). A one-day seminar on subsurface drainage was held for new county agricultural agents.

Laurent Ahiablame, South Dakota State University: South Dakota State University has a continuing project to evaluate the performance and utility of denitrifying bioreactors and phosphorous adsorption media in removing nitrate and phosphorus from tile drain water. 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: one near Baltic, SD (installed in July 2012), one near Montrose, SD (December 2012), one near Arlington, SD (July 2013), and one near Hartford, SD (November 2014). A phosphorous adsorption bed made of steel chips was installed near Baltic, SD, in October 2015 and is also being monitored.

Work continued on plot-scale research at the SDSU Southeast Research Farm near Beresford, SD. The study is 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). The tile plot area was in soybean in 2015 so no fertilizer was applied. The benefits of tile drainage were reflected in yield data, which were slightly higher on plots with drainage treatments, although there is no statistical significant difference in crop yields and related crop measurements. Shallow ground water quality showed less nitrate leached in drained plots compared to undrained plots, suggesting that tile drainage contributed to nitrate export to receiving waters.

Demonstration plots for controlled and conventional drainage (one plot for each drainage condition) were installed in September 2013. The tiles were installed at 4 feet deep with 40-ft spacing. Monitoring of the plots will start this year (i.e. 2016) with corn-soybean rotation to match the other plots discussed above. Corn was planted this year. The conventional drainage plot operates with an estimated drainage coefficient (design capacity of the drainage system) of ⅜ inches per day. Similarly to the plots discussed above, these plots were also instrumented and set up for measurements of soil moisture, drain flow, shallow ground water, infiltration, and water quality in drained water and shallow groundwater.

Zach Easton, Virginia Tech University: Research at Virginia Tech during the past year has focused on implementing drainage water management practices and quantifying nitrogen and phosphorus export from artificially drained systems in Virginia and Maryland. Toward the first goal, we have installed drainage water management practices at six producer farms representing a mix of practices (3 tile drainage bioreactors, 2 in-ditch reactors, 1 spring bioreactor, 1 glucose drip in a tile system, and 2 drainage control structures). These sites have been the focus of intensive monitoring and outreach activities (see Extension/Outreach Presentations section for examples). We have published several papers resulting from information collected from these sites and have several more in progress detailing both technical and extension results.

We have published a special issue in JEQ on "Phosphorus fate, management and modeling in artificially drained systems" which has already been highly cited. This special issue highlighted the challenges of preventing and treating P loss in tile drained systems and suggested some solutions to mitigate P loss in drained systems. One paper also discussed the various models that can (or have) been used to model artificially drained systems, their benefits and drawbacks and what needs to be done in the future to improve our ability to model these systems.

We have held several field and demonstration days aimed at outreach and education about various management strategies to improve water quality in artificially drained systems. We have also developed several short courses and trainings for Continuing Education Credit and have delivered them at several venues in the region. Our outreach program has reached over 400 producers, conservation personnel, extension agents and ag service providers. We have also developed a series of extension fact sheets that can be used by agents for their own programming.

Impact Statements

1) *All NCERA217 Members:* The NCERA group has published 41 peer reviewed publications in the past year in addition to well over 75 presentations, non-peer reviewed publications and extension materials. See lists below.
2) *Illinois – Laura Christianson and Richard Cooke, University of Illinois:* The end of 2015 saw us receiving funding to install a new replicated plot-style drainage facility in Illinois where we will be assessing the impacts of cover crops, nitrogen management, and bioreactors on drainage water quality (University of Illinois College of ACES Dudley Smith Initiative and the Illinois Nutrient Research and Education Council). With this work we seek to answer the question: are current efforts to improve tile drainage water quality primarily minimizing nitrate losses, but having negative impacts on crop productivity, nutrient utilization, tile drainage P losses, and/or greenhouse gas emissions?
3) *Indiana – Jane Frankenberger and Eileen Kladivko, Purdue University:* 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.
4) *Iowa – Dan Jaynes, USDA-ARS:* The 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 an NRCS Interim Conservation Standard # 739 "Vegetated Subsurface Drain Outlet" for the practice.

