2019 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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Synopsis:

Although it is well established that there are substantial nitrate losses from corn and soybean production systems, there is not a good understanding of the relationship of current and newly developing nitrogen management systems to nitrate loss from tile lines. Timing, split applications, and cover crop effects on nitrate losses need multi-year measurements to better understand the effects of weather, as well as the resulting crop yields. Because nitrate losses from tile systems are likely to stay at the forefront of state nutrient reduction strategies, we need to be able to tell producers which nitrogen management systems are most likely to reduce nitrate losses without reducing yields. This study will provide the needed data for that, by making multi-year tile nitrate measurements on a field in east-central Illinois where 36 individual tile lines will be monitored with six treatments, each replicated three times. Treatments will range from all N applied in the fall (with inhibitor) to a 50:50% split between spring preplant N and early side-dress N with cover crop, the latter representing what we expect to be the "best management practice" for minimizing nitrate loss.

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 5th 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 4 complete years of drainage data following the setup year of 2015.

Treatments for corn

1. Full rate of NH_3 (180 lb N/acre) applied in the fall with nitrapyrin.

2. 90 lb N applied as NH_3 in the fall with nitrapyrin followed by 45 lb N/acre as UAN at planting followed by 45 lb side-dressed as UAN.

3. Full rate applied as NH_3 (no nitrapyrin) in early spring (to before planting), with placement between rows by RTK.

4. Reduced rate (135 lb N/acre) applied as NH3 (no nitrapyrin) in early spring (before planting), with placement between rows by RTK.

5. 90 lb N applied as NH_3 early spring (before planting) followed by 90 lb N as UAN side-dressed.

6. Treatment #5 but with cover crops (oats-radish mixture after soybean crop; cereal rye after corn).

Note: N rate was increased to 180 lbs/A for the 2019 cropping year as determined by the MRTN calculator. N Rate had been 160 lbs/A from 2016-2018.

Project Update:

Field work was challenging this year, but thanks to the vigilance of Dan Schaefer all field work was completed. We continue to custom farm this site with Dan Schaefer and Eric Miller conducting field work (Refer to the IFCA report from Dan Schaefer for more details). We regularly meet with the landowners to discuss the operation and they continue to be very pleased with this arrangement.

- September 5, 2018: Aerial planting of cereal rye into corn; and annual ryegrass and radish into standing soybean
- October 22, 2018: Annual ryegrass and radish biomass collected before hard freeze
- October 25, 2018: Anhydrous ammonia application and strips made for corn (Full N rate is 180 lbs/A)
- November 8, 2018: Soil sampled (0-1, 1-2, 2-3 ft); soil health measurement and inorganic N determination
- May 6, 2019: Herbicide application on all plots except cover crop plots.
- May 21, 2019: Spring N application as anhydrous ammonia
- May 31, 2019: Corn planted
- June 7, 2019: Cereal rye biomass harvest, roller crimper, and terminated with glyphosate
- June 8, 2019: Soybean planted
- June 14, 2019: Side-dress application of UAN
- July 9, 2019: Corn biomass (V8 growth stage) collected for N, P, and K determination; soil sampled by KSI (0-1, 1-2 ft) for inorganic N determination. Chlorophyll measured.

- August 2, 2019: R1 ear leaf sample and chlorophyll measured.
- August 22, 2019: R3 chlorophyll measured
- September 20, 2019: Late R6 soybean biomass sampling
- September 21, 2019: Cereal rye aerially broadcast
- October 8, 2019: Hand-harvested soybean grain
- October 9, 2019: R6 corn biomass sampling
- October 9, 2019: Soybean combine harvested
- October 10, 2019: Winter wheat cover crop drill-planted
- October 19-20: Strip till soybean stubble
- November 6, 2019: Corn combine harvested
- November 6, 2019: Cereal rye drill planted to improve establishment after aerial seeding
- November 6, 2019: Soil sampled (0-1, 1-2, 2-3 ft); soil health measurement and inorganic N determination
- November 10, 2019: Anhydrous ammonia applied to soybean stubble near the strip

All treatments will remain in place through the 2020 growing season. This study receives supplemental funding from the Foundation for Food and Agricultural Research (FFAR) to investigate nutrient cycling and tile drainage loss of all three macronutrients (N, P and, K) through the 2020-2021 drainage season, which will mark the end of the FFAR study. In 2021, we will have the opportunity to consider if we want to modify treatments; or impart an entirely new evaluation comparing nutrient dynamics across a range of agricultural systems from conventional to no-till with cover crops.

