

NCERA 217 Termination Report for period October 1, 2009 – September 30, 2014

Project Title: Drainage design and management practices to improve water quality

Project Objectives:

1. Evaluate the impact of integrated drainage system design and agronomic management practices on reducing nitrate-N from drained agricultural lands.
2. Coordinate research on the water quality impact of manure application practices on drained agricultural land.
3. Assess the need for further research in other aspects of environmental quality from drained agricultural lands, such as salinity, implications of emerging feedstock production for biofuels, and potential greenhouse gas production in drained agricultural lands.
4. Develop strategies to facilitate communication between scientists and policy makers, develop extension/educational materials, and promote partnerships with stakeholders interested in drainage, soil and crop management, and environmental quality in agricultural landscapes.

Termination Report Accomplishments:

This Committee has been very active, as demonstrated by the many accomplishments documented in the Annual Reports for last four years. The Committee has helped to lead a regional NRCS CIG grant that led a special issue publication in the Journal of Soil and Water Conservation on the yield and water quality benefits of drainage water management in the Midwest. Collaborative relationships of Committee members were instrumental in development of a successful Coordinated Agriculture Project funded by USDA titled “Climate Change, Mitigation, and Adaptation In Corn-Based Cropping Systems” through USDA-NIFA A3101 Regional Approaches to Climate Change Cropping systems: cereal production systems (corn). This project involves Committee members from four states across the Midwest. The Committee has been instrumental in the development of NRCS Interim Conservation Standards #739 “Vegetated Subsurface Drain Outlet” and #747 “Denitrifying Bioreactor” and Conservation Practice Standard #554 “Drainage Water Management”.

The Committee includes about 20 official members who represent 12 states and two government agencies. Most members have attended the annual meetings held in Ohio (2009), Quebec, Canada (2010), North Dakota (2011), Michigan (2012), and South Dakota (2013). During each meeting, a block of time has been dedicated to focus on one or two key topics in a “mini-symposia” format. In 2009, the mini-symposium featured drainage ditch design and the ecological impacts of drainage water management. In 2010, the Committee meeting was held in conjunction with ASABE’s Ninth International Drainage Symposium. In 2011, the mini-symposium focused on Red River Valley tile drainage research projects. In 2012 the Committee held a mini-symposium on phosphorus in tile drainage. In 2013, the Committee focused on the hydrologic impacts of subsurface drainage.

Major Accomplishments by Objective

For Objective 1: Many states have established research activities to focus on reducing nutrient export, particularly on nitrate-nitrogen from tile drainage systems, using various drainage water management and crop practices. This includes studies on: (1) various land covers, such as continuous living mulch, winter cover crop, perennial grass, and diverse native prairie; (2) edge of field structures such as bioreactors, re-saturated riparian buffers, wetlands, vegetated open ditches, and nutrient retention basins; (3) agronomy practices, such as timing, rate, and form of fertilizer application; (4) drainage design, such as drainage depth and intensity; and (5) drainage water management such as controlled drainage and subirrigation. Model development and modeling applications have also been conducted to evaluate the impact of the drainage water management practices on hydrology, nutrient loss, and crop yield. Results from a NRCS CIG grant on the efficacy of drainage water management in the Midwest that was planned and executed as part of this Committee's work were presented in a series of papers in the Journal of Soil and Water Conservation in 2012

(<http://www.jswconline.org/content/67/6/167A.full.pdf+html>). Contributions from the Committee's members and the research coordinated by the Committee have been critical in the development of the various States' nutrient development plans (IA - <http://www.nutrientstrategy.iastate.edu/documents>; MN - <http://www.pca.state.mn.us/index.php/view-document.html?gid=19622>) to help curb hypoxia in the northern Gulf of Mexico.

For Objective 2: This Committee has provided a useful regional discussion forum for several members who are concerned about water quality impacts of manure application on drained agricultural land. Although several members secured their own research grant funding to address specific issues relevant to their state, lysimeter and field studies are now underway in several states to assess various manure-based contaminants in subsurface drainage effluents and some methods to better contain these contaminants. Committee collaboration and discussions have fostered a better understanding of the fundamental causes of this problem and which management practices might best be promoted to address this concern.

For Objective 3:

New research activities have been conducted on impact of various biomass production systems on drainage systems, drainage water management to reduce foliar disease, soil salinity management using tile drainage, variation in evapotranspiration between tile drained and undrained fields, controlled drainage and subirrigation, saturated buffers for nitrate removal, and crop and soil responses to waterlogging conditions.

