2018 Annual Report for NREC Project (2014-5-360847-320)

Nitrogen Management Systems in Tile-Drained Fields: Optimizing Yields while Minimizing Losses

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Objectives

The overall goal of this project is to improve our understanding of current and new N management systems on corn yields and nitrate losses from tile-drained fields in Illinois.

Specific objectives are to:

1. To conduct on-farm field trials of current and new N management systems for typical corn/soybean rotations, evaluating both the yield response and the tile losses of nitrate.
2. To determine when and why tile nitrate losses occur in these management systems, during both corn and soybean rotations.

Length of Project

This project is concluding the 4th year of funding. However, 2015 was a setup year as no fertilizer N was applied or cover crops planted in the fall of 2014. We now have 3 complete years of drainage data following the setup year of 2015.

Treatments

Note: Full rate of fertilizer N was 160 lbs/A from 2016-2018. For the 2019 growing season, we have increased the full rate to 180 lbs/A based on corn and fertilizer N prices this past fall using the MRTN calculator.

1. Full rate of fertilizer N (anhydrous NH_3) applied in the fall with nitrapyrin.
2. 3-way split application with 50% applied in the fall (as anhydrous NH_3 with nitrapyrin), followed by 25% applied as UAN at planting, followed by 25% side-dressed as NH_3 anhydrous with placement between rows by RTK.
3. Full rate of fertilizer N (anhydrous NH_3 without nitrapyrin) applied in the spring before planting with placement between strips by RTK.
4. Reduced rate (75%) of fertilizer N (anhydrous NH_3 without nitrapyrin) applied in the spring before planting with placement between strips by RTK.
5. 2-way split application with 50% applied in the spring before planting (anhydrous NH_3 without nitrapyrin) followed by 50% side-dressed as NH_3 anhydrous with placement between rows by RTK.
6. 2-way split application as in treatment #5 but with cover crops (oats-radish mixture following soybean and cereal rye after corn). **Note:** we switched to annual ryegrass and radish after soybean this past fall.

Project Update:

Field work was timely and crop growth proceeded quickly in 2018, with good corn yields and outstanding soybean yields. Strip till appears to be transforming this site as drainage continues to improve. Dan Schaefer manages field work and establishes N treatments at this site (Refer to the IFCA annual report from Dan Schaefer for more details) and Eric Miller conducts much of the custom field work.

- Oct. 5, 2017: Oat and radish planted after soybean (broadcast)
- Oct. 29, 2017: Cereal rye planted after corn (drilled)
- Nov. 14, 2017: Soil sampled for nitrate and soil health
- Nov. 14, 2017: Strip till for corn and fall anhydrous ammonia fertilizer applied
- Dec 1-2, 2017: Strip till for soybean
- Dec. 4, 2017: Oat and radish biomass collected
- April 21, 2018: Spring anhydrous ammonia applied
- May 7, 2018: Cereal rye biomass collected and cereal rye terminated with glyphosate
- May 8-9, 2018: Soybean planted in 30 inch rows
- May 11-12, 2018: Corn planted; N applied at planting for the 3 way split N treatment
- June 6, 2018: Side-dress UAN fertilizer applied
- June 18, 2018: Corn harvested and chlorophyll measured at V7
- June 19, 2018: Soil sampled for inorganic N
- July 9, 2018: Corn ear leaf sampled and chlorophyll measured at R1
- July 26, 2018: Chlorophyll measured on corn at R3
- August 30, 2018: Whole plant soybean biomass sampled prior to leaf drop at late R6
- September 5, 2018: Aerial seeding of cereal rye into corn and annual ryegrass and radish into soybean
- September 18-19, 2018: Whole plant corn biomass sampled at R6 (PM)
- October 2, 2018: Soybean combine-harvest
- October 9, 2018: Corn combine-harvest
- October 22, 2018: Annual ryegrass and radish biomass collected before hard freeze
- October 28, 2018: Anhydrous ammonia applied and strips made in corn
- November 8, 2018: Soil sampled for soil health and inorganic N

We have an excellent relationship with the landowner and regularly meet with him and his to discuss the operation. He understands the relevance of our findings and recognizes the importance of continuing this unique on-farm study.

Results:

Weather patterns and total rainfall from a given year may affect soil moisture status and tile flow in the subsequent year, therefore, weather data from the past two years were compared with the 30-yr average at a nearby municipality (Tuscola, IL).

