The impact of manure management and cover crops on drainage water quality and yields

Brian Dougherty, agricultural engineering field specialist, Iowa State University Extension and Outreach; Carl Pedersen, ag specialist, Iowa State University; Dan Andersen, associate professor, Agricultural and Biosystems Engineering, Iowa State University; Matt Helmers, professor, Agricultural and Biosystems Engineering, Iowa State University; Antonio Mallarino, professor, Agronomy, Iowa State University

Introduction

Water table management through the use of subsurface drainage has resulted in very productive lands in the Upper Mississippi River watershed, where subsurface drainage systems were installed to convert the prairie-wetlands landscape into agricultural production areas. Improved subsurface drainage results in less surface runoff, which can have higher concentrations of sediment, P, ammonium-nitrogen, and bacteria than subsurface drainage. The trade-off for improved subsurface drainage is a significant increase in nitrate-N and dissolved P losses (Gilliam et al., 1999; Ohio EPA, 2013). The movement of N from agricultural fields via subsurface drainage waters is a major factor in nonpoint source pollution of surface waters and ultimately the Gulf of Mexico, where it has been implicated as a primary contributor to the hypoxic zone (Rabalais et al., 1996; Mitsch et al., 2001). The primary objective of this project is to determine the impact of different cropping management practices on subsurface drainage water quality and crop yields.

Methods

Data were collected between 2008 and 2015 at the Iowa State University Northeast Research and Demonstration Farm (NERF) near Nashua, IA. The site has a subsurface drainage water monitoring system installed in thirty-six 1 acre plots with a drain spacing of 95 ft. and a depth of four ft. A detailed description of the subsurface drainage system can be found in Kanwar et al., (1999). Subsurface drainage flow depth in inches was calculated by dividing total flow volume by the drainage area. Manure was injected after fall harvest on 30 in. spacing with a tanker equipped with low-disturbance injectors. The cereal rye cover crop was seeded with a no-till drill in the fall after harvest and manure injection. Spring termination of the cover crop prior to corn was done with glyphosate approximately 3 to 4 days prior to planting for the 2008 - 2011 crop years and approximately 10 to 12 days prior to planting for the 2012 - 2015 crop years. The cover crop was terminated within ±2 days of soybean planting.

Five treatments compared the effect of timing and source of N on subsurface drain water quality and crop yields in a corn-soybean (CS) rotation and two treatments compare the effect of manure use on water quality under continuous corn (CC) rotation with and without stover removal. Spring applied UAN (urea-ammonium nitrate) with cereal rye cover crop and fall applied manure treatments were managed with no-till while the rest of the treatments used fall chisel plowing as the method of tillage. Treatment abbreviations are: FM = Fall Manure, SU = Spring UAN, CC = Continuous Corn, NT = No-Till, -S = Stover removal (30% by mass), and +R = Rye cover crop. Details are shown in Table 1.

Table 1. Experimental treatments for the 2008 through 2015 water quality study at the ISU Northeast Research Farm, Nashua, IA.

Treatment	Timing and source of N	N Rate lb ac^{-1}	Crop rotation	Tillage
SU150	Spring UAN	150	Corn	Chisel plow corn fall
	-	-	Soybean	Field cultivate both spring
SU150NT+R	Spring UAN	150	Corn + Rye cover	No-Till
	-	-	Soybean + Rye cover	No-Till
FM150	Fall Manure	150	Corn	Chisel plow corn fall
	-	-	Soybean	Field cultivate both spring
FM150/100	Fall Manure	150	Corn	Chisel plow corn fall
	Fall Manure	100	Soybean	Field cultivate both spring
FM150NT	Fall Manure	150	Corn	No-Till
	-	-	Soybean	No-Till
FM200CC	Fall Manure	200	Corn	Chisel plow fall
	Fall Manure	200	Corn	Field cultivate spring
FM200CC-S	Fall Manure	200	Corn + Stover removal	Chisel plow fall
	Fall Manure	200	Corn + Stover removal	Field cultivate spring

Results

Water quality

The effects of treatments on nitrate-N concentrations in subsurface drainage water are summarized in Figures 1 (corn plots) and 2 (soybean plots). Flow-weighted annual average nitrate-N concentrations (FWANC) in drainage from plots receiving swine manure were higher in comparison to plots receiving UAN when averaged over the 8-yr period. The SU150NT+R treatment had the lowest FWANC concentrations, with an 8-yr average of 10.4 mg N L^{-1} in corn plots and 9.6 mg N L^{-1} in soybean plots. FM150/100 had consistently higher FWANC in drainage compared to all other CS rotations.