For Objective 4: This multidisciplinary Committee includes research, teaching, and extension personnel, including a number of university faculty with joint extension and research appointments, and representatives from NRCS, ARS, and industry. As good drainage management is critical to both sides of the border, guests from Canada have frequently attended and contributed to annual Committee meetings. Several Committee members have coordinated the development of educational programs and materials (workshops, bulletins, web sites, etc.) for drainage design and management systems, and soil and crop management practices for improved environmental quality in agricultural landscapes. Statewide, regional, and local programming events have been developed to communicate among stakeholders, policy makers, contractors, and the public through various education and outreach activities, such as workshops, drainage research forums, field days, extension conferences, professional meetings, web sites, radio and

TV interviews, and publications. In addition, members of the committee have been successful in acquiring more than \$27,000,000 in outside grants to extend research and education efforts on drainage related issues (see partial list at end of report).

Significant Impacts by Objective

For Objective 1: Through continuous research efforts, we have gained improved understanding and knowledge on using drainage system design and agronomic practices to reduce nitrate-N from drained fields. This research-based information has been assembled and delivered to the general public through state extension activities, conferences, workshops, field days, and publications. Feedback from the participants has been used to continuously improve the research activities. The results have been used by state governments to identify practices that can improve water quality. A major impact of this Committee has been the development of recent NRCS Interim Conservation Standards #739 “Vegetated Subsurface Drain Outlet” and #747 “Denitrifying Bioreactor” as well as the Conservation Practice Standard #554 “Drainage Water Management”. These standards are the necessary first step in getting these practices adopted by farmers across the Midwest.

For Objective 2: Surface applications of liquid manure with a low solid content on soils exhibiting preferential flow are more vulnerable to being transported to subsurface drains. Thus, outreach efforts and field days for producers and CAFO farm advisors are being carried out to encourage paying close attention to timing of manure application, using appropriate management practices (i.e., pre-till or incorporate) when applying to soils exhibiting preferential flow, and reducing or splitting liquid manure application rates. Contractors are also being encouraged to design and utilize appropriate control structures in fields composed of soils exhibiting preferential flow and in which manure will likely be applied. The general public has increased their awareness of the potential for leaching of *E. coli* and other bacterial contaminants to surface water and a BMP has been developed for land application of liquid manure.

For Objective 3: Due to collaborative efforts among Committee members and increasing demand from the public, ND and SD have started new tile drainage research projects and extension activities. A better understanding and knowledge foundation on the impact of tiling on nutrient losses, salt removals, flooding, and other hydrologic impacts in the two states is quickly being developed in the two states and information is being delivered to stakeholders considering implementation of drainage practices. Members are continuing to work on developing site criteria and design standards for end-of-tile-drain denitrifying bioreactors. In addition, the Committee is looking at new methods to increase the efficacy of riparian buffers in tile drained landscapes for reducing nitrate and phosphorus losses to surface waters.

For Objective 4: Through extension activities, thousands of stakeholders annually were served and educated/trained on better understanding of drainage water management. Examples are the annual IA-MN-SD Drainage Research Forums, the Northeast (US) Agricultural and Biological Engineering Conferences, and annual state drainage schools and Land Improvement Contractors of America state meetings. Several web sites also served as the information platform for researchers, agricultural community, and the public on drainage water management (e.g. Agricultural Drainage Management Systems Task Force, <http://hostedweb.cfaes.ohio-state.edu/usdasdru/ADMS/ADMSindex.htm>; and Illinois Drainage Guide, <http://www.wq.uiuc.edu/dg/>). Numerous popular press articles have been written regarding Committee supported research and featuring Committee members. Recent examples include

“Improving water and nutrient use efficiency with Drainage Water” by Tanner Ehmke in Crops and Soils Magazine (<https://www.agronomy.org/publications/cns/pdfs/46/4/6>) and “Conservationists, farmers look to the future” by Dennis Anderson in the Minnesota Star Tribune <http://www.startribune.com/sports/outdoors/165006906.html>.. The impact of this Committee can also be measured by the number of visitors regularly attending Committee meetings. The following is an incomplete list of agencies and industries that have had representatives attend one or more annual meetings:

Universities

Michigan State University
Michigan State University Extension
North Dakota University
Purdue University
South Dakota University
University of Illinois
University of Iowa
University of Manitoba

Government

Ag and Agri Food Canada, MB
EPA, Region 5
Minnehaha Co. SD
Minnesota Dept. Agriculture
North Dakota Water Commission
NRCS, DC, AR, IN, MI, ND, OH, OR, SD, TX
South Dakota Dept. of Agriculture
USDA-ARS, IN, MN. OH

Industry

Agricultural Drainage Management Coalition
AgriDrain Corp., IA
Ecosystems Exchange (ESE), FL
Prinsco, MN
Springfield Plastic, IL
Trimble, OH

NGOs

Farm Bureau, SD
Illinois Soybean Association
Iowa Drainage District Association
The Nature Conservancy

Publications by Committee Members on Drainage Issues.