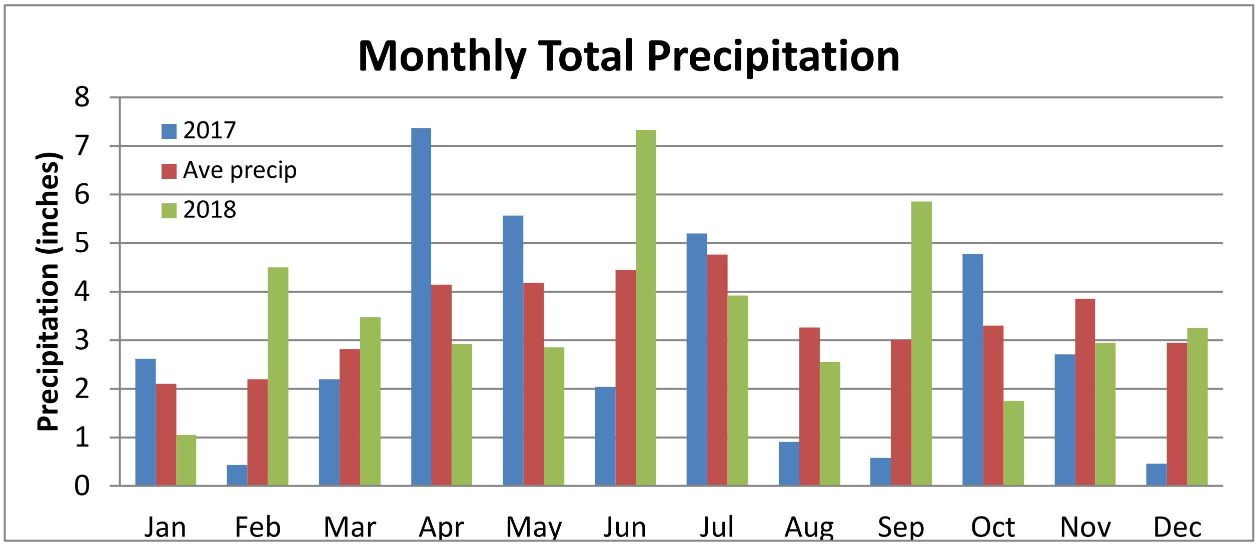


Figure 1. Monthly total precipitation at this site for 2017 and 2018 compared with the 30 year average at Tuscola, IL.

Annual precipitation in 2017 (34.9 inches) was 10% below the 30 yr average of 39 inches; however, more than 7 inches of rain occurred in April creating extreme field ponding (Figure 1). The months of August and September of 2017 received less than 30% of average precipitation stressing crops, especially soybean during the important grain filling period. Nearly 5 inches of rain occurred in October; however, there was minimal field ponding.

Annual precipitation in 2018 (42.4 inches) was 9% above the 30-yr average. The months of April and May received below average precipitation, which allowed the soil to better absorb and hold the 7+ inches of rain that fell in June (Figure 1). There was field ponding; however, the water receded rather quickly due to high temperatures and a rapidly growing crop.

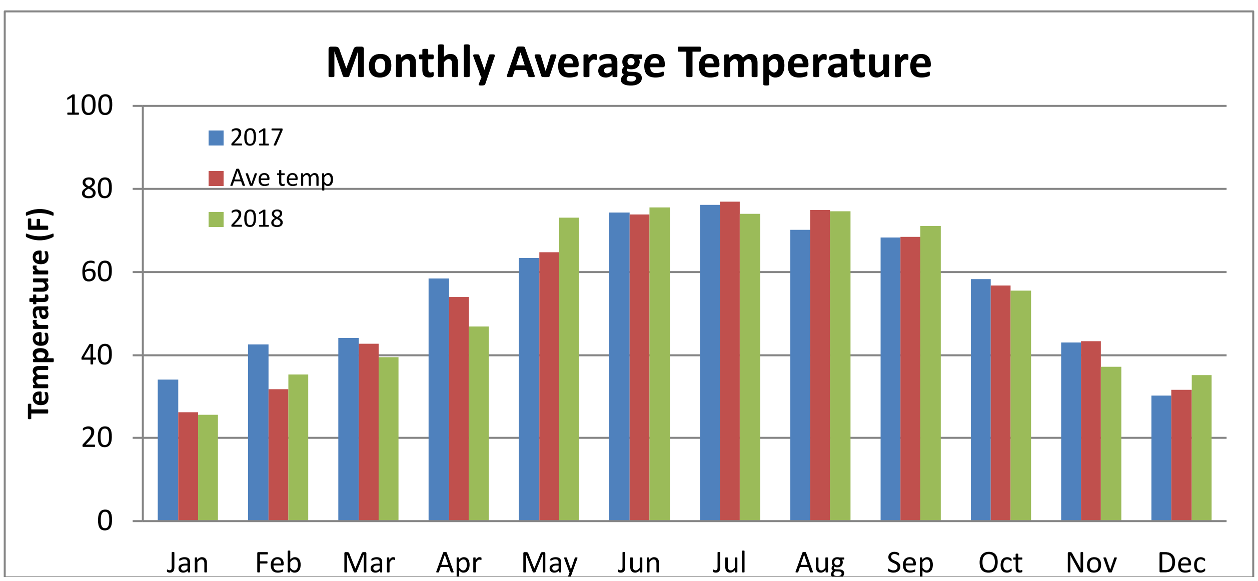


Figure 2. Monthly average temperature at this site for 2017 and 2018 compared with the 30 year average at Tuscola, IL.