Applying fall manure to both corn and soybeans resulted in 31% higher FWANC compared to applying manure only to the corn phase of the rotation. The 8-yr average FWANC for FM150/100 was 27.4 mg N L^{-1} in corn plots and 19.4 mg N L^{-1} in soybean plots. Comparing results from the SU150 treatments, there was a significantly lower FWANC for SU150NT+R, where the rye cover crop was used. Combining data across the corn and soybean phases of the rotation shows approximately 30% lower FWANC with the rye cover crop. The FWANC was not affected by the tillage comparison between FM150 and FM150NT or the corn grain vs. grain plus stover harvest between FM200CC and FM200CC-S.

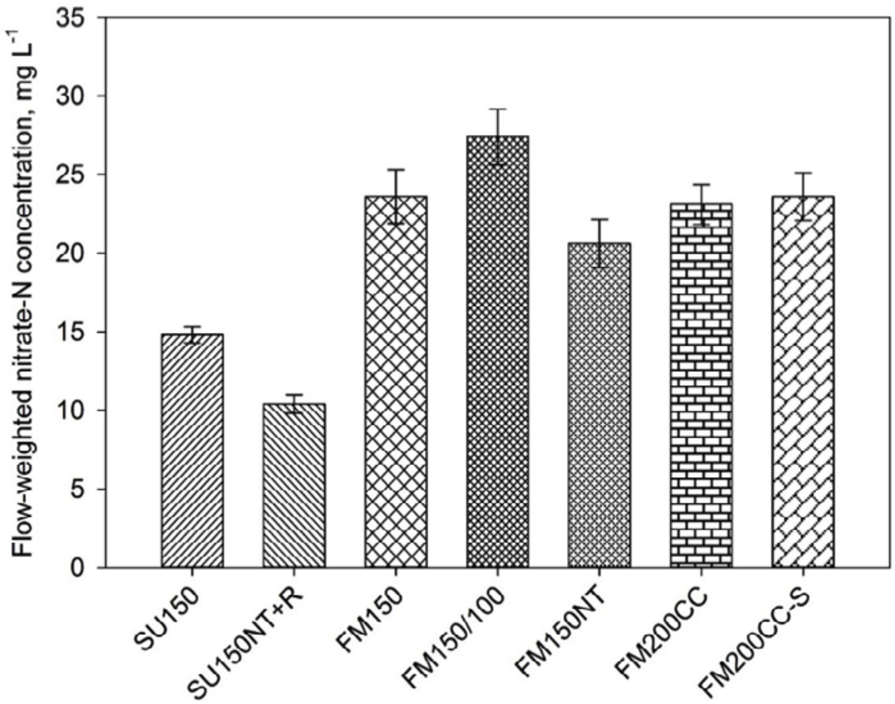

Figure 1. Average flow-weighted nitrate-N concentrations in drainage water from treatments planted to corn.