Peer Reviewed Journal Publications

1. Adeuya, R. N. Utt, J. Frankenberger, L. Bowling, E. Kladvko, S. Brouder and B. Carter, 2012. Impacts of drainage water management on subsurface drain flow, nitrate concentration,

- and nitrate loads in Indiana. *Journal of Soil and Water Conservation* 67(6): 474-484. doi: 10.2489/jswc.67.6.474.
2. Ale, S., L.C. Bowling, M.A. Youssef, S.M. Brouder. 2012. Evaluation of simulated strategies for reducing nitrate-nitrogen losses through subsurface drainage systems. *J. Environ. Qual.* 41:217–228.
 3. Ale, S., L.C. Bowling, S.M. Brouder, J.R. Frankenberger, and M.A. Youssef. 2009. Simulated effect of drainage water management operational strategy on hydrology and crop yield for Drummer soil in the Midwestern United States. *Agricultural Water Management* 96(4):653-665.
 4. Ale, S., L.C. Bowling, J.R. Frankenberger, S.M. Brouder, and E.J. Kladvko, 2010. Climate variability and drain spacing influence on drainage water management system operation. *Vadose Zone Journal*. doi:10.2136/vzj2008.0170.
 5. Ale, S., L.C. Bowling, P.R. Owens, S.M. Brouder and J.R. Frankenberger, 2012. A distributed modeling approach to assess the watershed-scale impact of drainage water management. *Agricultural Water Management*. 107:23-33. doi:10.1016/j.agwat.2012.01.003.
 6. Appelboom, T.W., G.M. Chescheir, R.W. Skaggs, J.W. Gilliam and D.M. Amatya. 2008. Nitrogen balance for a plantation forest drainage canal on the North Carolina coastal plain. *Trans of ASABE* 51(4):1215-1233.
 7. Christianson, L. A. Bhandari, and M. J. Helmers. 2009. Emerging technology: Denitrification bioreactors for nitrate reduction in agricultural waters. *Journal of Soil and Water Conservation* 64:139A-141A.
 8. Christianson, L., A. Bhandari, and M. J. Helmers. 2011. Pilot-scale evaluation of denitrification drainage bioreactors: Reactor geometry and performance. *Journal of Environmental Engineering* 137: 213-220.
 9. Christianson, L., A. Bhandari, and M.J. Helmers. 2012. A practice-oriented review of woodchip bioreactors for agricultural drainage. *Applied Engineering in Agriculture* 28(6): 861–874.
 10. Christianson, L., A. Bhandari, M.J. Helmers, K. Kult, T. Sutphin, and R. Wolf. 2012. Performance evaluation of four field-scale agricultural drainage denitrification bioreactors in Iowa. *Trans. ASABE* 55(6): 2163–2174.
 11. Christianson, L., A. Castelló, R. Christianson, A. Bhandari, and M. J. Helmers. 2010. Technical Note: Hydraulic property determination of denitrifying bacteria fill media. *Applied Engineering in Agriculture* 26(5):849-854.
 12. Christianson, L., J. Tyndall, and M.J. Helmers. In press (Accepted September 2013). Financial comparison of seven nitrate reduction strategies for Midwestern agricultural drainage. *Water Resources and Economics*.
 13. Christianson, L., M.J. Helmers, A. Bhandari, and T. Moorman. 2013. Internal hydraulics of an agricultural drainage denitrification bioreactor. *Ecological Engineering* 52: 298-307.
 14. Christianson, L., N. Hoover, A. Bhandari, and M. Helmers. 2012. Technical note: The potential of municipal yard waste to be denitrification bioreactor fill. *Applied Engineering in Agriculture* 26(5): 849–854.
 15. Christianson, L., R. Christianson, M.J. Helmers, C. Pederson, and A. Bhandari. 2013. Modeling and calibration of drainage denitrification bioreactor design criteria. *Journal of Irrigation and Drainage Engineering* 139: 699-709.
 16. David, M.B., S.J. Del Grosso, X. Hu, E. P. Marshall, G.F. McIsaac, W.J. Parton, C. Tonitto, and M.A. Youssef. 2009. Modeling denitrification in a tile-drained, corn and soybean agroecosystem of Illinois, USA. *Biogeochemistry* 93:7-30.
 17. Davidson, E.A., David, M.B., Galloway, J.N., Goodale, C.L., Haeuber, R., Harrison, J.A., Howarth, R.W., Jaynes, D.B., Lowrance, R.R., Nolan, B.T., Peel, J.L., Pinder, R.W., Porter,