Results:

Weather patterns and total rainfall from the previous year can affect tile flow in the subsequent year, therefore, we show on-site weather data from the past two years as compared with the 30-yr average recorded by a nearby municipality.

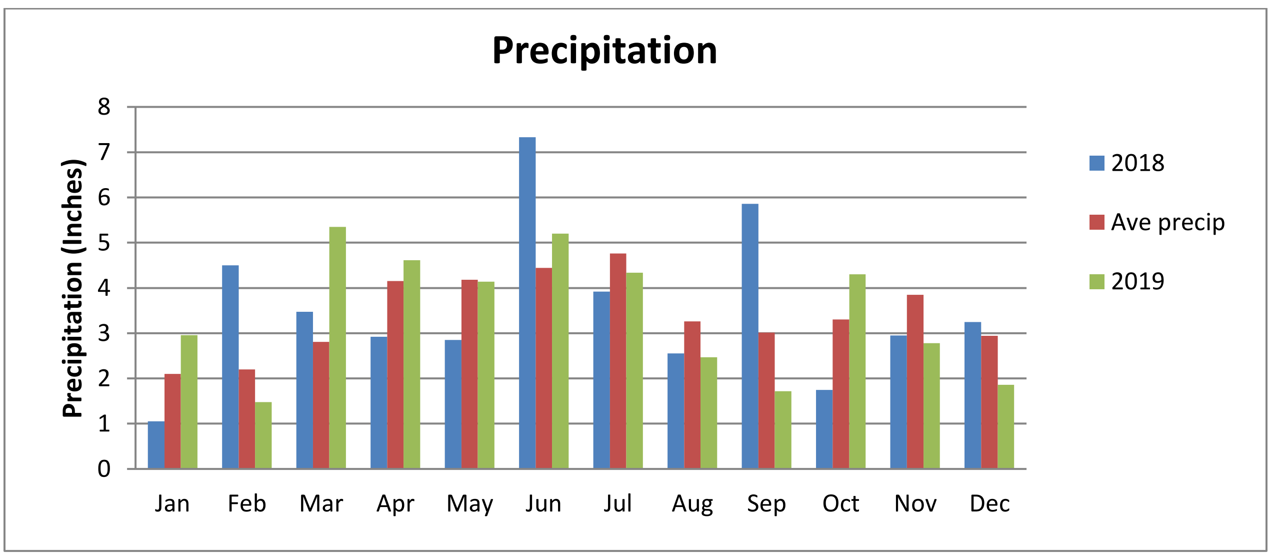

Figure 1. Monthly total precipitation at this site for 2018 and 2019 compared with the 30-year average at Tuscola, IL.

Annual precipitation in 2018 (42.4 inches) was 7% above the 30-yr average of 40 inches. 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.

Tile flow stopped in August of 2018; however, with nearly 6 inches of rain in September, tile flow resumed before crops were harvested. Annual precipitation in 2019 (41.2 inches) was only 4% above the 30-yr average; however, spring field work was delayed as March and April were wetter than average and frequent rains in May perpetuated delays.