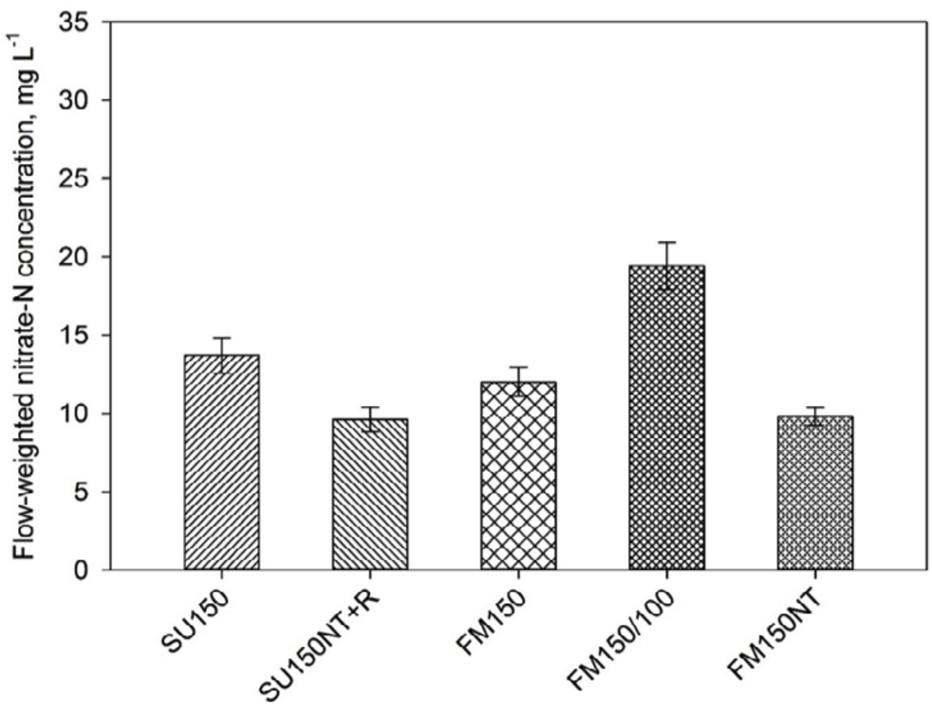

Figure 2. Average flow-weighted nitrate-N concentrations in drainage water from treatments planted to soybeans.

Cumulative N losses via drainage water (lb N ac^{-1}) averaged across rotations over the 8-yr period are shown in Figure 3. There was no significant difference between the FM150 and FM150NT treatments, suggesting that tillage did not significantly affect N loss. SU150 and SU150NT+R did not differ in total

N loss even though nitrate-N concentrations were lower in SU150NT+R. This is due to significantly greater subsurface drainage flow through SU150NT+R plots (8-yr average of 5.7 in yr^{-1}) compared to SU150 (8-yr average of 4.1 in yr^{-1}). The highest and lowest rotation average losses were in FM200CC and SU150NT+R, with an average of 30.7 and 13.6 lb N ac^{-1} yr^{-1}, respectively. Cumulative N losses from FM200CC and FM200CC-S were not significantly different.