- E., Snyder, C.S., Townsend, A.R., and Ward, M.H. 2012. Excess nitrogen in the U.S. environment: Trends, risks, and solutions. *Issues in Ecology* #15. Ecological Society of America, Washington, D.C.
18. Delbecq, Benoit A., Jason P. Brown, Raymond J.G.M. Florax, Eileen J. Kladvko, Adela P. Nistor, and Jess M. Lowenberg-DeBoer. 2012. The impact of drainage water management technology on corn yields. *Agron. J.* 104:1100-1109.
 19. Flores-López, F., Z. M. Easton, L.D. Geohring and T.S. Steenhuis. 2011. Factors affecting dissolved phosphorus and nitrate concentrations in ground and surface water for a valley dairy farm in the Northeastern US. *Water Environment Research* 83(2):116-127.
 20. Helmers, M.J., R. Christianson, G. Brenneman, D. Lockett, and C. Pederson. 2012. Water table, drainage, and yield response to drainage water management in southeast Iowa. *Journal of Soil and Water Conservation* 67(6): 495–501.
 21. Helmers, M.J., X. Xhou, J.L. Baker, S.W. Melvin, and D.W. Lemke. 2012. Nitrogen loss on tile-drained Mollisols as affected by nitrogen application rate under continuous corn and corn-soybean rotation systems. *Canadian Journal of Soil Science* 92: 493-499.
 22. Jaynes, D.B. 2011. Confidence bands for measured economically optimal nitrogen rates. *Precision agriculture* 12:196-213.
 23. Jaynes, D.B. 2012. Changes in yield and nitrate losses from using drainage water management in Central Iowa, USA. *J. Soil and Water Conservation* 67:485–494. 2012Jaynes, D.B., T.C. Kaspar, and T.S. Colvin. 2011. Economically optimal nitrogen rates of corn: Management zones delineated from soil and terrain attributes. *Agron. J.* 103:1026-1035.
 24. Jia, X., T.M. DeSutter, Z. Lin, W.M. Schuh, and D.D. Steele. 2012. Subsurface drainage and subirrigation effects on water quality in southeast North Dakota. *Transactions of the ASABE* 55(5): 1757–1769.
 25. Jin, C.X., G.R. Sands, J. Wiersma, H. Kandel. 2008. The Influence of Subsurface Drainage on Soil Temperature in a Cold Climate. *Journal of Irrigation and Drainage Engineering (ASCE)* 134(1):83-88.
 26. Kaspar, T.C., D.B. Jaynes, T.B. Parkin, T.B. Moorman, and J.W. Singer. 2012. Effectiveness of oat and rye cover crops in reducing nitrate losses in drainage water. *Agricultural Water Management*. Online pub.DOI: 10.1016/j.agwat.2012.03.010.
 27. Lawlor, P. A., M. J. Helmers, J. L. Baker, S. W. Melvin, and D. W. Lemke. 2008. Nitrogen application rate effects on nitrate-nitrogen concentrations and losses in subsurface drainage. *Trans. ASABE* 51(1): 83-94.
 28. Lawlor, P.A., M.J. Helmers, J.L. Baker, S.W. Melvin, and D.W. Lemke. 2011. Comparison of liquid swine manure and ammonia nitrogen application timing on subsurface drainage water quality in Iowa. *Trans. ASABE* 54(3):973-981.
 29. Lowery, B., C. Cox, D. Lemke, P. Nowak, K. Olson, and J. Strock. 2009. The 2008 Midwest flooding impact on soil erosion and water quality: implications for soil erosion control practices. *Journal of Soil and Water Conservation* 64:166A.
 30. Luo, W. G.R. Sands, M. Youssef, J.S. Strock, I. Song, and D. Canelon. 2010. Modeling the impact of alternative drainage practices in the northern corn belt with Drainmod-NII. *Ag. Water Mgmt.* 97:389-398.
 31. Malone, R.W., Jaynes D.B., Ma, L., Nolan, T.B., Meek, D.W., Karlen, D.L. 2010. Soil-test N recommendations augmented with PEST optimized RXWQM simulations. *J. Environ. Qual.* 39(5): 1711-1723.
 32. Moorman, Thomas B., Parkin, Timothy B., Kaspar, Thomas C., Jaynes, Dan B. 2010. Denitrification activity, wood loss, and N₂O emissions over 9 years from a wood chip bioreactor. *Ecological Eng.* 36(11): 1567-1574.

