North Dakota Report – NCERA_217
Prepared by Xinhua Jia, Thomas Scherer, and Aaron Daigh
July 22, 2020

Accomplishments:

North Dakota State University research focused on evaluating the drainage water management on soil quality, water budget and quality, and crop yield. Various instruments were used to measure the soil moisture, temperature, and salinity, water quality and quantity, water table, infiltration, snowfall and snow equivalent water contents. The results showed tile drainage and subirrigation can affect the soil properties in both positive and negative ways. Water quality sampling for the last nine years at a ND field showed that a decreasing trend in overall nutrient loss because of reduced drainage flow. However, all salt related parameters (%Na, Na^{+}, SAR, SO_4^{2-}, Ca^{2+} and Mg^{2+}) increased over time in the up and down streams of the surface waters, indicating that an overall increase of tile drainage area in this region affected the water quality.

Since fall 2017, we have started to investigate if subirrigation has any effect on yield decrease. A senior design project by four engineering students in 2019 concluded that the crop yield reduction was due to compaction in the subsurface layer and enhanced soil salinity near the surface. This can be solved by reducing the compaction through deep tillage or vertical drainage structures. After presented the results to the landowners, they have incorporated the soil salinity and solidicty into the drainage water management, kept the water table at least 2 feet below the soil surface, and avoided the compaction near the edge of the field. In 2019, the crops performed better, with the soybean yield 55.2 bu/ac, which is 11.5% higher than the untiled field, and 52.9% higher than the county average.

Another senior design team of four engineering students has designed a drainage water recycling system for a vegetable farm in MN. The design contains subsurface drainage, subirrigation, a pond, and sump pumps with various valves to manage the water. The system was installed by a commercial company in spring 2020.

Evapotranspiration measurements for corn over four years in Clay County, MN, found that controlled drainage has a positive effect on corn yield in wet years, with 26.7% higher yield comparing to the county average. Subirrigation has a positive effect on corn yield in dry years, 6.6% higher than the county average. The best yield was found in 2013 when off season precipitation was also high, indicating that an optimal antecedent soil moisture in the spring can be achieved through subsurface drainage.

Unmanned Aerial Vehicle (UAV) has been used in mapping the soil moisture conditions in the field for planting preparation and flood prediction. The UAV has also been used to develop educational videos for proper drainage water management.

North Dakota State University has also been investigating a producer's 65-ha field for soil salinity management via subsurface drainage, reduced tillage, and cover crop treatments. This is an ongoing investigation that was initiated in 2013. Soil salinity maps, grain yields, groundwater elevation and water quality, and various grid-scale soil samples are obtained each year. Soil salinity on this poorly drained, silty clay field has historically been an issue. The salinity stems

from proximity of the groundwater to the soil surface as well as from a saline seep. Over 7 years, there is some evidence that subsurface drainage is increasing the depth to groundwater and reducing surface salinity in the top 30 cm as compared to the non-drained portion of the field. Moreover, crop stands have substantially improved in the saline seep zone of the field where bare ground ware previously prevalent.

Extension Activities

Since 2012, annual precipitation amounts have been returning to normal levels after almost 20 years of above average amounts in North Dakota and northwestern Minnesota. However, rain amounts received across North Dakota in August, September and October of 2019 prevented the harvest of many crops. Many farmers had to wait until May, June and July to harvest corn from the 2019 growing season. Thus, there is still educational interest in subsurface drainage.

A one-day tile drainage design workshop was held on March 10th on the campus of NDSU. There were 32 participants that rated it a 3.6 out of 4.0 for educational value.

Magazine article in Drainage Contractor, title is Online Tools for Subsurface Drainage Design. It is now in press.

Revised NDSU bulletin SF1617 Evaluation of Soils for Suitability for Tile Drainage Performance together with L.J. Cihacek, and N. Kalwar. It will be on the web and in print shortly.

Impacts

NDSU is part of the large USDA NIFA in the Water for Agriculture program project, with our focus on subirrigation and education. A senior design team was recruited to design a drainage water recycling system in Clay County, MN. The senior design project result was shared with the landowner, who has adopted our plan and installed the system. We have started to use UAV for soil moisture estimation, and drainage water management. All these projects will improve our overall understanding of tile drainage impact on our environment.

Publications

1. Niaghi, A. R., and **X. Jia**. 2019. New approach to improve the soil water balance method for evapotranspiration estimation. Water 11, 2478; doi:10.3390/w11122478. https://www.mdpi.com/2073-4441/11/12/2478/pdf.
2. Cho, E., J. Jacobs, **X. Jia**, and S. Kraatz. 2019. Identifying tile drainage using satellite big data and machine learning via Google Erath Engine. Water Resources Research 55. Doi: 10.1029/2019WR024892.
3. Kadioglu, H., H. Hatterman-Valenti, **X. Jia,** X. Chu, H. Aslan, and H. Simsek. 2019. Groundwater table effects on the yield, growth and water use of canola (Brassica napus l.) plant. Water 11: 1730. Doi:10.3390/w11081730.
4. Niaghi, A. R., **X. Jia,** D. D. Steele, and **T. F. Scherer.** 2019. Drainage water management effects on energy flux partitioning, evapotranspiration, and crop coefficients for corn. Agricultural Water Management 225 (2019) 105760. https://doi.org/10.1016/j.agwat.2019.105760.