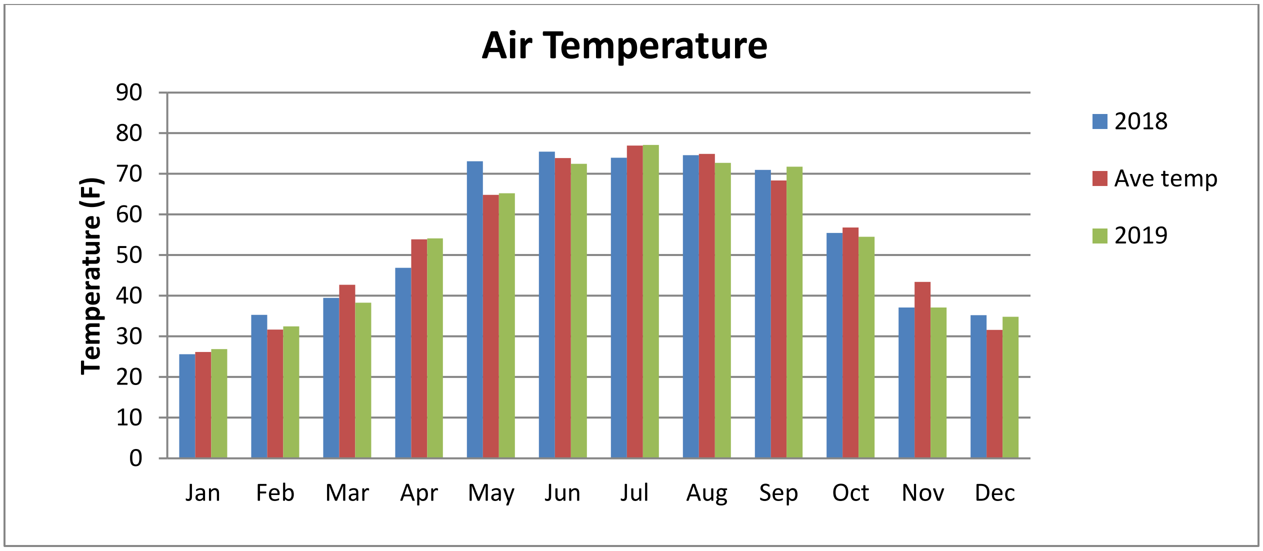

Figure 2. Monthly average temperature at this site for 2018 and 2019 compared with the 30-year average at Tuscola, IL.

Temperature patterns were very different between the two years (Figure 2) as 2018 could be characterized as having a cold spring (2nd coldest April on record) and an extremely warm start to the growing season (warmest May on record). In 2019, although the monthly average temperatures for January and February in 2019 were similar to the 30-yr average, a polar vortex spun across central Illinois, dropping temperatures to -20 F.

Without snow cover, our cover crop treatment following soybean (annual ryegrass) was killed by these temperatures. Cereal rye survived the extreme conditions and thrived this past spring. Due to wet spring conditions, we were unable to terminate the cereal rye until June 7. With this late termination date, the cereal rye accumulated the greatest biomass during the entire study period (1.6 tons/A). We used a roller crimper on the cereal rye and got effective weed suppression.

Monthly air temperatures were near normal this past summer, while September was warm, which helped to finish the crops. Crop yields were surprisingly good considering the late planting dates for both corn and soybean at this site.