33. Nangia, V., P. H. Gowda, D. J. Mulla, G. R. Sands. 2008. Water Quality Modeling for Impacts of Fertilizer Management Practices on Nitrate-N losses in Tile Drains at the Field-Scale. *Journal of Environmental Quality* 37:296-307.
34. Naz, B., and L.C. Bowling. 2008. A decision analysis system for mapping of subsurface drainage systems. *Trans. ASABE* 51:1937-1950.
35. Nelson, K.A., and C.G. Meinhardt. 2011. Soybean yield response to pyraclostrobin and drainage water management. *Agron. J.* 103(5): 1359-1365.
36. Nelson, K.A., and R.L. Smoot. 2012. Corn hybrid response to water management practices on claypan soil. Online. *Int. J. Agron.* doi:10.1155/2012/925408. pp. 10
37. Nelson, K.A., Meinhardt, C. G., and Smoot, R. L. 2012. Soybean cultivar response to subsurface drainage and subirrigation in Northeast Missouri. Online. *Crop Management* doi:10.1094/CM-2012-0320-03-RS. pp. 9.
38. Nelson, K.A., R.L. Smoot, and C.G. Meinhardt. 2011. Soybean response to drainage and subirrigation on a claypan soil in Northeast Missouri. *Agron. J.* 103:1216-1222.
39. Nelson, K.A., S.M. Paniagua, and P.P. Motavalli. 2009. Effect of polymer coated urea, irrigation, and drainage on nitrogen utilization and yield of corn in a claypan soil. *Agron. J.* 101:681-687.
40. Qi, Z. and M. J. Helmers. 2009. Soil water dynamics under winter rye cover crop in central Iowa. *Vadose Zone Journal* 9(1): 53-60.
41. Qi, Z. and M. J. Helmers. 2010. The conversion of permittivity as measured by a PR2 capacitance probe into soil moisture values for Des Moines loess soils in Iowa. *Soil Use and Management* 26(1): 82-92.
42. Qi, Z., L. Ma, M.J. Helmers, L.R. Ahuja, and R.W. Malone. 2012. Simulating nitrate-nitrogen concentration from a subsurface drainage system in response to nitrogen application rates using RZWQM2. *Journal of Environmental Quality* 41: 289–295.
43. Qi, Z., M. J. Helmers, and A. Kaleita. 2011. Soil water dynamics under various land covers in Iowa. *Agricultural Water Management* 98(4): 665-674.
44. Qi, Z., M. J. Helmers, R. Malone, and K. Thorp. 2011. Simulating long-term impacts of winter rye cover crop on hydrologic cycling and nitrogen dynamics for a corn-soybean crop system. *Trans. ASABE* 54(5): 1575-1588.
45. Qi, Z., M.J. Helmers, R.D. Christianson, and C.H. Pederson. 2011. Nitrate-Nitrogen losses through subsurface drainage under various agricultural land covers. *Journal of Environmental Quality*. 40(5): 1578-1585.
46. Rijal, I., X. Jia, X. Zhang, D. D. Steele, T. F. Scherer, and A. Akyuz. 2012. Effects of subsurface drainage on evapotranspiration for corn and soybean in Southeast North Dakota. *J. of Irrigation and Drainage* 138(12): 1060–1067.
47. Rijal, S., X. Zhang, and X. Jia. 2012. Estimating surface soil moisture in the Red River Valley of the North Basin using Landsat 5 TM data. *Soil Science Society of America Journal*. In press.
48. Riley, K. D., M. J. Helmers, P A. Lawlor, and R. Singh. 2009. Water balance investigation of controlled drainage in non-weighting lysimeters. *Applied Engineering in Agriculture* 25(4): 507-514.
49. Salazar, O., I Wesstrom, M.A. Youssef, R.W. Skaggs and A. Joel. 2008. Evaluation of the DRAINMOD-NII model for predicting nitrogen losses in southeast Sweden, *Agricultural Water Management*, 96(2):267-281.
50. Sands, G.R., I. Song, L.M. Busman, B. Hansen. 2008. The Effects of Subsurface Drainage Depth and Intensity on Nitrate Load in a Cold Climate. *Transactions of the ASABE* 51(3):937-946.