Temperature patterns were very different between the two years (Figure 2) as 2017 could be characterized as having a warm winter but a cool growing season; whereas, 2018 had a cold spring (2nd coldest April on record) and an extremely warm start to the growing season (warmest May on record).

Cover crop growth in the spring of 2018 lagged well behind the growth produced in the previous year. In mid-April we were approximately 4 weeks behind last year in growing degree days, which greatly reduced cereal rye growth and uptake of soil N. Cereal rye above ground biomass was 0.6 tons/A in 2018 versus 1.2 tons/A in 2017. Soil mineralization would also have been limited in the spring of 2018, yet crop growth was rapid due to the warm start to the growing season.

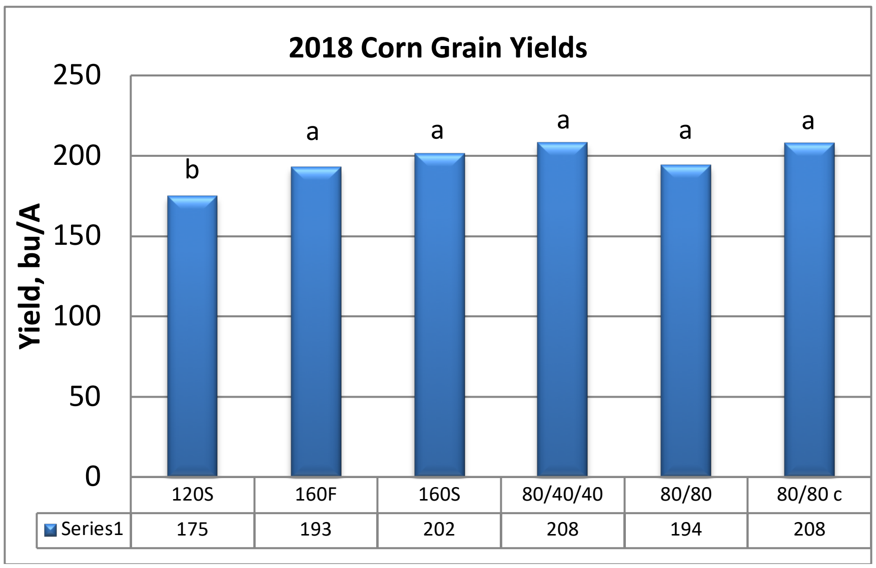


Figure 3. Corn grain yields across the 6 N treatments; P<0.05

Corn yields in 2018 were good averaging 201 bu/A across the 5 full N rate treatments (Figure 3). As in the previous 3 years, the reduced N rate treatment lost about 20 bu/A. There were no significant differences among the treatments based on timing of N application; only the reduced rate was significantly less. Stalk nitrate test values showed all plots to be N deficient. **Note:** Full N rate will be 180 lbs/A in 2019.

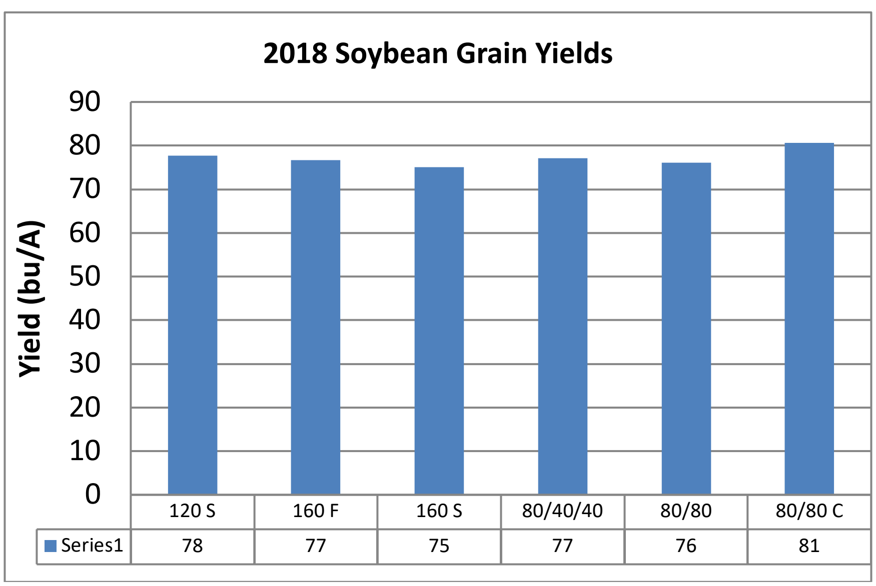


Figure 4. Soybean grain yields across the 6 corn N treatments; P<0.05

Soybean yields in 2018 were excellent averaging 77 bu/A across all corn N treatments with no significant differences (Figure 4). There appeared to be a positive effect of cover crop (at P<0.1) on soybean yield in 2018. This 6% yield increase during an excellent year offsets the decrease in soybean yield following cereal rye in the challenging year of 2017 (dry Aug. and Sept.)