5) *Iowa – Dan Jaynes:* The bioreactor research findings will further the understanding of how denitrification bioreactors function and should assist in developing models and design criteria for proper construction of the practice and improved estimates of their long-term performance.
6) *Iowa – Matt Helmers, Iowa State University:* 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 without Iowa and the broader corn belt region.
7) *Iowa – Matt Helmers:* An outcome from the IA-MN-SD Drainage Research Forum is that we are providing research-based information on drainage water quality to stakeholders including state agency personnel in Iowa and the Midwest with a goal of improving the knowledge of drainage water quality issues and practices that can be used to minimize drainage water quality impacts. Feedback from the IA-MN-SD Drainage Research Forum continues to indicate attendees valued the research based presentations, the cooperation of Iowa State University, University of Minnesota, and South Dakota State University on drainage issues, and the mix of basic and applied studies that were presented at the meeting.
8) *Iowa – Matt Helmers:* With Greg Brenneman and Kapil Arora, the 9th Iowa Drainage School was organized. Participants rate this program as good to excellent and nearly all participants indicate that the program will help them design more effective drainage systems that will improve their bottom line. We are conducting a survey of past participants to evaluate the overall impact of this program.
9) *New York – Larry Geohring, Cornell University:* More stakeholders have become aware of the positive benefits of utilizing denitrifying bioreactors and drainage water management to reduce water quality impacts to receiving watersheds. Given demonstrated nitrate removal efficiencies averaging from 40 to 70% in the field bioreactors, more interest is being generated that these bioreactors can be a viable and reasonably inexpensive best management practice for improving water quality. With the development of a Conservation Practice Standard and the potential for cost-share, more farmers have become interested in installing these practices.
10) *North Carolina – Mohamed Youssef, North Carolina State University:* 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.
11) *North Carolina – Mohamed Youssef:* The new generation of automated drainage water control structure has been adopted as a cost-shared practice by the state of North Carolina.
12) *North Carolina – Mohamed Youssef:* 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.

13) *North Carolina – Mohamed Youssef:* 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.
14) *North Carolina – Mohamed Youssef:* 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.
15) *North Dakota – Xinhua Jia, North Dakota State University:* NDSU is part of the large USDA NIFA Water for Agriculture program project, with our focus on subirrigation and education. The North Dakota 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 impact on our environment.
16) *South Dakota – Laurent Ahiablame, South Dakota State University*: the Baltic phosphorous adsorption bed is installed adjacent to an existing bioreactor; this area is used for annual field days, Ag PhD, organized by the private agricultural company, Hefty Seed Company. As usual, this field day primarily attracts producers. The bioreactor and phosphorous adsorption media installations will be on display at the field day scheduled for July 28, 2016.
17) *Virginia – Zach Easton, Virginia Tech University:* With the extent of artificial drainage expected to increase in the Mid-Atlantic, particularly on the Coastal Plain, properly managing these systems will be critical to both increase food and fiber production and protect critical natural resources. Conventional drainage management emphasizes the export of water, rather than the prudent management of local water tables, generally resulting in excessive drainage. Our ag water management program is shifting the drainage paradigm from one of rapid water removal to one of conservation drainage where water is managed as a resource and conserved in the system where appropriate. Stakeholders, particularly producers, are beginning to see the benefits of these approaches, and there has been good uptake of these practices across the region.

Publications by NCERA217 members

Peer reviewed

- David, M.B., C.G. Flint, L.E. Gentry, M.K. Dolan, G.F. Czapar, R.A. Cooke, and T. Lavaire. 2015. Navigating the socio-bio-geo-chemistry and engineering of nitrogen management in two Illinois tile-drained watersheds. Journal of Environmental Quality 44:368-381
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Non-peer reviewed publications and scientific meeting abstracts/presentations