51. Scherer, T. F., and X. Jia. 2010. A simple method to measure the flow rate and volume from tile drainage pump stations. *Applied Engineering in Agriculture*. 26(1):79-83.
52. Schilling, K. E., and M. J. Helmers. 2008. Effects of subsurface drainage tiles on streamflow in agricultural watersheds: exploratory hydrograph analysis. *Hydrological Processes* 22(23):4497-4506.
53. Schilling, K. E., and M. J. Helmers. 2008. Tile drainage as Karst: Conduit flow and diffuse flow in a tile-drained watershed. *Journal of Hydrology* 349: 291-301.
54. Schilling, K., P. Jindal, N. Basu, and M.J. Helmers. 2011. Impact of artificial subsurface drainage on groundwater travel times and baseflow discharge in an agricultural watershed, Iowa (USA). *Hydrological Processes* DOI: 10.1002/hyp.8337.
55. Schipper, Louis A., Robertson, Will D., Gold, Arthur J., Jaynes, Dan B., Cameron, Stewart C. 2010. Denitrifying bioreactors-An approach for reducing nitrate loads to receiving waters. *Ecological Eng.* 36(11): 1532-1543.
56. Singer, J.W., Malone, R.W., Jaynes, D.B., Ma, L. 2011. Cover crop effects on nitrogen load in tile drainage from Walnut Creek, Iowa, using Root Zone Water Quality Model (RZWQM). *Agricultural Water Management*. 98(10):1622-1628.
57. Singh, R., M. J. Helmers, A. L. Kaleita, and E. S. Takle. 2009. Potential impact of climate change on subsurface drainage in Iowa's subsurface drained landscapes. *Journal of Irrigation and Drainage Engineering* 135:459-466.
58. Skaggs, R.W., M.A. Youssef, and G.M. Chescheir. 2012. Methods to estimate effects of drainage water management on annual nitrogen losses to surface waters. *Trans. ASABE* 55(3):799-808.
59. Skaggs, R.W., M.A. Youssef, G.M. Chescheir. 2012. DRAINMOD: Model use, calibration and validation. *Trans. ASABE* 55(4):1509-1522.
60. Stenback, G., W. Crumpton, K. Schilling, and M. J. Helmers. 2011. Rating curve estimation of nutrient loads in Iowa Rivers. *Journal of Hydrology* 396: 158-169.
61. Sui, Y. and J.R. Frankenberger, 2009. Nitrate loss from subsurface drains in an agricultural watershed using SWAT 2005. *Trans. Am. Soc. Agric. Biol. Eng* 51(4): 1263-1272.
62. Thorp, K.R., Jaynes, D.B and Malone, R.W. Simulating the Long-Term Performance of Drainage Water Management Across the Midwestern United States. *Trans. ASABE* 51(3):961-976.
63. Thorp, K.R., M.A. Youssef, D.B. Jaynes, R.W. Malone, and L. Ma. 2009. DRAINMOD-N II: Evaluated for an agricultural system in Iowa and compared to RZWQM-DSSAT. *Trans. ASABE* 52(5):1557-1573.
64. Tian, S., M.A. Youssef, R.W. Skaggs, D.M. Amatya, and G.M. Chescheir. 2012. DRAINMOD-FOREST: Integrated modeling of hydrology, soil carbon and nitrogen dynamics, and plant growth for drained forests. *J. Environ. Qual.* 41:764-782.
65. Tian, S., M.A. Youssef, R.W. Skaggs, D.M. Amatya, and G.M. Chescheir. 2012. Modeling water, carbon, and nitrogen dynamics for two drained pine plantations under intensive management practices. *Forest Ecology and Management* 264:20-36.
66. Tian, S., M.A. Youssef, R.W. Skaggs, D.M. Amatya, G.M. Chescheir. 2012. Temporal variations and controlling factors of nitrogen export from an artificially drained coastal forest. *Environmental Science and Technology* 46(18):9956-9963.
67. Zhang, W., V.L. Morales, M.E. Cakmak, A.E. Salvucci, L.D. Geohring, A.G. Hay, J-Y Parlange, and T.S. Steenhuis. 2010. Colloid transport and retention in unsaturated porous media: Effect of colloid input concentration. *Environmental Science and Technology* 44 (13):4965-4972.

68. Zhang, X., X. Jia, J. Yang, and L. Hu. 2010. Comparison of sensible heat flux measured by eddy-covariance and large aperture scintillometer over a corn field with subsurface drainage. *Journal of Agricultural and Forest Meteorology*. 150:1182-1191.
69. Zhou, X., M.J. Helmers, Z. Qi. Field scale modeling of subsurface tile drainage using MIKE SHE. Submitted December 2011 to *Applied Engineering in Agriculture*.

Book Chapters

1. Liebman, M., M.J. Helmers, and L. Schulte Moore. 2011. Integrating conservation with biofuel feedstock production. In: M. Schnepf (ed.), *Managing Agricultural Landscapes for Environmental Quality II*. Soil and Water Conservation Society of America, Ankeny, IA.
2. Jia, X., and T. Scherer. 2013. Reducing cost of water quality monitoring in tile drainage outflow using electrical conductivity as a surrogate. In *Using 21st Century Technology to Better Manage Irrigation Water Supplies*, Seventh International Conference on Irrigation and Drainage Proceedings. Edited by Wallin, B. T., and S. S. Anderson. U.S. Committee on Irrigation and Drainage, Denver, CO. Pp 213–225.
3. Malone, R.W., D.W. Meek, L. Ma, L., D.B. Jaynes, B.T. Nolan, and D.L. Karlen. 2011. Quality assurance of weather data for agricultural system model input. *In: Ahuja, L.R., Ma, L.,(ed.)*. *Methods of Introducing System Models into Agricultural Research*. Madison, WI. American Society of Agronomy, Crop Science of America and Soil Science Society of America. p. 283-296.
4. Nolan, B.T., R.W. Malone, L. Ma, C.T. Green, M.N. Fienen, and D.B. Jaynes. 2011. Inverse modeling with RZWQM2 to predict water quality. In L. Ahuja and L. Ma (ed.), *Methods of Introducing System Models into Agricultural Research, Advances in Agricultural Systems Modeling 2*.
5. Strock, J.S., G.R. Sands, and M.J. Helmers. 2011. Subsurface drainage design and management to meet agronomic and environmental goals. In: J.L. Hatfield and T.J. Sauer (eds.), *Soil Management: Building a Stable Base for Agriculture*. American Society of Agronomy and Soil Science Society of America.