Table 1. Annual tile discharge (in inches of runoff), flow weighted mean (FWM) nitrate-N concentration, and nitrate load from six corn N treatments during the corn production phase of the 2-yr rotation in 2016, 2017, and 2018. **Note:** Annual data based on a water year (Oct. 1 of the previous year through Sept. 30 of the named year). Significance at P<0.05.

Corn															
N Treatment	Tile Discharge (inches)			Tile NO_3-N Conc. (FWM) (ppm)						Tile NO_3-N Load (lbs/A)					
	2016	2017	2018	2016		2017		2018		2016		2017		2018	
120S	9.8	10.7	9.2	10.0	b	8.9	bc	5.9	b	22.3	bc	21.5	bc	12.3	b
160F	10.1	11.6	9.8	13.6	a	12.6	a	9.5	a	30.8	a	33.0	a	20.9	a
160S	10.1	12.2	8.7	9.1	b	10.2	ab	6.5	b	20.9	c	28.2	ab	13.1	b
80/40/40	9.4	12.5	8.1	12.5	a	10.7	ab	9.7	a	26.8	ab	30.3	ab	18.2	ab
80/80	9.5	10.6	8.3	9.1	b	9.1	bc	6.5	b	19.6	c	21.9	bc	12.3	b
80/80C	10.7	11.2	9.6	8.9	b	6.9	c	6.0	b	21.5	c	17.6	c	13.1	b

Annual tile discharge averaged across all corn plots in 2018 was 9 inches, representing 21% of the annual precipitation, whereas tile discharge represented 33% of the annual precipitation in 2017. It is important to note that there are no significant differences based on treatments for annual tile discharge (Table 1). Timing of precipitation as well as antecedent soil moisture (especially before intense storm events) controls tile flow during the non-growing season, which is when the vast majority of tile flow occurs. All tiles began flowing continuously following 4.5 inches of rain in February of 2018 (Figure 1). Although annual precipitation in 2018 was above average, annual tile discharge was approximately 22% less than in 2017. High rates of evapotranspiration led to cessation of tile flow in early summer.

Tile FWM nitrate concentrations have tended to decline during the study period for all 6 N treatments regardless of initial level in 2016 (Table 1). This is likely due to a combination of applying a lower fertilizer N rate than had been used in 2015, but also the fact that temperatures last spring (March and April) were abnormally cold, likely limiting soil N mineralization.

Regardless of the declining trend in annual tile nitrate concentration over the past 3 years, timing of fertilizer N application had a profound effect on the pattern of tile nitrate loss (Figures 7A and B) and on the annual FWM nitrate concentrations across the treatments. It is clear that tiles from plots receiving the full or half rate of fertilizer N in the fall transport the greatest nitrate concentrations and tile loads (Table 1 and Figure 5). The annual tile FWM nitrate concentration and nitrate load for 160S treatment in 2017 is an exception to the declining trend (Table 1).

The oat and radish cover crop appeared to have no effect on tile nitrate concentration or load (demonstrated by referring to 2016 data for 80/80C vs. 80/80). There was a carryover from the beneficial effect of the large cereal rye crop ahead of the 2016 soybean crop, which lowered tile nitrate concentrations throughout the winter of 2016-2017 until spring fertilizer N was applied in 2017 (Figure 7B).

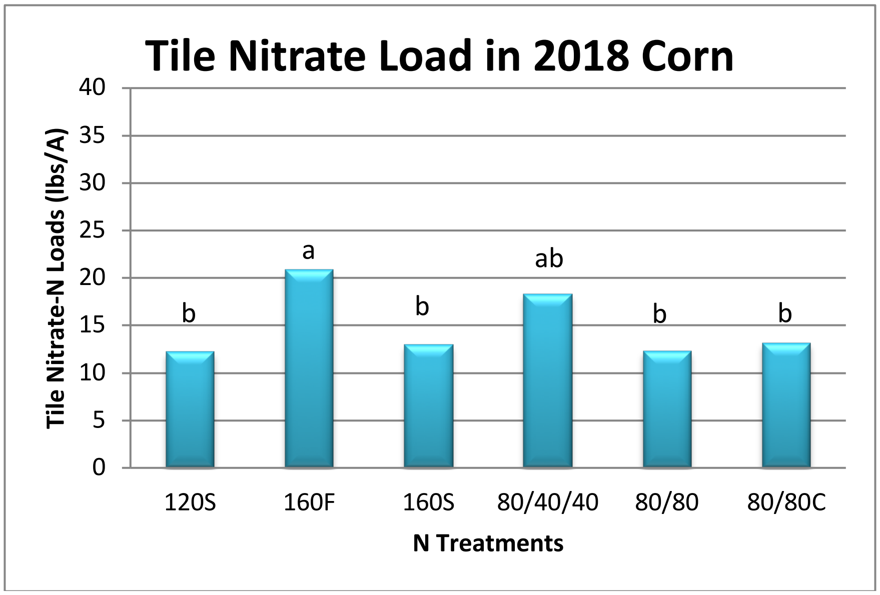


Figure 5. Tile nitrate load from corn plots across the 6 N treatments; P<0.05

Tile nitrate loads were lower in 2018 than in 2017 as previously discussed. Plots with the full rate of fertilizer N applied in the fall lost significantly more tile nitrate (8 lbs/A) than plots with the full rate of spring N. As we have seen in past years, there was no reduction in tile nitrate from plots with oats and radish (80/80C vs. 80/80).