- Rendall, T. J. 2015. Effect of passive and active heating on the performance of denitrifying bioreactors. MS Thesis, University of Illinois. http://hdl.handle.net/2142/89097
- Kaur, G., P. P. Motavalli, K.A. Nelson, and F.B. Fritschi. 2015. Changes in Soil Properties and Corn Plant Parameters Due to Early Season Soil Waterlogging. Abstr. ASA-CSSA-SSSA. On-line.
- Kaur, G., P.P. Motavalli, K. Nelson, and F. Fritschi. 2015. Use of Nitrogen Fertilizer Sources to Enhance Tolerance and Recovery of New Corn Hybrids to Excessive Soil Moisture. Missouri Soil Fertility and Fertilizers Research Update 2013-14. Agronomy Miscellaneous Publ. #15-01. pp. 101-109.
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- Nash, P.R., P.P. Motavalli, K.A. Nelson and R.J. Kremer. 2015. Ammonia and Nitrous Oxide Gas Loss with Subsurface Drainage and Polymer-Coated Urea Fertilizer in a Poorly-Drained Soil. Greenley Research Center Field Day Report. pp. 80-82.
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- Jia, X., T. F. Scherer, and D. Steele. 2015. Impact of controlled drainage on reducing nitrogen loss in the Red River Valley. ASA, CSSA, and SSSA Annual Meeting, Nov. 15-18, 2015. Minneapolis, MN. Presentation by Jia.
- Jia, X. 2015. Comparison of measured and modeled evapotranspiration rates for turfgrass in North Dakota. Nov. 15-18, 2015. ASA, CSSA, and SSSA Annual Meeting, Nov. 15-18, 2015, Minneapolis, MN. Presentation by Jia.
- Wamono, A., D. Steele, Z. Lin, T. DeSutter, and X. Jia. 2015. Effects of gypsum and sugar beet spent lime application on hydraulic properties of subsurface drained sodic-saline soils. ASABE Annual International Meeting, July 26-29, 2015. New Orleans, LA. Presentation by Wamono.
- Roy, D., X. Jia, D. Steele, and X. Chu. 2015. Measurement and simulation of infiltration rates into undrained and subsurface drained soils. ASABE Annual International Meeting, July 26-29, 2015. New Orleans, LA. Presentation by Roy.
- Jia, X. 2015. Drainage capture and use in the Red River Valley. Mini-Symposium on Drainage Retention at NCERA 217 Annual Meeting. April 14-15, 2015. Ames, IA. Presentation by Jia.
- Roy D., X. Jia, and D.D. Steele. 2015. Infiltration. Written for presentation at the North Central American Society of Agricultural and Biological Engineers Conference, 10-11 April 2015, Fargo, North Dakota. Presentation No. RRV15-031.
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- Easton, Z.M., J.M. Davis, B. Coleman, and E. Bock. 2015. Biochar enhanced nitrate and phosphate removal in denitrifying bioreactors. ASABE Special Session on Bioreactors. ASABE Annual Meeting, New Orleans, LA. July 29th 2015. (Invited).
- Coleman, B., E. Bock, and Z.M. Easton. 2015. Managing nitrogen in agroecosystems: Practical approaches to reducing edge of field nitrogen loss. Geological Society of America Annual Meeting, Chattanooga TN.
- Easton, Z.M. 2015. Lessons from agricultural drainage- Modeling and management of ag drainage. Chesapeake Bay Science and Technical Advisory Committee, Re-Plumbing the Chesapeake, Easton MD. (invited).

- Frankenberger, J., Allred, B., Brown, L., Gamble, D., Gunn, S., Baule, W., Andresen, J. 2016. On-Farm Water Recycling as an Adaptation Strategy for Drained Agricultural Lands in the Western Lake Erie Basin. In: Project Reports. D. Brown, W. Baule, L. Briley, E. Gibbons, and I. Robinson, eds. Available from the Great Lakes Integrated Sciences and Assessments (GLISA) Center.
- Hughes, C., 2015. *Understanding yield effects of controlled drainage through soil moisture excess and deficit metrics*. MS Thesis, Purdue University.
- Feyereisen, G., L. Christianson, T. Moorman, R. Venterea, and J. Coulter. 2015. Improving denitrifying bioreactor performance by adding a post-bed processing chamber. ASABE Annual Meeting, New Orleans, LA. July 29, 2015.