5. Schroeder, R., J. Jacobs, E. Cho, C. Olheiser, M. DeWeese, B. Connelly, M. Cosh, **X. Jia,** C. Vuyovich, and S. Tuttle. 2019. Comparison of satellite passive microwave with modeled snow water equivalent estimates in the Red River of the North Basin. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing 12(9): 3233-3246. DOI: 10.1109/JSTARS.2019.2926058.
6. Niaghi, A. R., **X. Jia, T. F. Scherer,** and D. D. Steele. 2019. Measurement of non-irrigated turfgrass evapotranspiration rate in the Red River Valley. Vadose Zone Journal. 18(1): 1-11. doi:10.2136/vzj2018.11.0202.
7. Kolars, K., **X. Jia,** D.D. Steele, and **T.F. Scherer**. 2019. A soil water balance model for subsurface water management. Applied Engineering in Agriculture 35(4): 633-646.
8. Fidantemiz, Y.Z., **X. Jia, A. L. Daigh**, H. Hatterman-Valenti, D.D. Steele, A. R. Niaghi, and H. Simsek. 2019. Effect of water table depth on soybean water use, growth, and yield parameters. Water 11(5): 931. https://doi.org/10.3390/w11050931.
9. Mack, T., **X. Jia,** P. Flores, and X. Sun. 2019. Using UAV images to determine soil moisture in the Rd River Valley. ASABE Annual International Meeting, July 7-10, 2019. Boston, MA. Poster by Mack.
10. Roy, D., **X. Jia,** and J. Jacobs. 2019. Comparison between simulated and field measured infiltration in frozen and unfrozen soils in the Red River of the North Basin. ASABE Annual International Meeting, July 7-10, 2019. Boston, MA. Presentation by Roy.
11. Almen, K., **X. Jia,** T. Mack, P. Flores, and D. Lin. 2019. Using UAS to evaluate a drainage system and develop educational materials. Transforming drainage project Shark Tank, June 4, 2019. Moorhead, MN. Presentation by Almen.
12. Brilz, J., R. Carda, A. Klos, M. Werlinger, and **X. Jia.** 2019. Designing a drainage structure to improve vertical movement of water in clayey soils. Transforming drainage project meeting, June 5, 2019. Moorhead, MN. Poster by Werlinger.
13. **Jia, X.,** and T. Scherer. 2019. Drainage water management on saline and sodic soils. NCERA 217 Annual Meeting, June 5-6, 2019. Moorhead, MN. Presentation by Jia.
14. **Jia, X.,** and T. Scherer. 2019. Drainage water management and subsurface irrigation to reduce nutrient runoff. Red River Basin/Cold Climate Agricultural Nutrients BMP Workshop, April 17, 2019. Crookston, MN. Presentation by Jia.
15. Roy, D., and **X. Jia.** 2019. Hydraulic conductivity measurement of three frozen soils in the Red River of the North Basin. Soil Science Society of America International Soils Meeting, January 6-9, 2019. San Diego, CA. Presentation by Jia.

NCERA-217 Annual Report (July 2020)
USDA-ARS Soil & Water Management Research Unit, & University of Minnesota, St. Paul, MN
Submitted by: Gary Feyereisen

Accomplishments

Tile drainage research at the USDA-ARS Soil and Water Management Research Unit continues to be focused on mitigating loss of nitrate-N from tile drainage on agricultural cropland. During 2019, research to improve performance of denitrifying bioreactors continued and a concerted effort to engage producers in efforts to reduce tile nutrient and sediment losses began. Denitrifying bioreactors are a structural practice used to treat tile drainage effluent via microbially mediated conversion of nitrate-N to dinitrogen gas (N_2). The process is temperature-dependent and therefore less effective in colder, northern climates. Laboratory and field research on isolation of cold-temperature denitrifiers resulted in a peer-reviewed publication. Results indicated some improvement in performance after inoculation, but the impact is short-lived. Additionally, research was published on the efficacy of using bromide as a tracer to evaluate hydraulic characteristics and performance of aged woodchip beds.

In addition to structural practices to treat drainage water, in-field management and cropping/vegetative changes are strategies for improving water quality. Often these strategies are researched singly. With a county Soil and Water Conservation District, we have initiated a program with local producers in a county drainage ditch district to look at making changes to management and cropping systems that, in combination with a large woodchip bioreactor at the system outlet, can make a marked reduction in nitrate-N, phosphorus, and sediment losses. The program is set up for the producers to be involved in and to choose change, with science to serve by providing technical expertise and feedback on system performance.

Impacts

The county drainage ditch district project has resulted in increased interest among producers on agricultural water quality issues.

Peer-reviewed Publications

1. Ranaivoson, A., P. Rice, J.F. Moncrief, G.W. Feyereisen, and M. Dittrich. 2019. Acetochlor and atrazine dissipation in a woodchip denitrifying bioreactor: a comparison of experimental results with model estimates. Int. J. Hydrol. 3(4): 286-306. doi:10.15406/ijh.2019.03.00191
2. Ezzati, G., M.G. Healy, L.E. Christianson, G.W. Feyereisen, S.F. Thornton, K. Daly, and O. Fenton. 2019. Developing and validating a decision support tool for media selection to mitigate drainage waters. Ecol. Eng. X 2:100010 doi.org/10.1016/j.ecoena.2019.100010
3. Ghane, E., G.W. Feyereisen, and C.J. Rosen. 2019. Data of bromide sorption experiments with woodchips and tracer testing of denitrification beds treating agricultural drainage water. Data in Brief. https://doi.org/10.1016/j.dib.2019.103914
4. Jang, J., E. Anderson, R.T. Venterea, M. Sadowsky, C. Rosen, G.W. Feyereisen, and S. Ishii. 2019. Denitrifying bacteria active in woodchip bioreactors at low-temperature conditions. Environ. Microb. doi.org/10.3389/fmicb.2019.00635

5. Ghane, E., G.W. Feyereisen, and C.J. Rosen. 2019. Efficacy of bromide tracers for evaluating the hydraulics of denitrification beds treating agricultural drainage water. J. Hydrol. doi.org/10.1016/j.jhydrol.2019.02.031

Scientific Presentations/Activities

1. Feyereisen, G., C. Rosen, S. Ishii, P. Wang, J. Jang, E. Anderson, M. Sadowsky, E. Dorsey, and S. Schumacher. 2019. Optimizing woodchip bioreactors to reduce nitrogen and phosphorus in subsurface drainage water. MN Dept. of Agric. and MN Dept. of Health Brown Bag Lunch Series. 12 April 2019. St. Paul, MN.
2. J. Strock, Feyereisen, G., A. Ranaivoson, A. Garcia-y-Garcia, B Dalzell, D. Mulla, and K. Spokas. 2019. Nutrient reduction BMPs to treat tile drainage discharge. Red River Basin/Cold Climate Agricultural BMP Workshop. Crookston, MN. 16 – 17 April 2019.
3. Feyereisen, G., E. Ghane, and M. Dittrich. 2019. Denitrification bioreactors as a structural water quality measure at catchment scale: Performance & lessons learned. International Interdisciplinary Conference on Land Use and Water Quality. Aarhus, Denmark. 3 – 6 June 2019.
4. Feyereisen, G., E. Ghane, and M. Dittrich. 2019. Denitrification bioreactors as a structural water quality measure at catchment scale: Performance & lessons learned. ASABE-AIM, Boston, MA. 7 – 10 July 2019.
5. Feyereisen, G., C. Hay, L. Christianson, K. Kult, M. Soupir, and M. Dittrich. 2019. Woodchip bioreactor recharge: Current and future research. IA-MN-SD Drainage Research Forum. 26 November 2019. Brookings, SD.