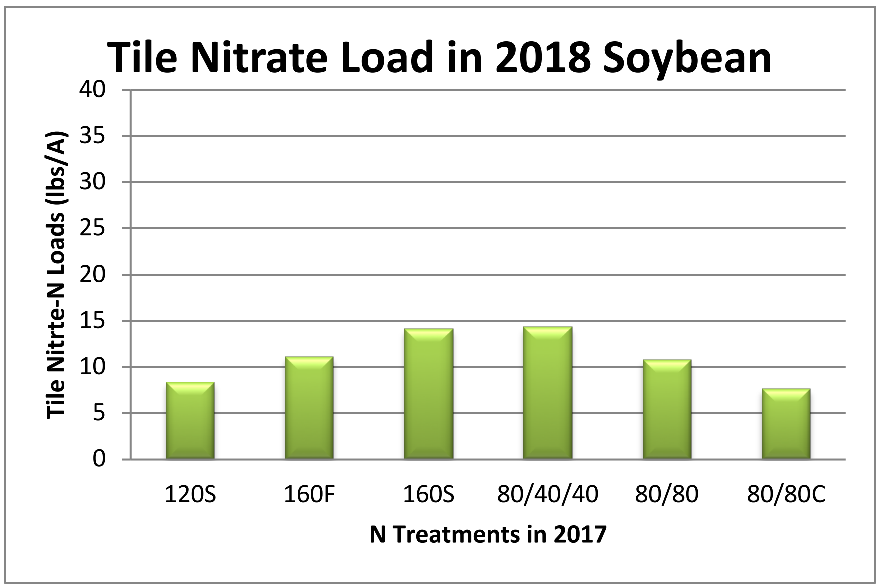
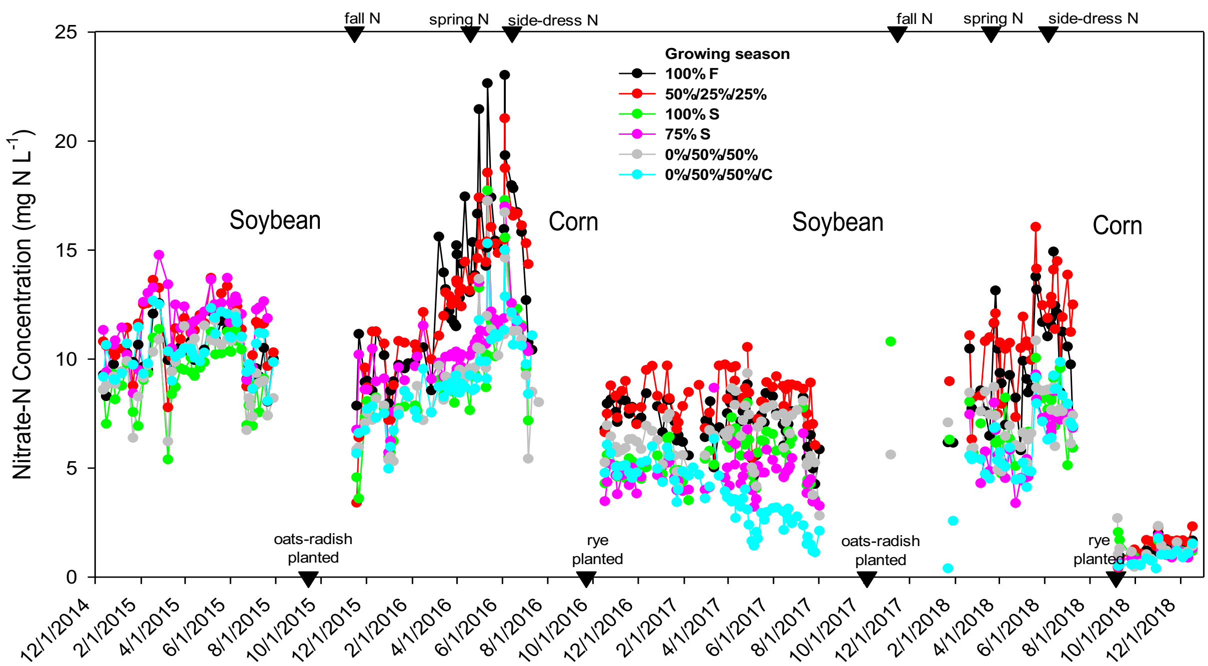


Figure 6. Tile nitrate load from soybean plots across the 6 N corn treatments; P<0.05

There were no significant differences for tile nitrate load from soybean plots in 2018, regardless of the N treatment from the previous year. These data suggest that tile nitrate losses following soybean are often greater than 10 lbs/A.