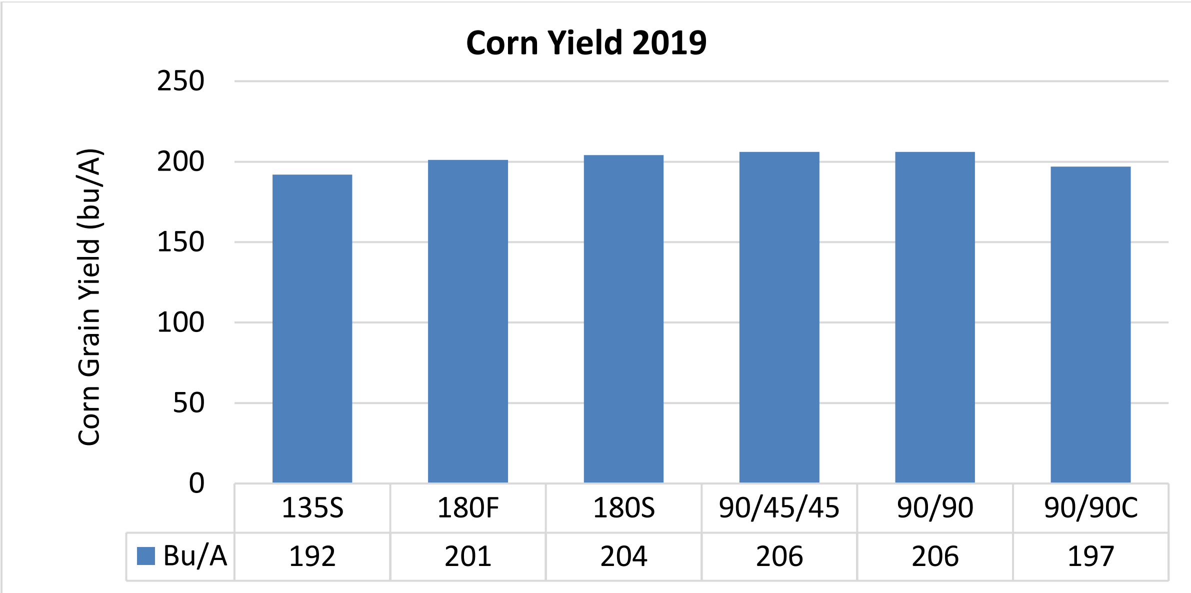

Figure 3. Corn grain yields across the 6 N treatments; no significant difference.

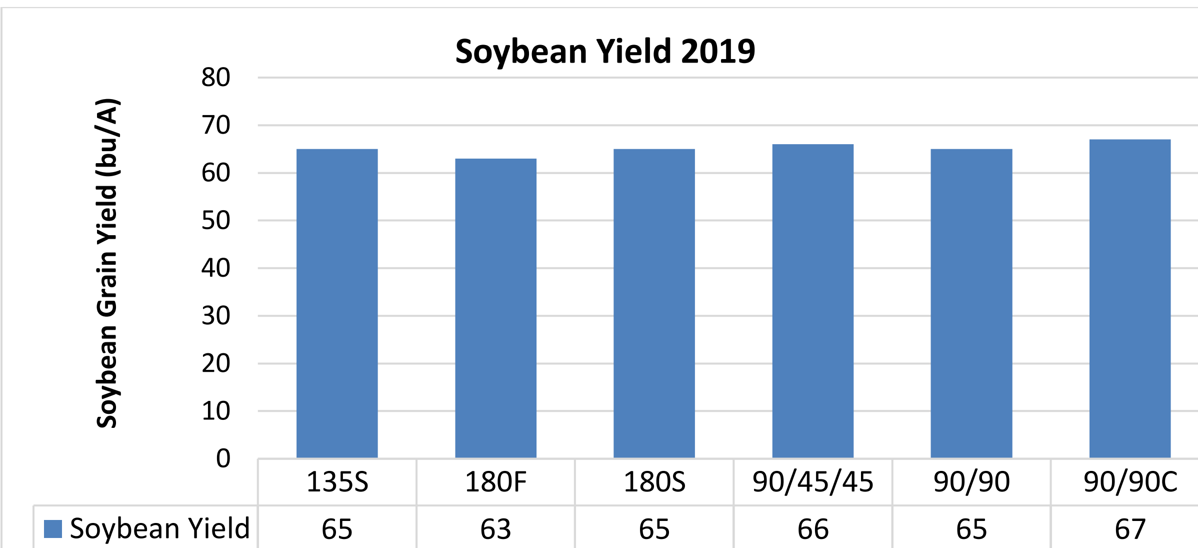

Figure 4. Soybean grain yields across the N treatments from the previous year; no significant difference.

Corn yield was reduced by the 75% N rate treatment; however, it was not significantly different from the other treatments this year (it had been in all previous years). Again, as in the past 4 years at this site, there was no N treatment effect among the other 5 N treatments on corn yield.

Soybean yields were good and averaged 65 bu/A with no yield differences from previous corn N treatments. It is worth noting that soybean yield was not hindered by planting directly into the lush cereal rye cover crop.