Extension Activities

1. Feyereisen, G., S. Matteson, and W. VanRyswyk. 2019. Faribault County Ditch 62 Bioreactor: A monitoring and research plan. Faribault County Soil and Water Conservation District Lunch-and-Learn Stakeholder Meeting. 27 June 2019.
2. Feyereisen, G., and M. Dittrich. 2019. In-field questions and answers about woodchip bioreactors. WoodchipBioreactor Field Day. MN Dept. of Agric., Blooming Prairie, MN. 28 June 2019.
3. Feyereisen, G. and M. Stindtman. 2019. One-on-one meetings with eight producers operating in the CD62 County Ditch watershed. 23 July through 1 October 2019.
4. Stindtman, M., G. Feyereisen, and M. Lore. 2019. Lunch and Learn: CD62 Watershed initiative. Faribault County Soil and Water Conservation District Stakeholder Meeting. 17 December 2019.

NCERA 217 Report for Iowa (July 2020)
Submitted by: Matt 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 2019 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 2019 looking at the impact of nitrogen application timing on nitrate-N loss along with examining timing of liquid swine manure application on N loss and whether cereal rye crops can mitigate N loss with early swine manure application. We also continued work examining whether use of gypsum as a soil amendment can reduce dissolved phosphorus loss in subsurface drainage.

Two papers were published using long-term drainage water quality data sets documenting cover crops reduced nitrate-N concentration and drainage. This work also found limited impact of no-till on nitrate-N concentration and loss. One study found positive impacts over the first five years of no-till but the other study found no impact when no-till was in place 10+ years.

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

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 2020, an Iowa Drainage School was held near Nashua, IA that focused on hands-on design of drainage systems. Approximately 35 individuals participated in this event. On December 19, 2019, a drainage water quality practice design workshop was held with watershed coordinators and drainage engineers. The design of saturated buffers, controlled drainage, bioreactors and wetlands was discussed.

Impacts

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

Journal Publications

1. Archontoulis S.V., Castellano M.J., Licht M.A., Nichols V., Baum M., Huber I., Martinez-Feria R., Puntel L., Ordonez R.A., Iqbal J., Wright E.E., Dietzel R.N., Helmers M., Vanloocke A., Liebman M., Hatfield J.L., Herzmann D., Cordova S.C., Edmonds P., Togliatti K., Kessler A., Danalatos G., Pasley H., Pederson C., Lamkey K.R. (2020) Predicting crop yields and soil-plant nitrogen dynamics in the US Corn Belt. Crop Science 60:721-738. DOI: 10.1002/csc2.20039.
2. Castellano M.J., Archontoulis S.V., Helmers M.J., Poffenbarger H.J., Six J. (2019) Sustainable intensification of agricultural drainage. Nature Sustainability 2:914-921. DOI: 10.1038/s41893-019-0393-0.
3. Dougherty B.W., Pederson C.H., Mallarino A.P., Andersen D.S., Soupir M.L., Kanwar R.S., Helmers M.J. (2020) Midwestern cropping system effects on drainage water quality and crop yields. Journal of Environmental Quality 49:38-49. DOI: 10.1002/jeq2.20007.
4. Hoover N.L., Law J.Y., Long L.A.M., Kanwar R.S., Soupir M.L. (2019) Long-term impact of poultry manure on crop yield, soil and water quality, and crop revenue. Journal of Environmental Management 252. DOI: 10.1016/j.jenvman.2019.109582.
5. Martin A.R., Kaleita A.L., Soupir M.L. (2019) INUNDATION PATTERNS OF FARMED POTHOLE DEPRESSIONS WITH VARYING SUBSURFACE DRAINAGE. Transactions of the Asabe 62:1579-1590. DOI: 10.13031/trans.13435.
6. Martin A.R., Soupir M.L., Kaleita A.L. (2019) SEASONAL AND INTRA-EVENT NUTRIENT LEVELS IN FARMED PRAIRIE POTHOLES OF THE DES MOINES LOBE. Transactions of the Asabe 62:1607-1617. DOI: 10.13031/trans.13414.
7. Maxwell B.M., Birgand F., Schipper L.A., Christianson L.E., Tian S.Y., Helmers M.J., Williams D.J., Chescheir G.M., Youssef M.A. (2019) Increased Duration of Drying-Rewetting Cycles Increases Nitrate Removal in Woodchip Bioreactors. Agricultural & Environmental Letters 4. DOI: 10.2134/ael2019.07.0028.
8. Reinhart B.D., Frankenberger J.R., Hay C.H., Helmers M.J. (2019) Simulated water quality and irrigation benefits from drainage water recycling at two tile-drained sites in the US Midwest. Agricultural Water Management 223. DOI: 10.1016/j.agwat.2019.105699.
9. Sharpley A., Helmers M.J., Kleinman P., King K., Leytem A., Nelson N. (2019) Managing crop nutrients to achieve water quality goals. Journal of Soil and Water Conservation 74:91A-101A. DOI: 10.2489/jswc.74.5.91A.
10. Smith W., Grant B., Qi Z.M., He W.T., VanderZaag A., Drury C.F., Helmers M. (2020) Development of the DNDC model to improve soil hydrology and incorporate mechanistic tile drainage: A comparative analysis with RZWQM2. Environmental Modelling & Software 123. DOI: 10.1016/j.envsoft.2019.104577.
11. Smith W., Grant B., Qi Z.M., He W.T., VanderZaag A., Drury C.F., Verge X., Balde H., Gordon R., Helmers M.J. (2019) Assessing the Impacts of Climate Variability on Fertilizer Management Decisions for Reducing Nitrogen Losses from Corn Silage Production. Journal of Environmental Quality 48:1006-1015. DOI: 10.2134/jeq2018.12.0433.
12. Waring E.R., Lagzdins A., Pederson C., Helmers M.J. (2020) Influence of no-till and a winter rye cover crop on nitrate losses from tile-drained row-crop agriculture in Iowa. Journal of Environmental Quality 49:292-303. DOI: 10.1002/jeq2.20056.

Extension Meetings and Events Organized

1. 19th Annual IA-MN Drainage Research Forum

November 26, 2019 – Coordinated with Dr. Gary Sands from the University of Minnesota, John McMaine from South Dakota State University, and Chris Hay from the Iowa Soybean Association the forum in Brookings, SD. There were 55 attendees consisting of producers, contractors, and agency

2. Drainage Water Quality Field Day
   September 11, 2019 – Organized a field day at the Gilmore City Drainage Research and Demonstration project site. There were 40 attendees consisting of producers and agency representatives.
3. Iowa Drainage School
   August 20-22 2019 – Coordinated with Kapil Arora and Greg Brenneman. There were 29 attendees consisting of drainage contractors, drainage sales people, and county agency representatives from Iowa, South Dakota, North Dakota, Wisconsin, and Minnesota.