Extension or Non-refereed Publications

1. Adhikari, U., D.M. Reinhold and Timothy Harrigan. 2012. 12th Annual American Ecological Engineering Society Meeting “Nutrient Recovery and Pathogen Reduction in Duckweed Based Constructed Wetlands.” Syracuse, New York. (June 7-9, 2012).
2. Adhikari, U., T.M. Harrigan, D.M. Reinhold and A. Johnson. 2011. ASABE Annual International Meeting, "Seasonal Variation in Pathogen Removal Efficiency of Treatment Wetlands Subjected to Pulse Loading." Louisville, Kentucky. (August 7-10,2011).
3. Adhikari, U., T.M. Harrigan, D.M. Reinhold and A.A. Waldhorn. 2012. NCERA217: Drainage Design and Management Practices to Improve Water Quality “Pathogen Removal Efficiency of Constructed Wetlands Subjected to Pulsed Pathogen Loading.” Dundee, Michigan. (April 17-19, 2012).
4. Adhikari, U., T.M. Harrigan, D.M. Reinhold, A.A. Waldhorn and J.Li. 2011. 8th International Phytotechnology Conference, "Nutrient Recovery and Pathogen Reduction in Duckweed Based Constructed Wetlands." Portland, Oregon. (September 13-16, 2011).
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Thesis or Dissertations

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2. Ale, S. 2009. Impact of Drainage Water Management on Watershed Nitrate Load in West Central Indiana, PhD Dissertation, Purdue University, West Lafayette, IN.
3. Pang, X. 2011. Impact of subsurface drainage on water availability in the Red River Basin. M.S. thesis, Fargo, North Dakota: North Dakota State University, Department of Agricultural and Biosystems Engineering.
4. Rijal, I. 2011. Reference evapotranspiration and actual evapotranspiration measurements in southeastern North Dakota. M.S. thesis, Fargo, North Dakota: North Dakota State University, Department of Agricultural and Biosystems Engineering.
5. Royem, A. Alisa. 2012. Fate and transport of agricultural nutrients in macro-porous soils. M.S. Thesis. Cornell University, Ithaca, NY. 47pp.
6. Utt, Nathan J. 2010. Impacts of drainage water management on crop growth, soil quality, and nitrate loads. Purdue University, M.S. Thesis. 169pp.

NCERA MEMBER, LOCATION	SUPPORTING AGENCY AND AGENCY ACTIVE AWARD/PENDING PROPOSAL NUMBER	TOTAL \$ AMOUNT	TITLE OF PROJECT
D. Jaynes, ARS	Leopold Center for Sustainable Agriculture	\$39,881	Reconnecting Iowa Riparian Buffers with Tile Drainage.
D. Jaynes, ARS	Leopold Center for Sustainable Agriculture	\$36,647	Reconnecting Riparian Buffers with Tile Drainage: An Emerging Technology to Reduce Nitrate Loss from Croplands
D. Jaynes, ARS	USDA AFRI	\$489,191	Denitrification within Saturated Riparian Buffers Re-designed to Remove Nitrate from Artificial Subsurface Drainage
D. Jaynes, ARS	USDA/NRCS-CIG	\$ 195,623	Demonstrate and evaluate saturated buffers at field scale to reduce nitrates and phosphorus from surface and subsurface field drainage systems
L. Goering, NY	NFWF/NRCS-CIG	\$284,683	Subsurface Drainage Water Management to Reduce Manure Contaminated Drain Discharge
L. Goering, NY	USDA/NIFA-Federal Formula Hatch Funds	\$90,000	Evaluating Denitrifying Bioreactors for Treatment of Subsurface Drainage Discharges.,
L. Goering, NY	USDA/NRCS-CIG	\$530,043	Managing Subsurface Drain Discharge Effluents with Bioreactors
L. Goering, NY	USDA-NRI-CSREES	\$ 85,572	Assessing Farm-Source E. coli and Salmonella Mobility to Water
M. Helmers, IA	Iowa Corn Promotion Board	\$36,657	Nutrient use and land management: A component of the Iowa landscape systems initiative
M. Helmers, IA	Iowa Soybean Association	\$66,757	Drainage water quality from manure-treated soybean crops: Assessment of woodchip bioreactors for edge-of-field treatment
M. Helmers, IA	USDA-NRCS	\$485,850	Evaluating Planting Techniques for the Successful Establishment of Cover Crop Mixtures and Single Species in Iowa
M. Helmers, IA	Iowa Department of Agriculture and Land Stewardship	\$559,867	Water and nutrient research: In-field and offsite strategies
M. Helmers, IA	Iowa Department of Agriculture and Land Stewardship	\$42,643	Demonstration of the impacts of mixed annual-perennial agroecosystems on water quality
M. Helmers, IA	Iowa Corn Promotion Board	\$19,840	Nutrient use and land management: A component of the Iowa landscape systems initiative
M. Helmers, IA	Farm Pilot Project	\$87,907	Impacts of cover crops, nitrogen timing, and nitrogen source on nitrate-nitrogen export