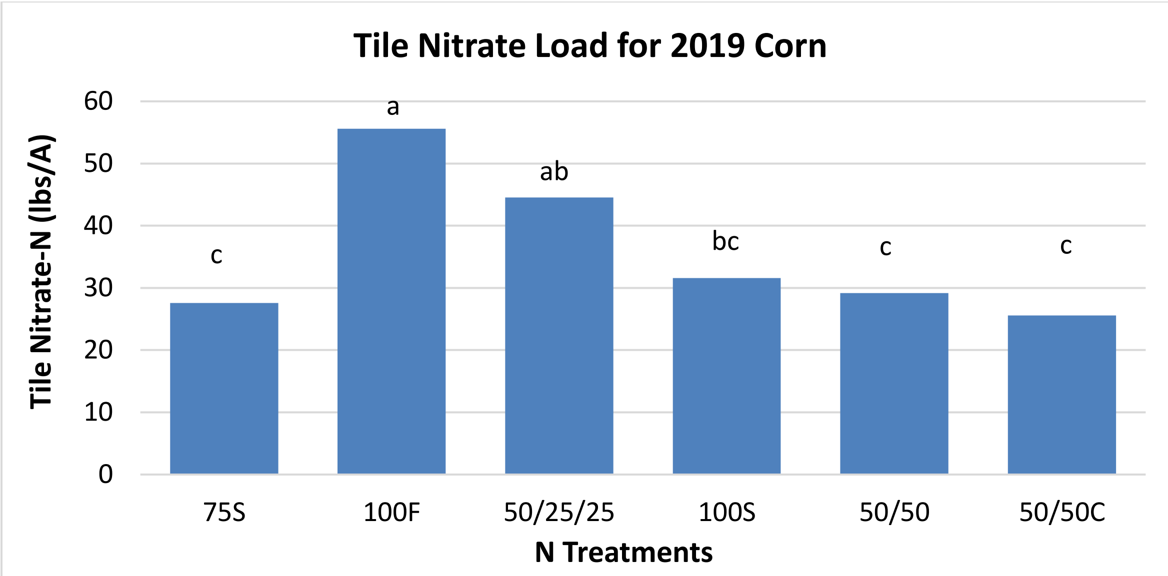

Figure 5. Tile nitrate load from corn plots across 6 N treatments; P<0.05.

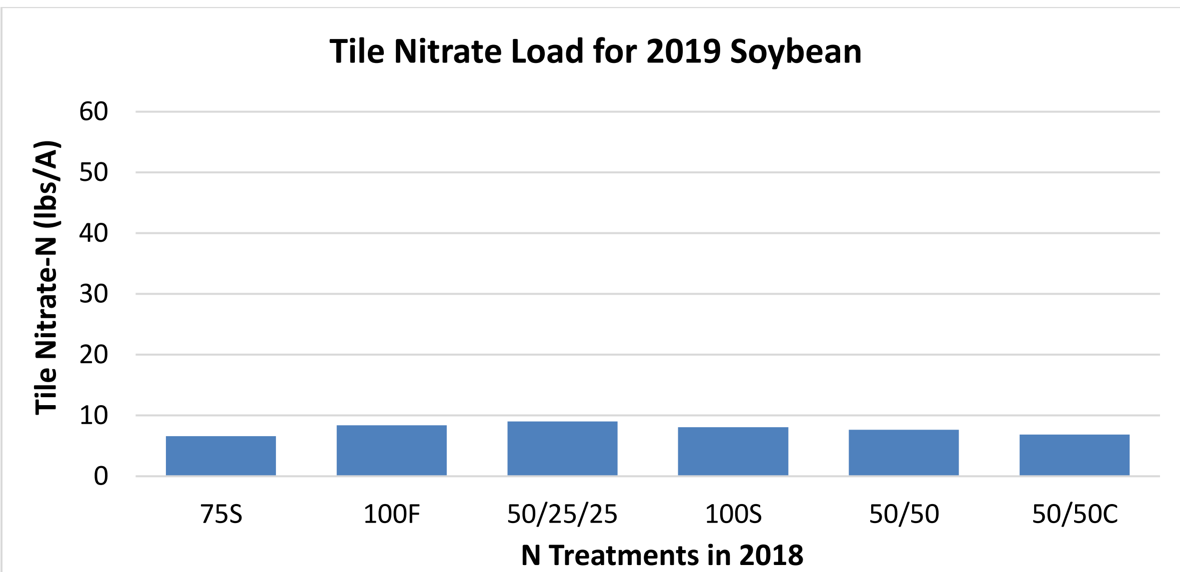

Figure 6. Tile nitrate load from soybean plots across the 6 N treatments: No significant difference.

In contrast to corn yield, N treatment had a significant impact on tile nitrate load with fall N treatments losing 55 and 44 lbs/A, respectively, while the other treatments lost between 25 and 31 lbs/A (Figure 5). There was no statistical difference in tile nitrate load across any of the soybean plots (Figure 6).