When averaged across the past 3 years, we have not seen a significant grain yield reduction associated with the application of fertilizer N in the fall (3-yr corn average not shown). Although there is a greater tile nitrate load under fall N management, the increase in tile load only represents 5% of the fertilizer. However, this same 8 lbs/A represents 38% of the tile load in 2018 (Figure 5). This level of tile nitrate loss is not enough to significantly decrease corn yield as ample soil mineralization can likely make up for this shortfall. Although tile nitrate loads were greater following corn, our results show that substantial amounts of tile nitrate can occur following unfertilized (for N) soybean production (Figure 6).



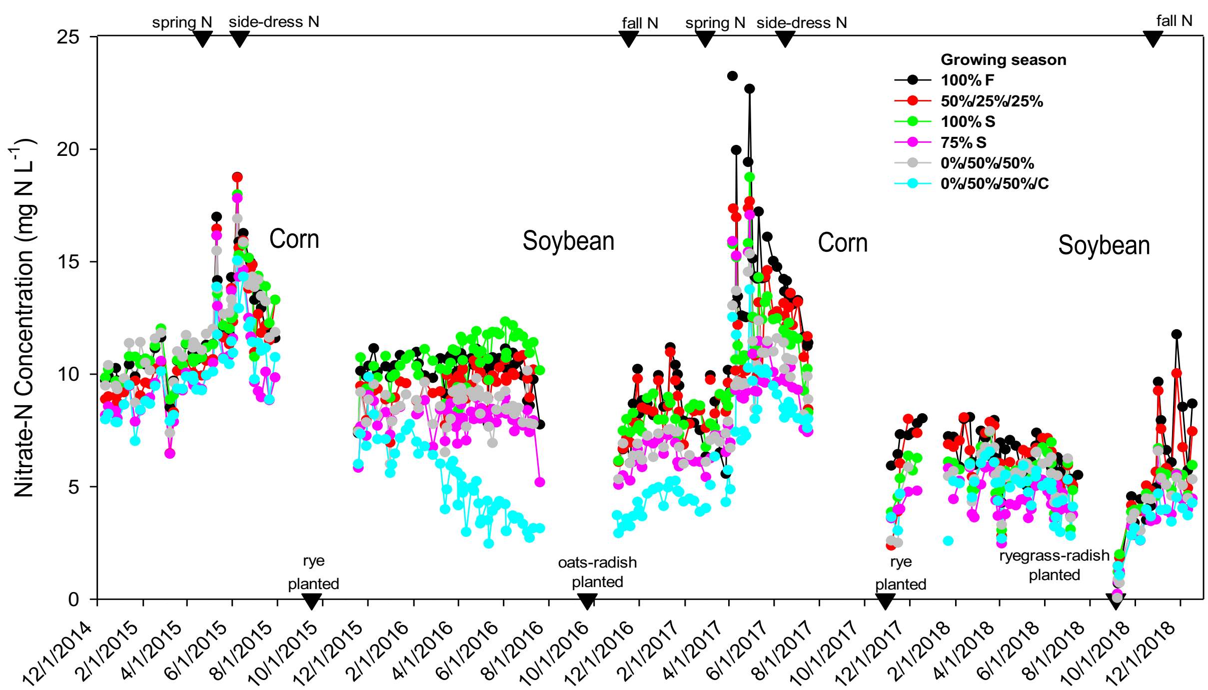


Figure 7A (top) and **7B** (bottom) show tile nitrate concentrations for six corn N treatments for the past four years. **Note:** Each dot represents the average of the 3 replicates and shaded areas represent the crop growing season (planting date to harvest date).