Extension presentations and publications

Dan Jaynes – USDA-ARS, Ames, Iowa

- Interviewed by Donnelle Eller for article in the Des Moines Register on Saturated Buffers to appear in April 2015.
- Gave interview on saturated buffers for the Iowa Minute by Laurie Johns, Iowa Farm Bureau, 24 June, Miller Creek, IA.
- Gave presentation "Field-edge practices to reduce nitrate losses to surface waters from tile-drained fields," at the Apple Canyon Lake Watershed Landowner Planning Group meeting. July 9, 2015 Apple Canyon Lake, IL. 25 watershed residents and farmers.
- Gave presentation "Field-edge practices to reduce nitrate losses to surface waters from tile-drained fields," at 2015 Summer Education Week for American Society of Farm Managers and Rural Appraisers, 21 July 2015, Omaha, NE. 10 farm managers.
- Gave interview for article on Saturated Buffers for water quality improvement with Kacey Birchmier for article in Successful Farming magazine and as part of their video series. Roland, IA 8 Sept., 2015.
- Gave presentation "Saturated Buffers for Water Quality Improvement," at the Natural Resources & Environmental Stewardship Fall In-Service meeting. Ames, IA 17 Sept., 2015. 15 Iowa State University field extension personnel.
- Helped tour for Secretary Vilsack at saturated buffer and denitrification bioreactor site at Nick Meier's farm, Black Hawk Co., IA. 16 Oct., 2015. 50 in attendance.
- Gave presentation for the Ag Drainage Water Management Webinar Series on saturated buffers. Ames, IA 21 Oct 2015. 77 attendees for live broadcast.
- Appeared in October, 2015 issue of Successful Farming Magazine in article addressing saturated buffers by Dan Looker.
- Quoted in article "Saturated buffers reduce nitrates in runoff from farms" by By Rona Kobell in the December 14, 2015 issue of Bay Journal.
- Provided information and was quoted in article "Upriver cleanup Illinois farmer's conservation practices target water quality" by Liz Morrison, appearing in the Apr-May 2016 issue of Corn and Soybean Digest.
- Gave presentation "Siting Criteria for Saturated Buffers," at the annual Water Quality and Watershed Project Coordinators Meeting, Ames, IA, March 22, 2016.
- Gave interview and provided pictures for article "This Easy Fix is How You Stop Poisoning the Fish in the Gulf of Mexico," by Chris Peak, appearing in the NationSwell on March 28, 2016 (pdf).

Matt Helmers – Iowa State University

- December 15, 2015 – Presentation on "Iowa Nutrient Reduction Strategy: One Farm Many Practices" as part of the United Suppliers Sustain Training (45 attendees)

- December 11, 2015 – Presentation on “Drainage and the Iowa Nutrient Reduction Strategy Science Assessment” at Worth and Cerro Gordo county regional extension meetings (85 attendees)
- December 10, 2015 – Presentation on “Tile drainage and water quality: Controlled drainage, bioreactors, and wetlands” at Drainage Workshop near Altoona, IA (75 attendees)
- December 10, 2015 – Presentation on “Long-term benefits of tiling” at Drainage Workshop near Altoona, IA (75 attendees)
- December 4, 2015 – Presentation on “25 Years of Drainage Water Quality Data from Gilmore City” at the Iowa Drainage District Association Annual Meeting in Fort Dodge, IA (85 attendees)
- December 3, 2015 – Presentation on “Effects of nitrogen application timing and source on nitrate-nitrogen leaching and crop yields” at the Integrated Crop Management Conference in Ames, IA (455 attendees)
- November 19, 2015 – Presentation on “Field to stream nitrate reduction: Nutrient management, cover crops, bioreactors, and wetlands” at Iowa Learning Farms field day near Plainfield, IA (105 attendees)
- October 27, 2015 – Presentation on “Iowa Nutrient Reduction Strategy” to Association of Department of Agriculture Communicators at the LICA Farm near Melbourne, IA (55 attendees)
- October 15, 2015 – Presentation on “Field to stream nitrate reduction: Nutrient management, cover crops, bioreactors, and wetlands” at Squaw Creek Watershed Management Authority meeting in Ames, IA (10 attendees)
- September 16, 2015 – Presentation on “Field to stream nitrate reduction: Nutrient management, cover crops, bioreactors, and wetlands” at Iowa State University Extension and Outreach Crops Extension Professional Development (35 attendees)
- September 2, 2015 – Presentation on “Field to stream nitrate reduction: Nutrient management, cover crops, bioreactors, and wetlands” at Iowa Learning Farms field day near Otho, IA (55 attendees)
- July 23, 2015 – Presentation on “Nutrient Reduction” at Iowa Learning Farms Field Day near Eddyville, IA (57 attendees)
- “Results from 25 Years of drainage water quality research” at the Water Resources Coordinating Council (25 attendees)
- June 25, 2015 – Presentation on “Soil Loss and Drainage” at the Water Rocks! Teacher Summit in Ames, IA (35 attendees)
- June 24, 2015 – Presentation on “Drainage and nitrate reduction” at the Northeast Iowa Summer Field Day (95 attendees)
- June 23, 2015 – Presentation on “Drainage Water Management and nitrate reduction” at the Southeast Iowa Summer Field Day (75 attendees)
- June 23, 2015 – Presentation on “Iowa Nutrient Reduction Strategy: How do we reach our goals?” at the Southeast Iowa Summer Field Day (45 attendees)
- June 10-11, 2015 – Presentation on “Soil Loss and Drainage” at the Water Rocks! Teacher Summit in Ames, IA (35 attendees)
- June 9, 2015 – Presentation on “Nutrient reduction in the Loess Hills” at Workshop in Southwest Iowa (15 attendees)
- May 20, 2015 – Presentation on “Field to stream nitrate reduction: Nutrient management, cover crops, bioreactors, and wetlands” at Soil and Land Valuation Conference in Ames, IA (150 attendees)
- September 28, 2015 – Presentation on “Tile drainage and nitrate loss” to The Fertilizer Institute Advisory Board in Boston, MA (45 attendees)