When averaged across the past 4 years, we have not seen a significant grain yield reduction associated with the application of fertilizer N in the fall (4-yr corn average not shown). Clearly, fall N treatments lost the most tile nitrate, but N loss across all treatments was greater this year compared to other years (100% Fall N at 27 ppm on June 16, 2019; See Figure 7). This is due in part to the late planting and lack of plant uptake (of fertilizer N) before heavy rains in mid-June.

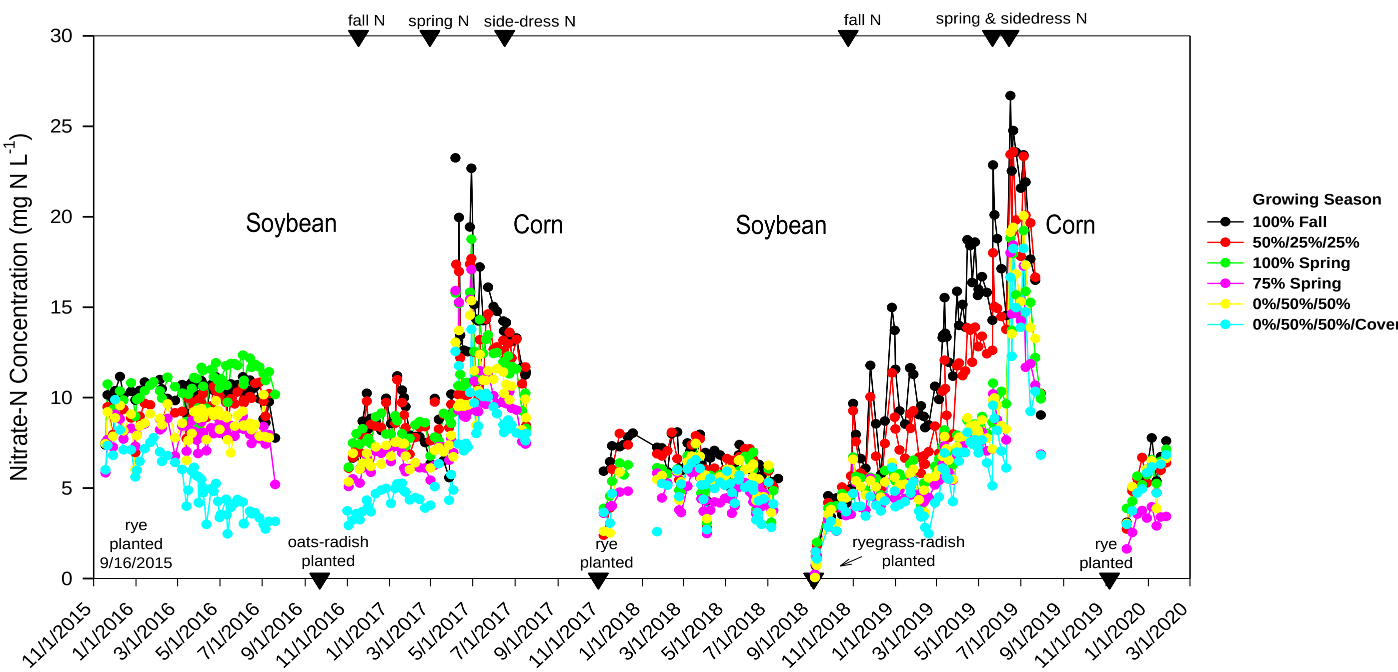

Figure 7. Tile nitrate concentrations from the past 4 years (Soy-Corn-Soy-Corn).