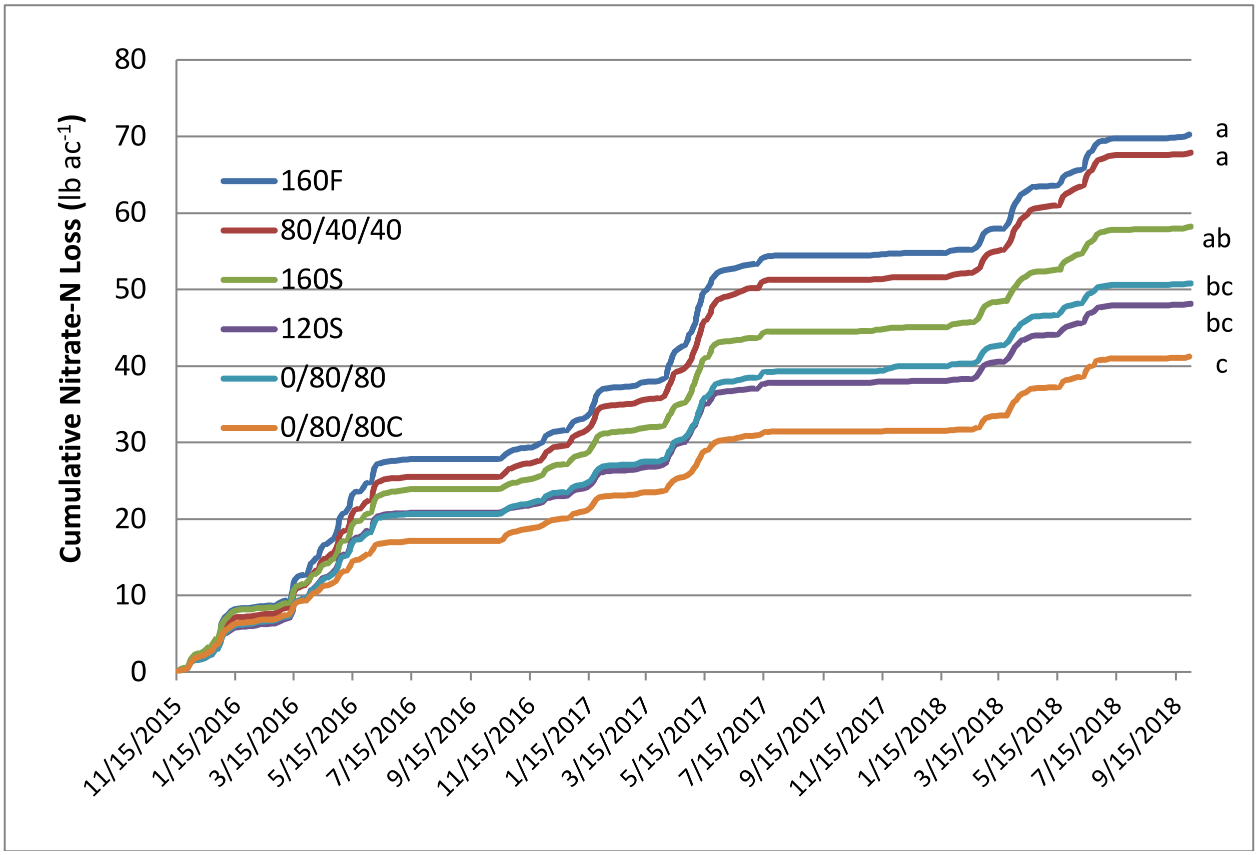
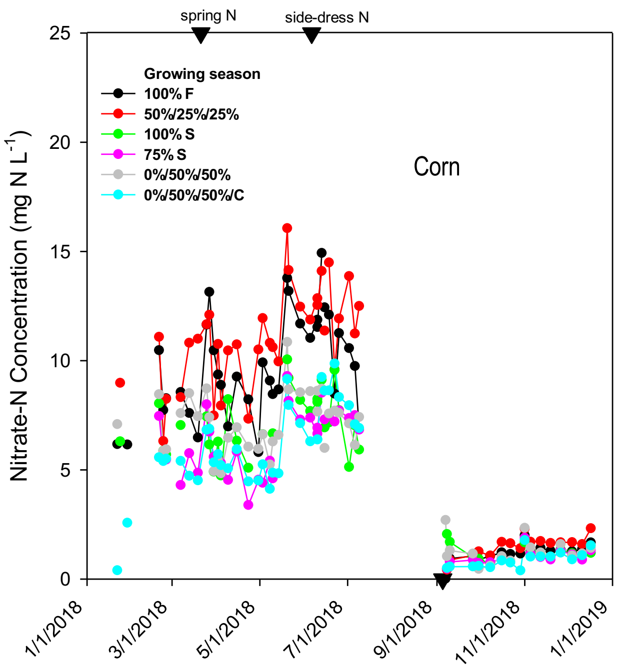


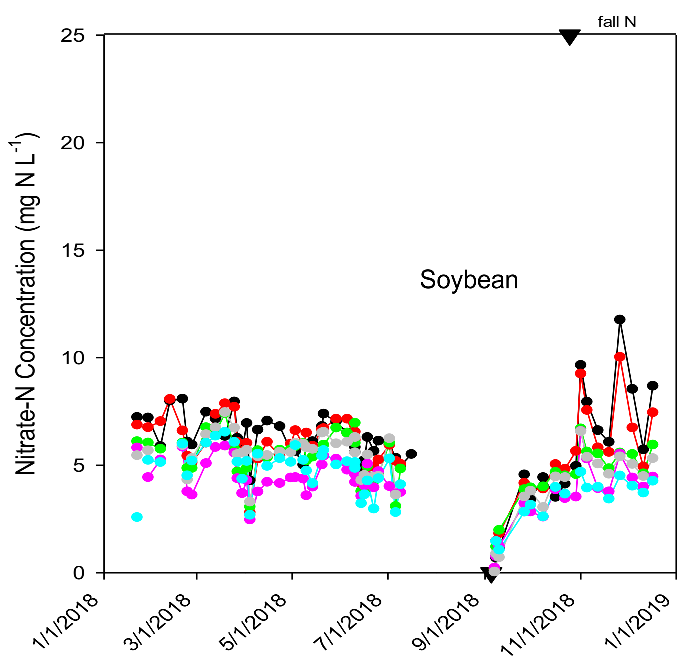
Figure 8. Cumulative daily tile nitrate load from the fall of 2015 through the summer of 2018 for each of the six corn N treatments averaged over both phases of the rotation.