Extension Presentations (Iowa)

1. February 17, 2020 – Presentation on Nutrient reduction strategy and source water protection" at Iowa Rural Water Association Annual Conference in Des Moines, IA (85 attendees)
2. January 15, 2020 – Presentation on "Iowa Nutrient Reduction Strategy: On the edge" at Crop Advantage Series meeting in Spirit Lake, IA (50 attendees)
3. January 14, 2020 – Presentation on "Iowa Nutrient Reduction Strategy: On the edge" at Crop Advantage Series meeting in Spirit Lake, IA (28 attendees)
4. January 14, 2020 – Presentation on "Conservation Learning Labs" at Crop Advantage Series meeting in Spirit Lake, IA (28 attendees)
5. January 7, 2020 – Presentation on "Conservation Learning Labs" at Crop Advantage Series meeting in Storm Lake, IA (18 attendees)
6. December 18, 2019 – Presentation on "Bioreactor design" at Drainage Design Workshop near Fort Dodge, IA (21 attendees)
7. December 5, 2019 – Presentation on "Stacking of in-field and edge-of-field practices" at Integrated Crop Management Conference in Ames, IA (185 attendees)
8. November 7, 2019 – Presentation on "Conservation Learning Labs" at the Iowa Learning Farms Field Day held at the Northeast Research Farm (33 attendees)
9. September 8, 2019 – Presentation on "Edge-of-field nitrate-N reduction practices" at the Southeast Research Farm Summer Field Day (150 attendees)
10. September 8, 2019 – Presentation on "Edge-of-field nitrate-N reduction practices" at the High School Innovation Day at the Southeast Research Farm (30 attendees)
11. August 22, 2019 – Presentation on "Controlled drainage design" at the 2019 Iowa Drainage School near Nashua, IA (29 attendees)
12. August 13, 2019 – Bioreactor installation and open house at the ISU Northwest Research and Demonstration Farm (15 attendees)
13. June 25, 2019 – Presentation on "Water quality, soil health, and nutrient transport: An Iowa perspective" at the Water Rocks Teacher Summit in Ames (45 attendees)
14. June 21, 2019 – Presentation on "Water quality, soil health, and nutrient transport: An Iowa perspective" at the Water Rocks Teacher Summit in Ames (45 attendees)
15. June 20, 2019 – Presentation on "Edge-of-Field nitrate reduction practices" at Certified Crop Advisor Training at the ISU Southeast Research and Demonstration Farm (29 attendees)

16. March 13, 2019 – Presentation on “Water quality benefits of prairie strips” at Iowa Water Conference in Ames, IA (80 attendees)
17. March 5, 2019 – Presentation on “Drainage design and edge-of-field practices” at Drainage Workshop in Emmetsburg, IA (21 attendees)

Extension Presentations (Regional):

1. February 14, 2020 – Presentation “Edge of field practices for nitrate reduction” as part Missouri Drainage Workshop (38 attendees)
2. December 12, 2019 – Presentation on “Impacts of 4R Nitrogen Management on Drainage Water Quality” at the South Dakota Agronomy Conference (180 attendees) [Invited]
3. April 30, 2019 – Presentation on “Challenges and opportunities of nitrate reduction in Iowa” at Global Water for Food Conference (175 attendees) [Invited]
4. April 17, 2019 – Presentation on “Challenges and opportunities of Iowa’s nutrient reduction strategy” at University of Kansas Environmental Engineering Conference (125 attendees) [Invited]
5. January 28, 2019 – Presentation on “Nitrogen fertilizer: Environmental aspects” at Illinois Fertilizer Association meeting in Peoria, IL (125 attendees) [Invited]

NCERA 217 Annual Station Report – University of Georgia

Gary L. Hawkins, Ph.D.
Water Resource Management Specialist and Assistant Professor
University of Georgia
Crop and Soil Science

Submitted 7 July 2019

2019 Annual State Report

Accomplishments

- The Georgia Department of Agriculture (Specialty Crop Program) grant was finished and final report submitted. Samples were collected from tile drain system from a blueberry farm to monitor the nutrient loss. Results indicated that the highest concentration of nitrate in the drain water was a little over five times less than the EPA drinking water standard. There were continuous concentrations of iron that were higher than standards. This is expected as a result of the soil composition.
- The bench scale blueberry drainage tests were continued.
- The grant from the Georgia State Environmental Protection Division is on going and the blueberry trial mentioned in #2 is part of that project.

Impacts

- Data indicated that the concentrations of nutrients in the drain water from the blueberries was less than EPA drinking water standards. This indicates that the blueberry producers are managing nutrients.

Peer-reviewed publications

- Since we are still collecting initial data, there are no Peer Reviewed Publications to date.

Extension presentations

- The project has been mentioned in multiple presentations related to nutrient movement and management.

NCERA-217 Missouri Report, July 2020
Kelly Nelson, Division of Plant Sciences, University of Missouri

Accomplishments

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 is ongoing. Research on nitrification inhibitors (NI), polymer coated urea (PCU) and waterlogging of poorly drained claypan soils was completed during the period. Enhanced efficiency fertilizers such as nitrification inhibitors and polymer-coated urea can be utilized to reduce leaching and gaseous loss of N fertilizer in poorly- and well-drained fields. Nitrogen management technology can be utilized to enhance food production while minimizing loss to the environment.

A review of the impacts and management strategies for crop production in waterlogged/flooded soils was completed. Globally, flooding is one of the most damaging abiotic stresses, besides drought, that affects 17 million km2 of land surface annually. This review paper summarized the current state of knowledge on the impacts of flooding or soil waterlogging on crop production losses, nitrogen (N) losses, and provided potential management strategies to reduce these losses. The factors affecting the extent of flooding injury in plants as well as plant adaptations under waterlogging stress are also discussed briefly. Soil waterlogging promotes soil N losses through runoff, leaching, and denitrification. Potential management practices that can be used to mitigate soil waterlogging stress include the use of flood-tolerant varieties, adjusting management practices, improving drainage, and practicing adaptive nutrient management strategies. However, these might be site- or crop-specific management practices and they should be validated for their economic viability before developing future management plans that promote sustainable crop yields from waterlogged soils.

Research was completed on the impact of nitrogen fertilizer management (enhanced efficiency N fertilizers) and hybrid selection under waterlogged conditions in the field and greenhouse. Excessive rainfall occurring in the early spring season in the Midwestern United States result in waterlogged soils contributing to corn production losses. Waterlogging decreased grain and silage yields in different years; however, significant interactions were observed among treatments. Rescue N applications increased grain yields by 6–46% in non-waterlogged treatments, but not in waterlogged treatments. The PCU (polymer-coated urea) and NCU (noncoated urea) + NI (nitrapyrin) increased grain yields compared to the control. Pre-plant N sources showed no significant differences in grain yield, probably due to existing environmental conditions or incorporation of fertilizer. The N source, application method, and timing for post-waterlogging rescue N application and flood-tolerant corn hybrids needs further investigation in poorly-drained claypan soils prone to waterlogging under a changing climate. In addition, identification of corn hybrids that can withstand wet soil conditions is one approach to prevent crop production losses from abiotic stress caused by excessive soil moisture during early spring season in the midwestern United States. A greenhouse pot experiment was conducted to screen and identify corn hybrids tolerant or susceptible to soil waterlogging at the V2 growth stage. Large variability occurred among corn hybrids in response to soil waterlogging durations.