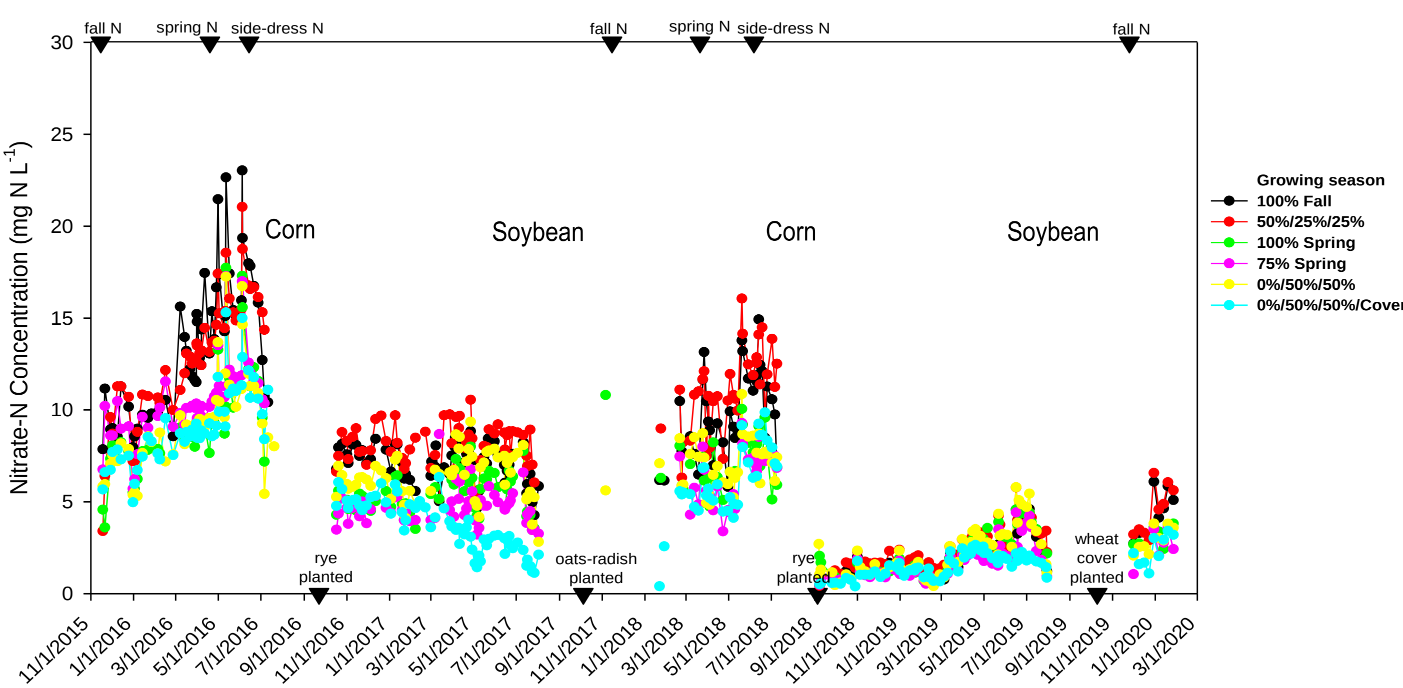

Figure 8. Tile nitrate concentrations from the past 4 years (Corn-Soy-Corn-Soy).

The most unusual result from the 2018-2019 drainage season was how extremely low tile nitrate concentrations were following the 2018 corn crop (Figure 8). Unlike previous years, tile flow started before crop harvest in early September, two months earlier than previous years. The first tile water samples in September had very low nitrate concentrations, regardless of previous crop indicating that both corn and soybean crops left little nitrate in the soil after harvest. For tiles following corn, nitrate remained at about 1 ppm all winter and increased in the spring, reaching 3 ppm. However, in tiles following soybean, nitrate quickly reached 4 ppm in October and steadily increased through the fall and again in the spring, reaching 8 ppm (prior to spring fertilizer N application on May 21).