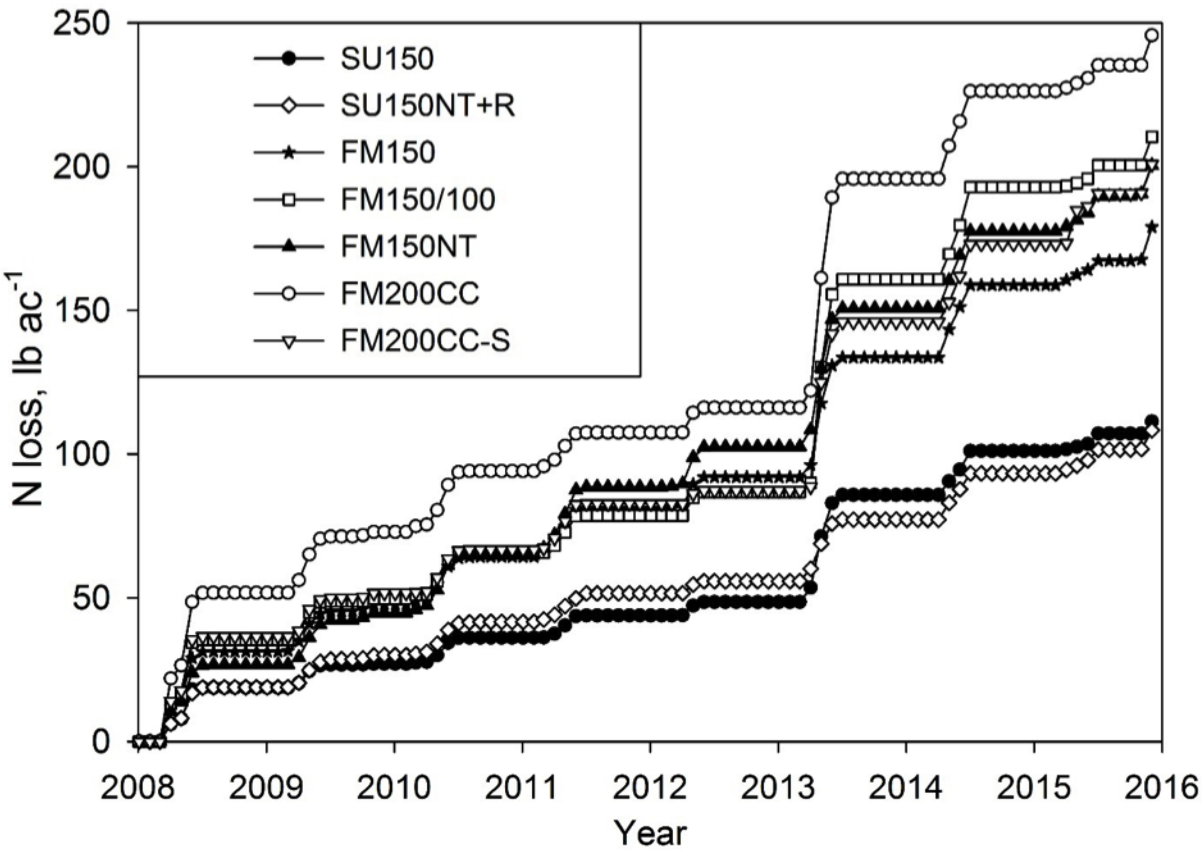

Figure 3. Treatment average cumulative nitrate-N losses via drainage water over 8 years.

Cover crops

Cereal rye aboveground biomass and N uptake at NERF is detailed on in Table 2, along with a comparison to other studies conducted in Iowa. Rye biomass growth preceding the soybean crop was significantly greater than growth preceding the corn crop in 2011, 2012, and 2013, with the remainder of the years showing no significant difference. The 8-yr average biomass growth was not significantly different preceding corn vs. soybeans.

Table 2. Cereal rye biomass growth and N in aboveground biomass at the Northeast Research Farm in Nashua compared to other locations in Iowa. Locations are listed in order from north to south.

Location	Years in dataset	Biomass before corn *dry lb ac⁻¹*	N uptake before corn *lb ac⁻¹*	Biomass before soybeans *dry lb ac⁻¹*	N uptake before soybeans *lb ac⁻¹*
NERF Nashua, IA	8	380	12.5	696	21.4
Gilmore City, IA	9	230	8.0	946	17.0
Ames, IA	7	1423	-	1518	-
Crawfordsville, IA	2	1098	25.9	2071	30.4

Gilmore City data is from Qi et al. (2011) and Waring, (2016). Ames data is from Basche et al. (2016). Crawfordsville data is from Pantoja et al. (2016).

Yields

Eight-yr average corn yields are shown in Figure 4. Averaged over the eight years, all CS rotation treatments with tillage had statistically greater corn yield compared to the NT treatments. Eight-yr average corn yields from SU150, FM150, and FM150/100 were not significantly different, with yields of 197, 188, and 190 bu ac^{-1}, respectively. Corn yield for SU150NT+R and FM150NT were not significantly different. Yields in the CC treatments were substantially lower in 2008 but appeared to improve over time relative to the other treatments. No-till management in the FM150NT treatment resulted in a significant reduction in yield relative to FM150. Similarly, the combination of NT and cover crop in the SU150NT+R treatment led to an even greater reduction in yield relative to SU150, suggesting that both NT management and the cereal rye cover crop caused yield reductions in this study. It is important to note that fall swine manure was applied at inconsistent N rates among treatments and years, which could add to the annual variation in corn yields in treatments receiving manure.