Cumulative tile nitrate loads over the past three years ranged from a high of 70 lbs/A with the full rate of fertilizer N in the fall (160F) to a low of 41 lbs/A with the 50:50 split application and cover crops (80/80C) (Figure 8). The three year average tile nitrate loss on an annual basis ranged from a high of 23 lbs/A (160F) to a low of 13 lbs/A (80/80C), representing a 43% decrease in tile nitrate load. This value is close to the 2035 goal put forth in the IL NLRS.

It is interesting to note that after three years, cumulative tile nitrate loads for the reduced N rate treatment (120 lbs/A) and the 2-way split application treatment of the full rate (160 lbs/A) were similar (47.9 vs. 50.6 lbs/A), yet the reduced rate treatment decreased corn yields by about 10%. Therefore, although N deficiency limited corn yields; nitrate continued to leach from the reduced rate treatment. This indicates that tile nitrate loads are not simply a matter of excessive N fertilization, suggesting that the leaching of mineralized N during the non-growing season is also an important source of tile nitrate.

Overall, our results clearly implicate timing of N fertilization as a major factor controlling tile nitrate export and that cereal rye after corn can be an effective management strategy to further reduce tile nitrate loads.





Figures 9A (left) and **9B** (right). Tile nitrate concentrations during the past year and into the 2019 water year. **Note:** Each dot represents the average of the 3 replicates and shaded areas represent the crop growing season (planting date to harvest date).

With nearly 6 inches of rain in September of 2018 (Figure 1), tile flow began in early September and has been continuous throughout October, November, and December. The occurrence of continuous tile flow throughout the fall is unusual and may provide more evidence as to the influence of previous crop on net soil N mineralization. Both sets of 18 tiles (corn vs. soybean) started to flow with low tile nitrate concentrations (<2 ppm) indicating that both corn and soybean crops left little inorganic N in the soil following crop growth this past summer (Figures 9A and B).

Tile nitrate concentrations from corn plots have remained below 2 ppm throughout the fall (Figure 9A), while tile nitrate from soybean plots has continued to increase to 5 ppm by the end of December (Figure 9B). Note: the black and red dots represents the two fall N treatments where fall N was applied in late October of 2018 (Figure 9B). These data suggest that there is greater net soil N mineralization following soybean than corn; and that a significant portion of annual tile load (and therefore river load) is likely derived from mineralization of soil organic matter following soybean production. Cover crops may be the best way to manage and decrease this type of N loss compared to other proposed strategies. Note: Tilling soybean residue in the fall may make this problem worse as aeration of soil would stimulate microbial growth and mineralization, making more nitrate-N susceptible to leaching during the winter and spring.

Summary

This study continues to add to our understanding of when and how nitrate is lost via tile drainage in corn and soybean rotations. **Our current research documents the complexities of nitrate leaching and shows that tile nitrate loads are not simply a reflection of excessive N fertilization, but rather the interaction of weather patterns (temperature and precipitation), timing and rate of fertilizer N application, and previous crop.**

Outreach

In 2018, Mr. Gentry was invited to present results from this study (and the Piatt County Study) at 16 events including: Illinois Fertilizer and Chemical Association Conference on January 16; Illinois Farm Bureau Winter Conservation Workshop on January 17; Illinois Association of Drainage Districts Conference on January 18; Conservation Cropping Seminar Series on January 23, 24, and 25; Central Illinois Professional Wastewater Operators Winter Meeting on January 31; Central States Water Environment Association 2018 Government Affairs Seminar held jointly with AWA Mini Conference on February 28; Illinois Chapter of the Soil and Water Conservation Society on March 16; Risk Management Conference hosted by the Illinois Sustainable Ag Partnership on June 19; webinar (Partnership for Ag Resource Management) on August 9; webinar (Illinois Soybean Association) on August 21; IL 4R Field Day on October 23; American Society of Agronomy annual meeting on November 6; poster at IL NLRS workshop on November 13; and IL Certified Crop Advisor conference on December 12.

Project Budget (Jan.1 through Dec. 31)

C3801: 1-552850-875000-191100 (NREC agreement 2014-02347):

Personnel:	**Salary**	**Fringe benefits**
Administrative/professional	$76,061.85	$29,101.42
Other academic (intern)	5,872.73	51.09
Wages	44,660.68	2,869.50
Total personnel	$126,595.26	
Total fringe benefits	32,022.01	
Travel (domestic)	18,775.00	
Supplies	9,802.92	
Contractual services	(2,731.65)	
Facilities and administration	20,475.51	
Tuition		
Total expenditures	$204,939.05	

We thank NREC for their continued support of this research. This study is providing needed information on nitrogen management systems, and associated tile nitrate losses, while supporting high-yielding row crop agriculture.