Xinhua Jia – North Dakota State University

- Jia, X. 2016. Summary of tile drainage water quality monitoring for seven years in Southeast North Dakota. 3rd ND Water Quality Monitoring Conference, March 2-4, Bismarck, ND. Presentation by Jia.

Zach Easton –Virginia Tech University

- Easton, Z.M. and E.M. Bock. 2016. Soil and soil water relationships. BSE-194P.
- Easton, Z.M. and E.M. Bock. 2015. Hydrology basics and the hydrologic cycle. BSE-191P
- Easton, Z.M. and E. Bock. 2015. Hydrology basics and the water cycle. Mid Atlantic Crop School, Ocean City, MD. Nov 2015. (invited).
- Bock, E. and Z.M. Easton. 2015. Drainage basics and drainage water management. Mid Atlantic Crop School, Ocean City, MD. Nov 2015. (invited).
- Bock, E. and Z.M. Easton. 2015. Ag water management and water quality. AgriDrain Field Day, Shirley Plantation, Charles City, VA. October 2015
- Easton, Z.M. and E. Bock. 2015. Biofilter performance and GHG emissions. NRCS Biofilter Demonstration Day, Corbin Hall Farm, Waterview, VA. August 2015.
- Bock, E., and Z.M. Easton. Drainage basics and drainage water management. 2015. Soil and Water Conservation Society Annual Meeting, Richmond, VA, 28 Oct. (invited)
- 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 Mar. (invited).

Jane Frankenberger – Purdue University

- Jun. 1, 2015 - Managing Water for Resilient Agriculture. Clinton County (IN) Drainage Workshop. 80 Attendees.
- Aug. 19, 2015. Drainage Issues and Water Quality. Pinney Purdue Field Day. 250 Attendees.
- Jun. 22, 2015. Transforming Drainage: A multi-state project to increase resiliency of drainage agricultural landscapes. Indiana Water Resources Association Meeting. Muncie, IN. 100 Attendees.
- Jan. 28, 2016. Managing Water for Resilient Agriculture. Indiana Land Improvement Contractors Annual Meeting. 40 Attendees.

Eileen Kladivko – Purdue University

- March 10-11—Advanced Conservation Cropping Systems Trainings—Greensburg, IN, and Vincennes, IN "Agricultural drainage and water quality" ~120 total participants
- March 24- Muncie, IN Soil Health Workshop, spoke on tile drainage and water quality. ~40 attendees
- December 1—Kentuckiana Conference, French Lick, IN. "Making Drainage Decisions" ~150 attendees

Gary Feyereisen – USDA-ARS, St. Paul, Minnesota

- Feyereisen, G., E. Ghane, and C. Rosen. 2016. Gorans Discovery Farm Update. Minn. Agric. Water Resource Ctr. and Minn. Discovery Farms Board Meeting. Mar. 1, 2016.