M. Helmers, IA	Iowa Pork Producers Council	\$54,265	Occurrence and movement of antibiotics, antibiotic resistant bacteria and resistance genes in tile-drained agricultural fields receiving swine manure
M. Helmers, IA	Iowa Pork Producers Council	\$73,900	Evaluating nutrient export with subsurface drainage water from manure applied sub-watersheds planted to soybeans
M. Helmers, IA	Iowa Flood Center	\$17,868	Quantifying field water balance components as affected by shifts in land-use patterns: Implications for minimizing agricultural impacts on water quality in Iowa
M. Helmers, IA	Leopold Center for Sustainable Agriculture	\$162,100	Investigation of bacteria transport and resistance mechanisms and implications for water quality from confinement swine and beef grazing production systems in Iowa
M. Helmers, IA	Iowa Department of Agriculture and Land Stewardship	\$220,819	Impacts of cropping, tillage, and phosphorus management on soil and phosphorus loss with surface runoff
M. Helmers, IA	Iowa Department of Agriculture and Land Stewardship	\$492,058	Water and nutrient research: In-field and offsite strategies
M. Helmers, IA	USDA-AFRI	\$599,521	Nitrogen and greenhouse gas balances in constructed wetlands in agricultural watersheds within the Upper Mississippi River Basin Iowa
M. Helmers, IA	Iowa Department of Agriculture and Land Stewardship	\$49,734	Soil nutrient mass balance study
M. Helmers, IA	Leopold Center for Sustainable Agriculture	\$18,898	Drainage water quality impacts of current and future agricultural management practices
M. Helmers, IA	USDA-NIFA-AFRI-CAP	\$19,992,144	Climate change, mitigation, and adaptation in corn-based cropping systems
M. Helmers, IA	Iowa Dept. of Economic Development	\$299,532	Hydrologic impacts of drainage systems
M. Helmers, IA	NASA and USDA-NIFA-AFRI	\$726,508	Biofuel cropping systems for feedstock production and greenhouse gas mitigation
M. Helmers, IA	Iowa Department of Agriculture and Land Stewardship	\$472,058	Water and nutrient research: In-field and offsite strategies
M. Helmers, IA	U.S. EPA	\$225,999	Improving a watershed scale model to integrate wetlands into watershed planning
M. Helmers, IA	Iowa Department of Agriculture and Land Stewardship	\$410,842	Water and nutrient research: In-field and offsite strategies
M. Helmers, IA	Leopold Center for Sustainable Agriculture	\$250,000	Integration of water, nutrient and carbon cycling under diverse annual-perennial plant community systems in agricultural landscapes
M. Helmers, IA	Leopold Center for Sustainable Agriculture	\$55,000	Evaluating denitrifying bioreactors for edge-of-field nitrogen management in Iowa's tile-drained landscapes
M. Helmers, IA	Iowa Department of Agriculture and Land Stewardship	\$314,601	Water and nutrient research: In-field and offsite strategies
M. Helmers, IA	Iowa Department of Agriculture and Land Stewardship	\$528,520	Water and nutrient research: In-field and offsite strategies
X. Jia	ND State Water Commission	\$9,825	Subirrigation with high sodium adsorption ratio groundwater and its effect on soil and water quality
X. Jia	ND State Water Commission	\$13,283	Feasibility of the use of tile drainage for subsurface irrigation in the Red River Valley and its impact on soil chemical and physical properties
X. Jia	USDA-NRCS	\$42,056	Tile drainage and subirrigation evaluations in Richland County for effects on soil and water quality.
X. Jia	USDA-CSREES	\$100,000	Impact of subsurface drainage on water availability in the Red River Basin.
X. Jia	USEPA	\$304,361	Red River Valley tile drainage water quality assessment phase II.
X. Jia	NCR SARE	\$199,706	Effect of optimal water management for sustainable and profitable crop production and improvement of water quality in Red River Valley.