Fertilizer placement and the use of enhanced efficiency fertilizer technology can reduce N loss in poorly drained soils. Corn (*Zea mays* L.) production in poorly drained claypan soils in the US Midwest is a challenge due to low soil permeability, which may result in wetter soil conditions and relatively large amounts of soil N2O emissions early in the growing season. Results suggest that deep banding urea with a nitrification inhibitor is an effective management strategy for reducing cumulative soil N2O emissions and increasing grain yields over the growing season. Nitrogen (N) losses due to leaching, denitrification and/or ammonia volatilization are of utmost concerns since they reduce farm profitability and adversely affect environmental quality. To combat these N losses, a new nitrification inhibitor (NI), pronitridine, can be used to slow down the nitrification process. A field experiment was conducted to evaluate the effectiveness of pronitridine at different rates with anhydrous ammonia (AA) when applied in the fall or pre-plant on claypan soils in northeast Missouri. Results indicated that pronitridine was effective in increasing yields when applied in the fall and was similar to other NI's when applied pre-plant in the spring.

Finally, there is ongoing research on the impacts of 4R nitrogen management on crop yield, soil health, nutrient losses with water, and gaseous emissions. This work is being conducted across seven sites in the Upper Midwest US cornbelt and one site in Ontario, CA.

Publications

Peer-reviewed publications

1. Kaur, G., G. Singh, P.P. Motavalli, K.A. Nelson, J.M. Orlowski, and B. Golden. 2020. Impacts and management strategies for crop production in waterlogged/flooded soils: A review. Agron. J. 1-27. https://doi.org/10.1002/agj2.20093.
2. Kaur, G., K.A. Nelson, P.P. Motavalli, and G. Singh. 2020. Adaptation to early-season soil waterlogging using different nitrogen fertilizer practices and corn hybrids. Agronomy 10:1-15. doi:10.3390/agronomy10030378
3. Kaur, G., B.A. Zurweller, P.P. Motavalli, and K.A. Nelson. 2019. Screening corn hybrids to soil waterlogging at an early growth stage. Agriculture. 9:1-18. doi:10.3390/agriculture9020033.
4. Steusloff, T., K.A. Nelson, P.P. Motavalli, and G. Singh. 2019. Enhanced efficiency liquid nitrogen fertilizer management for corn production. Int. J. Agron. pp. 1-12. doi: 10.1155/2019/9879273.
5. Steusloff, T.W., K.A. Nelson, P.P. Motavalli, and G. Singh. 2019. Fertilizer placement affects corn and nitrogen use efficiency in a claypan soil. Agron. J. 111:1-11. doi:10.2134/agronnj2019.02.0108.
6. Steusloff, T.W., K.A. Nelson, P.P. Motavalli, and G. Singh. 2019. Urea nitrapyrin placement effects on soil nitrous oxide emissions in claypan soil. J. Environ. Qual. 48(5):1444-1453. doi: 10.2134/jeq2019.01.0031.
7. Singh, G., and K.A. Nelson. 2019. Pronitridine and nitripyrin with anhydrous ammonia for corn. J. Agric. Sci. 11:1-24. doi:10.5539/jas.v11n4p13.

Other publications

1. Singh, G., and K.A. Nelson 2019. Long-term drainage, subirrigation, and tile spacing effect on corn production. Universities Council on Water Resources/ National Institutes for Water Resources (UCOWR/NIWR), Annual Water Resources Conference, Snowbird, UT. 11-13

June.

2. Singh, G., and K.A. Nelson 2019. Long-term drainage, subirrigation, and tile spacing effect on corn production. NCERA-ADMS Task Force Annual Meeting, June 5-6, 2019 – Moorhead, Minnesota.
3. Singh, G., and K.A. Nelson 2019. Integrated best management practices of terraces, cover crops, and no-tillage for managing nutrient loss. Universities Council on Water Resources/ National Institutes for Water Resources (UCOWR/NIWR), Annual Water Resources Conference, Snowbird, UT. 11-13 June.
4. Singh, G., P.R. Nash, and K.A. Nelson. 2019. Nutrient loss from floodplain soil with controlled tile drainage under forage production. Abstr. ASA-CSSA-SSSA. Online.
5. Burnett, S., K.A. Nelson, and P. Motavalli. 2019. Impact of 4R nutrient management on nutrient loss. Abstr. ASA-CSSA-SSSA. Online.
6. Chighladze, G., M. J. Helmers, L.J. Abendroth, L. Ahiablame, B. Allred, L.C. Bowling, N. Fausey, J. Frankenberger, D.B. Jaynes, E.J. Kladivko, K.A. Nelson, L. Pease, B. Reinhart, J.S. Strock, and M.A. Youssef. 2019. Seasonal variability of nitrate-N loads from controlled drainage systems across the Midwest region. Abstr. ASA-CSSA-SSSA. Online.
7. Singh, G., and K.A. Nelson, University of Missouri-Columbia, Novelty, MO. 2019. Phosphorus application on frozen soils and loss from a no-till cover crop terrace. Abstr. ASA-CSSA-SSSA. Online.
8. Strock, J.S., E. Ghane, M.A. Youssef, L.S. Negm, S.S. Tian, L.J. Abendroth, G. Chighladze, N. Fausey, J, Frankenberger, C.H. Hay, M.J. Helmers, D.B. Jaynes, E.J. Kladivko, J. McMaine, L. Pease and K.A. Nelson. 2019. Regional analysis of corn yield under different drainage water management systems. Abstr. ASA-CSSA-SSSA. Online.
9. Dhakal, D., L. Sandler, K.A. Nelson, and G. Singh. 2019. Effect of tillage, planting date and grazing radish cover crop on weed suppression and corn grain yield. Abstr. ASA-CSSA-SSSA. Online.
10. Burnett, S., K.A. Nelson, and P. Motavalli. 2019. Impact of 4R nutrient management on crop production. Abstr. ASA-CSSA-SSSA. Online.