In soybeans (Figure 5), 8-year averages show that treatments where manure was applied only for the corn phase resulted in statistically greater soybean yield than in treatments receiving UAN fertilizer. Soybean yield for FM150/100 was not significantly different from yield of FM150, indicating that the application of manure prior to soybeans did not affect soybean yield. We also saw no difference in soybean yields when comparing NT to tillage in the FM150NT and FM150 treatments. However, there was a statistically significant soybean yield decrease in the SU150NT+R treatment relative to SU150. This suggests that while NT did not appear to affect soybean yields in this study, there was a yield reduction due to the cover crop.

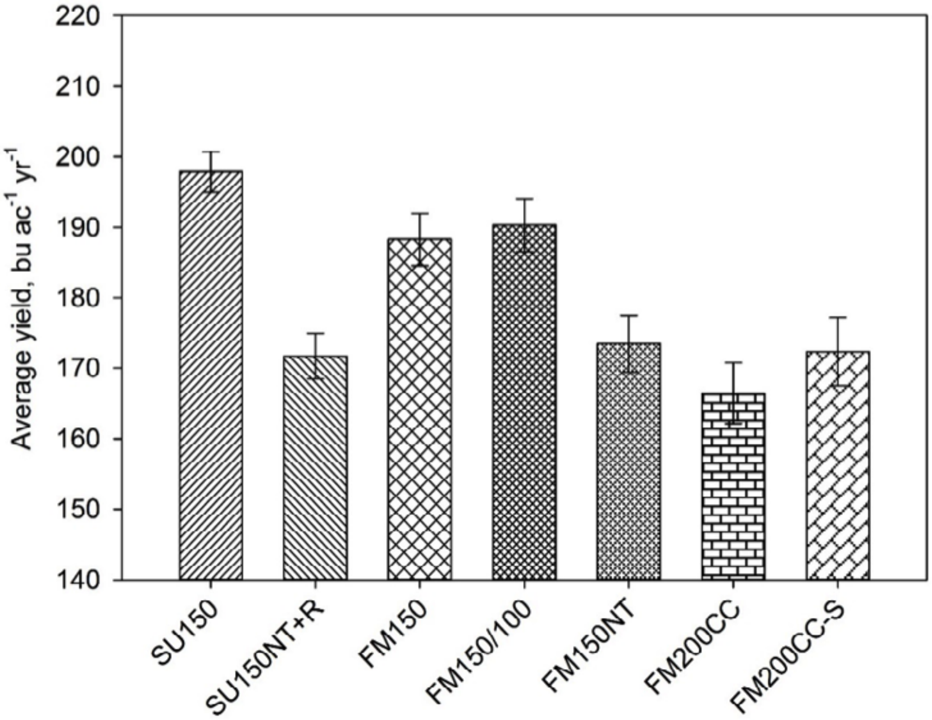

Figure 4. Average corn yields from 2008 to 2015.