Extension Presentations and Programs

1. Missouri Conservation Showcase; July 22, 24, and 26 2019: Organized a field day at the MU Grace Greenley Research Farm on drainage water recycling, bioreactors, saturated buffer, and controlled drainage. There were 150 attendees including producers, agency representatives, Missouri LICA, and Missouri Conservation Commission.
2. Iowa Drainage School; August 21 2019: Presented on Subirrigation in Nashua, IA. There were 29 attendees consisting of drainage contractors, drainage sales people, and county agency representatives from Iowa, South Dakota, North Dakota, Wisconsin, and Minnesota.
3. Missouri Agriculture Leaders of Tomorrow; July 18 2019: Presented on Drainage and subirrigation at Novelty. There were 35 attendees consisting of agriculture leaders, farmers, agency, and agribusiness representatives.
4. Greenley Research Center Field Day; August 6 2019: Presented drainage research of the Coordinated Site Network for Studying the Impacts of 4R Nutrient Management on Crop Production and Nutrient Loss. There were 150 attendees consisting of farmers, agency, and agribusiness representatives.
5. Northeast Missouri CCAs; February 21 2019: Presented on Taking Yields to the Next Level with Water Management. There were 30 attendees.

6. Northwest Missouri CCAs; January 22 2019: Presented on bioreactor and saturated buffer installed in Northeast Missouri. There were 200 attendees including farmers, agency, and agribusiness representatives.

Michigan NCERA-217 Report (Jan 1st, 2019 to Dec 31st, 2019)
Ehsan Ghane

Research Accomplishments

In our edge-of-field drainage project, we successfully collected calibration data from three on-farm sites. In 2020, this project will move to the next stage of implementing conservation drainage practices to evaluate their performance. Results from this research will be used to educate farmers on how to reduce phosphorus loss from subsurface-drained fields. We presented at one professional annual meeting and published two peer-reviewed papers.

Extension Accomplishments

We presented at 3 field days, presented at 6 workshops/conferences, published 3 online extension news articles, published a Drainage Extension Website, and answered producers' drainage-related questions. The goal of these Extension activities was to increase knowledge of water-quality issues and educate farmers on how to alleviate this issue.

Impacts

Overall, my extension activities were targeted towards producers, drainage contractors, agency personnel, policymakers, and stakeholders. We delivered several extension products across Michigan including extension talks, field-day talks, and news articles. The impact of our extension activities was increased knowledge of methods to combat water-quality issues through implementation of conservation drainage practices.

Peer-reviewed Publications

1. **E. Ghane**, G.W. Feyereisen, C.J. Rosen. 2019. Efficacy of bromide tracers for evaluating the hydraulic performance of denitrification beds treating agricultural drainage water. Journal of Hydrology. 574, 129-137.
2. **E. Ghane**, G.W. Feyereisen, C.J. Rosen. 2019. Data of bromide sorption experiments with woodchips and tracer testing of denitrification beds treating agricultural drainage water. Data in Brief. 24, 103914.

Indiana Report – NCERA-217 – 2019
Submitted by Jane Frankenberger

Accomplishments

Surface runoff in tile-drained fields is poorly quantified, although it can be strongly affected by conservation practices that seek to mitigate pollutant transport through subsurface drainage. We determined the frequency and extent of occurrence of surface ponding and runoff to understand their generation processes in a seasonally frozen, subsurface drained agricultural field in eastern Indiana (Saadat et al., 2019). The simulation results indicated that surface runoff represented 1–10% of annual precipitation, while subsurface drainage represented between 26 and 45%. On average, 45% of simulated ponding occurred during the cold season, indicating the importance of soil freezing and snow accumulation. Results from both simulations and observations indicated that all of the ponding events in this location were generated by saturation excess rather than infiltration excess processes.

Drainage water recycling, the practice of capturing and storing water drained from fields and using the stored water to irrigate crops when there is a soil water deficit, has been proposed to increase the resiliency of drained agriculture, but the potential benefits have not been quantified. We determined irrigation and nutrient reduction benefits of drainage water recycling for various reservoir sizes at two tile-drained sites in the U.S. Midwest with differing climates and soils (Reinhart et al., 2019). At the Indiana site, a reservoir size representing 6% of the field area (3.05 m depth) would provide water storage for meeting irrigation requirements in all ten years. This reservoir would capture 37% of annual tile drain flow on average, resulting in average annual load reductions of 11 kg ha^{-1} yr^{-1} (37%) for nitrate-N and 0.05 kg ha^{-1} yr^{-1} (39%) for soluble reactive phosphorus. At the Iowa site, a reservoir size of 8% was necessary to meet the irrigation requirements, which were zero in most years but were higher than at the Indiana site for the three years in which irrigation was needed. Quantifying nutrient load reductions and irrigation potential at these two sites showed the promise of drainage water recycling for the tile-drained landscape of the U.S. Midwest, providing a strategy to manage water-related risks while also contributing to water quality goals.

The Transforming Drainage project, led by Purdue University, continues to support collaboration to understand and implement storage of drainage water in the environment. The project has established a robust network of 38 research sites where the evaluation of drainage water storage practices previously has, or is currently, taking place. This includes 21 controlled drainage research sites, 9 drainage water recycling, and 8 saturated buffer sites. The Transforming Drainage database has been established and serves as the foundation for research, synthesis, and modeling for the project. Currently, the database has compiled and cataloged more than 195 site-years of crop yield data, 204 site years of tile drain flow, 91 site-years of water table measurements, 163 site-years of tile drain flow nitrate concentration, 94 site-years of tile drain flow phosphorus concentration, 222 site-years of weather data, and supporting field management data (e.g. planting/harvest date, water table management, soils characteristics, fertility, etc.) from research sites. The establishment of the research database has enabled and strengthened the informational and technological infrastructure to allow for the characterization of impacts on agricultural production and environmental benefits that come from storing water on the landscape.

We have formed a new national partnership, the Conservation Drainage Network (https://conservationdrainage.net/). The group was formed out of the Agricultural Drainage Management Systems (ADMS) Task Force which operated between 2002 and 2019. NCERA-217 is a key participant in the Organizing Committee, which has developed a website and organized an annual meeting for which 175 people registered. This will enhance networking among researchers, conservation agencies, non-governmental organizations, and the drainage industry, with the goal of improving drainage practices to meet future demands of crop production while reducing adverse environmental impacts of drainage.

Peer-reviewed Publications

1. Saadat, S., Frankenberger, J., Bowling, L. and Ale, S., 2020. Evaluation of Surface Ponding and Runoff Generation in a Seasonally Frozen Drained Agricultural Field. *Journal of Hydrology*, p.124985. https://doi.org/10.1016/j.jhydrol.2020.124985.
2. Reinhart, B.D., Frankenberger, J.R., Hay, C.H. and Helmers, M.J., 2019. Simulated water quality and irrigation benefits from drainage water recycling at two tile-drained sites in the US Midwest. *Agricultural Water Management*, *223*, p.105699. https://doi.org/10.1016/j.agwat.2019.105699.
3. Lahdou, G.B., Bowling, L., Frankenberger, J. and Kladivko, E., 2019. Hydrologic controls of controlled and free draining subsurface drainage systems. *Agricultural Water Management*, *213*, pp.605-615. https://doi.org/10.1016/j.agwat.2018.10.038
4. Peterson, H., Williams, M., Frankenberger, J., King, K., McGrath, J., Moody, L., Ribaudo, M., Strock, J., Johnson, K. and Nelson, N., 2019. Reducing the impacts of agricultural nutrients on water quality across a changing landscape. *Issue Paper-Council for Agricultural Science and Technology*, (64).

Extension Publications

1. Kladivko, E. 2020. Drainage for the long haul: Key takeaways from the SEPAC study. Purdue Exten. Publ. AY-396-W. https://ag.purdue.edu/agry/drainage/Pages/New-Summaries.aspx
2. Kladivko, E. 2020. Soil drainage and crop yields: Insights from long-term SEPAC study. Purdue Exten. Publ. AY-397-W. https://ag.purdue.edu/agry/drainage/Pages/New-Summaries.aspx
3. Kladivko, E. 2020. Soil drainage impacts on cover crop growth and soil improvement: Insights from long-term SEPAC study. Purdue Exten. Publ. AY-398-W. https://ag.purdue.edu/agry/drainage/Pages/New-Summaries.aspx
4. Kladivko, E. 2020. Soil drainage and nitrate losses to surface waters: Insights from long-term SEPAC study. Purdue Exten. Publ. AY-399-W. https://ag.purdue.edu/agry/drainage/Pages/New-Summaries.aspx

Illinois Report – NCERA-217 – 2019
Dr. Richard Cooke and Dr. Laura Christianson
(NCERA 217 IL representatives)

Accomplishments

Agricultural drainage research and outreach at the University of Illinois continue to focus on proper drainage design and practices that reduce nutrient transport through tile drainage systems while maintaining or increasing in-field crop production. Data collection at a variety of sites around the state continued through 2019 which was a year where the need for good drainage was a hot topic given the very wet spring. Denitrifying woodchip bioreactors continue to be a cornerstone of our drainage research and outreach. More than 12 bioreactors across the state are currently being monitored by the NCERA 217 representatives with approximately 10 additional sites monitored by colleagues. The sites include bioreactors on private farms and university farms, NRCS-designed bioreactors and novel bioreactors designs.

Impacts

Dr. Laura Christianson presented on conservation drainage, bioreactors, and nutrient loss issues to more than 700 attendees at events in 2019 (including invited in-state and out-of-state conferences; field events, etc.) and shared information via more than six interviews. Dr. Christianson was an invited keynote speaker at a bioreactor specialty conference in Spain in December 2019 to discuss her team's integrated research and outreach bioreactor work in Illinois (*Jornada Técnica Internacional "Uso De Biorreactores Con Madera Y Humedales Para La Desnitrificación De Efluentes Agrícolas": International Technical Conference on the "Use of Bioreactors with Wood and Wetlands for the Denitrification of Agricultural Effluents"; Universidad Politécnica de Cartagena, Cartagena, Spain*). Dr. Richard Cooke continues to contribute to the IL LICA newsletter with wide distribution across Illinois. Dr. Rabin Bhattarai (University of Illinois) has ongoing research on drainage system optimization and watershed-scale evaluation of drainage water management. Drs. Wei Zheng (Illinois Sustainable Technology Center) and Olawale Oladeji (Metropolitan Water Reclamation District) have ongoing research on reducing the transport of phosphorus from tile drainage systems.

Peer-Reviewed Publications (NCERA 217 representatives underlined)

1. Ezzati, G., M.G. Healy, L.E. Christianson, G.W. Feyereisen, S. Thornton, K. Daly, and O. Fenton. 2019. Developing and validating a decision support tool for media selection to mitigate drainage waters. *Ecol. Eng. X*: 2.
2. Maxwell, B., F. Birgand, L. Schipper, L. Christianson, S. Tian, M. Helmers, D. Williams, G. Chescheir, and M. Youssef. 2019. Increased duration of drying-rewetting cycles increases nitrate removal in woodchip bioreactors. *Agricultural & Environmental Letters* 4:190028.
3. Christianson, L.E., R.D. Christianson, A.E. Lipka, S. Bailey, J. Chandrasoma, C. McCoy, G. Preza Fontes, J. Roh, A.P. Sanchez Bustamante Bailon, N. Wickramarathne, and R.A. Cooke. 2019. Calibration of stainless steel-fronted v-notch weir stop logs for water level control structures. *Applied Engineering in Agriculture* 35(5): 745-749.
4. Hertzberger, A.J., C.M. Pittelkow, R.D. Harmel, and L.E. Christianson. 2019. Analysis of the MANAGE Drain Concentration database to evaluate agricultural management effects on drainage water nutrient concentrations. *Trans. of the ASABE* 62(4):929-939.

5. Hertzberger, A., C.M. Pittelkow, R.D. Harmel, and L.E. Christianson. 2019. The MANAGE Drain Concentration database: A new tool compiling North American drainage nutrient concentrations. *Agricultural Water Management* 216:113-117.
6. Chandrasoma, J.M., R.D. Christianson, and L.E. Christianson. 2019. Saturated buffers: What is their potential impact across the US Midwest? *Agricultural & Environmental Letters* 4:180059. doi: 10.2134/ael2018.11.0059.
7. Maxwell, B., F. Birgand, L. Schipper, L. Christianson, S. Tian, M. Helmers, D. Williams, G. Chescheir, and M. Youssef. 2019. Drying–rewetting cycles affect nitrate removal rates in woodchip bioreactors. *Journal of Environmental Quality* 48(1):93-101.
8. Holscher, J.A. and Davidson, P.C. (2019) Impact of Annual Ryegrass on Nitrate-N Losses during One Growing Season of Maize in the Midwestern United States. *Journal of Water Resource and Protection*, 11, 606-625. https://doi.org/10.4236/jwarp.2019.115035
9. Jeong, H., Pittelkow, C. M., & Bhattarai, R. 2019. Simulated responses of tile-drained agricultural systems to recent changes in ambient atmospheric gradients. *Agricultural Systems*, 168, 48-55.
10. Preza Fontes, G., Bhattarai, R., Christianson, L. E., & Pittelkow, C. M. 2019. Combining environmental monitoring and remote sensing technologies to evaluate cropping system nitrogen dynamics at the field-scale. *Frontiers in Sustainable Food Systems*, 3, 8.
11. Zhou, H.V, Bhattarai, R. Li, Y., Li, S., & Fan, Y. 2019. Utilization of coal fly and bottom ash pellet for phosphorus adsorption: sustainable management and evaluation. Resources, Conservation & Recycling, 149, 372-380
12. Shrestha, S., Sharma, S., Gupta, R., & Bhattarai, R. 2019. Impact of global climate change on stream low flows: A case study of the Great Miami River watershed, Ohio. International Journal of Agricultural and Biological Engineering, 12(1), 84-95.