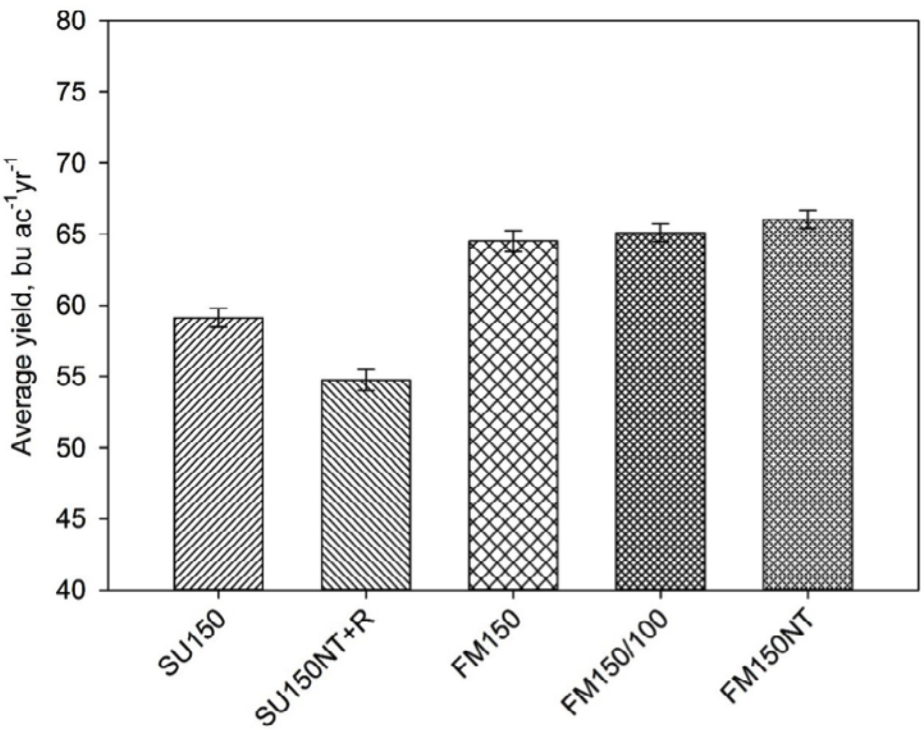

Figure 5. Average soybean yields from 2008 to 2015.

Conclusions

Results from this study indicate that tillage had little impact on FWANC in drainage water in a corn-soybean rotation. Swine manure applied prior to both corn and soybeans led to an increase in FWANC compared to swine manure applied only before corn in a corn-soybean rotation. Residue removal over 8 years had little impact on nitrate-N concentrations or yields in a continuous corn treatment. Results show that cereal rye cover crops have the potential to reduce nitrate-N concentrations in drainage water but management changes may be required to alleviate yield impacts. Further research is needed to determine the impact of spring vs. fall-applied manure on nitrate-N leaching losses.

Acknowledgements

Funding for this research was provided by the Leopold Center for Sustainable Agriculture and the Iowa Nutrient Research Center. This research was made possible by Ken Pecinovsky and other staff at the Northeast Research and Demonstration Farm in Nashua, IA.

References

Basche, A.D., T.C. Kaspar, S.V. Archontoulis, D.B. Jaynes, T.J. Sauer, et al. 2016. Soil water improvements with the long-term use of a winter rye cover crop. Agric. Water Manag. 172: 40–50. doi: 10.1016/j.agwat.2016.04.006.

Gilliam, J.W., J.L. Baker, and K.R. Reddy. 1999. Water quality effects of drainage in humid regions. Agricultural drainage. American Society of Agronomy : Crop Science Society of America : Soil Science Society of America, Madison, Wis., USA. p. 801–830

Kanwar, R.S., D. Bjorneberg, and D. Baker. 1999. An automated system for monitoring the quality and quantity of subsurface drain flow. J. Agric. Eng. Res. 73(2): 123–129. doi: 10.1006/jaer.1998.0398.

Mitsch, W.J., J.W. Day, J.W. Gilliam, P.M. Groffman, D.L. Hey, et al. 2001. Reducing nitrogen loading to the Gulf of Mexico from the Mississippi River Basin: Strategies to counter a persistent ecological problem. BioScience 51(5): 373–388.

Ohio EPA. 2013. Ohio Lake Erie Phosphorus Task Force II final report. Ohio Department of Agriculture, Ohio Department of Natural Resources, Ohio Environmental Protection Agency, Ohio Lake Erie Commission.

Pantoja, J.L., K.P. Woli, J.E. Sawyer, and D.W. Barker. 2016. Winter rye cover crop biomass production, degradation, and nitrogen recycling. Agron. J. 108(2): 841. doi: 10.2134/agronj2015.0336.

Qi, Z., M.J. Helmers, R.D. Christianson, and C.H. Pederson. 2011. Nitrate-nitrogen losses through subsurface drainage under various agricultural land covers. J. Environ. Qual. 40(5): 1578–1585. doi: 10.2134/jeq2011.0151.

Rabalais, N., R. Turner, D. Justic, Q. Dortch, W. Wiseman, et al. 1996. Nutrient changes in the Mississippi River and system responses on the adjacent continental shelf. Estuaries 19(2): 386–407. doi: 10.2307/1352458.

Waring, E.R. 2016. Thesis - Quantifying the impact of a winter cereal rye cover crop and no-till on soil moisture, soil temperature, and nitrate loss via subsurface drainage. Iowa State University.