Non-Peer Reviewed Publications, Reports, and Outreach Articles and Factsheets (NCERA 217 representatives underlined)

1. Bhattarai, R. and R. Cooke. How far apart? How deep? Understanding the influence of tile depth and spacing on nutrient loss and crop yield. ILICA News 2019, 1, 20-21
2. Zheng, W.; Cooke, R., How to keep phosphorous in a closed agricultural loop? An innovative practice to capture and recover phosphates from tile drainage. ILICA News 2019, 2, 12-13
3. Cooke, R., H. Jeong and R. Bhattarai. Performance of small diameter drainage tile. ILICA News 2019, 4, 12-13
4. Cooke, R. Drainage coefficient effects on drainage system response to large rainfall events. ILICA News 2019, 5, 12-14
5. McIsaac, G. Maintaining and improving open woodchip bioreactors. ILICA News 2019, 6, 12

Contribution to NCERA217 Annual Report
Zachary Easton
Professor, Biological Systems Engineering, Virginia Tech

Accomplishments

Research at Virginia Tech has pivoted from the application of denitrifying bioreactors to treat agricultural drainage to investigating the potential of bioreactors to remove legacy nitrogen discharged via emergent groundwater (e.g., springs). We have demonstrated the potential of bioreactors in spring applications with a pilot-scale system in Southwest Virginia, achieving over 40% nitrogen removal with a median influent nitrogen concentration of 8.6 mg/L. This work has generated interest from the Virginia Department of Environmental Quality, who have included spring bioreactors as a potential tool to meet the Chesapeake Bay Total Maximum Daily Load in the Draft Phase III Water Quality Implementation Plan. Building on the success of the pilot system and an analysis of nitrogen loads discharged by springs throughout the region, Co-PIs Kurt Stephenson, Zachary Easton, Emily Bock, and Kelly Coburn were awarded USDA-NIFA Grant through the Environmental and Resource Economics Program entitled "Development and Evaluation of Market-like Pay-for-Performance Programs to Address Legacy Nutrients" in the amount of $499,627. The specific objectives of this project are to 1) quantify nitrogen removal from spring bioreactors, 2) develop and evaluate prototype payment for demonstrated performance contract options for securing demonstrated nitrogen reductions, 3) develop a decision aid for landowners to assess and evaluate bid and contracting options, and 4) evaluate a buyer demand for PDP contracts for nitrogen removal from springs. This project began in spring 2019 and will be conducted over the next three years. In partnership with local non-profit Ridge to Reefs, we installed a 2,000 m^3 woodchip bioreactor treating 2,000-5,000 m^3/d flows from a large spring in the Shenandoah Valley discharging 8,000-13,000 m^3/d. While this project focuses on the development on contracts to support the nutrient trading market, we are studying the processes internal to the bioreactors and how their performance can be optimized.

Outcomes

The pay-for-performance project will explore mechanisms to incentivize agricultural landowners to treat the largely neglected issue of legacy nutrients in cost effective ways. Like most water quality programs, the US EPA Chesapeake Bay Program (CBP) has no active policy to address legacy nutrients. Conventional agricultural nonpoint source control programs focus on providing financial assistance (cost share) to agricultural producers for implementing practices that prevent or reduce nutrient losses from production areas during the current growing season. However, nonpoint pay-for-performance program could improve water quality and economic outcomes since payment is conditioned on demonstrated outcomes, PDP can provide water quality managers greater certainty that claimed nutrient reductions are actually being achieved. Since the nutrient reducing effectiveness of nonpoint source control technologies are not directly observed or measured in the field, substantial uncertainty exists over the nutrient control effectiveness of BMPs in current nutrient trading schemes. Additionally, performance measurement provides the agricultural land managers with critical feedback linking management actions to on-the-ground pollutant reductions. Feedback on performance facilitates innovation by providing land managers with the means to continuously develop, test, and refine nutrient reduction strategies over time. PDP programs offer the potential to achieve inexpensive nutrient reductions simply by making operational changes without making new investments in expensive structural control practices

and provide landowners incentives to acquire site-specific information to choose the most cost-effective investments (most reduction per cost).

Publications and Public Engagement

Peer-reviewed Journal Articles

1. Easton, Z.M., E.M. Bock**,** and K. Stephenson. 2020. Feasibility of employing bioreactors to treat legacy nutrients in emergent groundwater. Environ. Sci and Technology. http://dx.doi.org/10.1021/acs.est.9b04919
2. Stephenson, K., E.M. Bock, and Z.M. Easton. 2020. Evaluation of regulatory compliance options to meet Chesapeake Bay water quality goals: Treatment of legacy nitrogen using bioreactors. Environ. Sci and Technology. (In Revision).
3. Bock, E.M., B.S. Coleman, and Z.M. Easton. 2019. Biochar fails to enhance nutrient removal in woodchip bioreactor columns following saturation. J. Environ Manage. https://doi.org/10.1016/j.jenvman.2018.11.074.
4. Kleinman, P., R. Fanelli, B. Hirsch, A.R. Buda, L. Wainger, C. Brosch, M. Lowenfish, A. Collick, Z.M. Easton, A. Shirmohammadi, K. Boomer, J. Hubbart. 2019. Phosphorus and the Chesapeake Bay – Lingering issues and emerging concerns for agriculture. J Environ. Qual. 2019 48:1191-1203. doi:10.2134/jeq2019.03.0112

Conference Abstracts and Presentations

1. Bock, E.M., Stephenson, K., and Z.M. Easton (2019), Artificial Sinks to Treat Legacy Nutrients in Agricultural Landscapes, Abstract B33E-2712 presented at 2018 Fall Meeting, AGU, Washington, D.C., 10-14 Dec.
2. Bock, E.M., Stephenson, K., and Z.M. Easton (2020), Opportunities and Challenges for Mitigating the Water Quality Impacts of Agricultural Drainage with Denitrifying Bioreactors in the Chesapeake Bay Watershed, Poster presentation delivered at 2018 Chesapeake Community Research and Modeling Symposium, Annapolis, MD, 12-14 June.