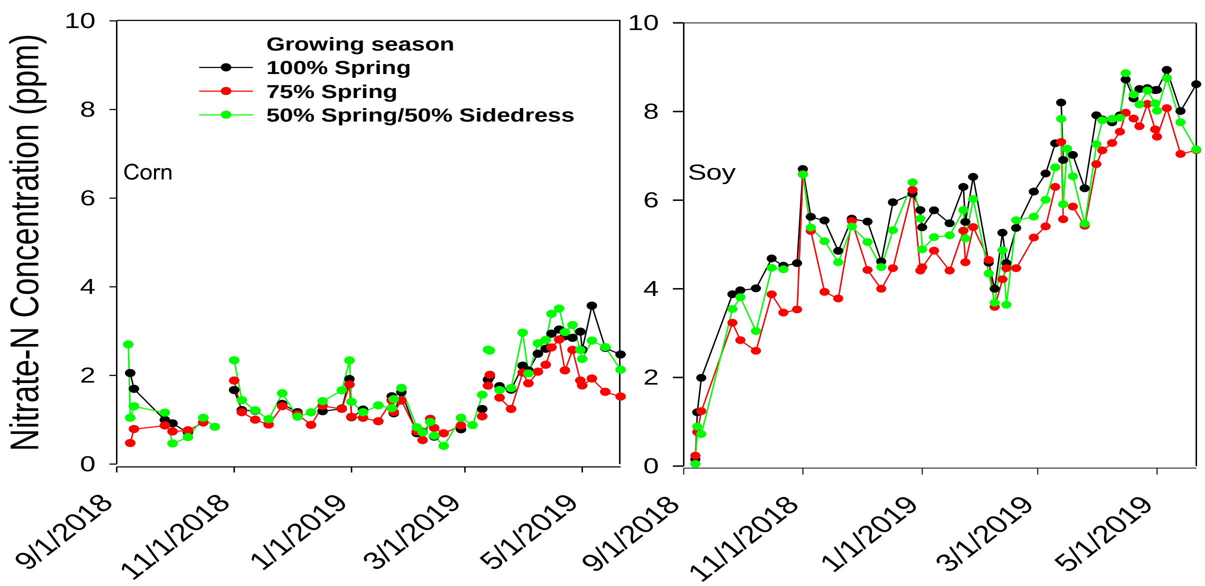

Figure 9. Eliminating the fall N treatments and the cover crop treatment from this graph, we show tile nitrate following either corn or soybean during a period of no fertilizer N application. Graph ends on May 21, 2019, which was the day spring N was applied ahead of corn.

Conditions this past year have provided us with a view of nitrate leaching that has not been documented. With early tile flow and late application of spring fertilizer N (May 21), we saw the influence of the previous crop on tile nitrate loss. Although it is well established that microbial decomposition of corn residue can immobilize soil N, the 2018 corn crop was particularly interesting as all plots were found to be N deficient by the end of the growing season (as indicated by very low stalk nitrate values). This lean corn crop produced residue that had a very wide C:N ratio (>70:1). We believe that immobilization of soil N during the decomposition of this C-rich (and N-poor) corn residue limited nitrate leaching and decreased tile nitrate loss. On the other hand, we speculate that the soil system is C limited after soybean production and that nitrate liberated from soil mineralization can substantially add to tile nitrate loads. The similarity between the pattern of tile nitrate loss from the reduced N rate treatment (red dots) and the full rate treatments (black and green dots) suggest that tile nitrate loss following soybean production had little to do with how much fertilizer N was applied to corn the previous year.

Table 1. Annual tile nitrate load and flow weighted mean nitrate-N concentration (FWMC) from six corn N treatments during the corn production phase of the 2-yr rotation in 2016, 2017, 2018, and 2019. **Note:** Annual data presented on a water year basis (Oct. 1 of the previous year through Sept. 30 of the named year). Significance at P<0.05.

Corn																
N treatment	Mean annual tile NO_3-N load (lbs/A)								Mean NO_3-N FWMC (mg/L)							
	2016		2017		2018		2019		2016		2017		2018		2019	
75% Spring	22.3	bc	21.5	bc	11.1	b	27.6	c	10.04	b	8.92	bc	5.87	b	7.82	c
100% Fall	30.8	a	33.0	a	19.4	a	55.6	a	13.62	a	12.63	a	9.45	a	14.60	a
50%/25%/25%	26.7	ab	30.3	ab	19.4	a	44.5	ab	12.51	a	10.65	ab	9.69	a	11.87	ab
100% Spring	20.9	c	28.2	ab	12.3	b	31.6	bc	9.10	b	10.19	ab	6.48	b	8.57	bc
50%/50%	19.6	c	21.9	bc	12.3	b	29.2	c	9.10	b	9.07	bc	6.50	b	8.43	bc
50%/50%/Cover	21.5	c	17.6	c	12.2	b	25.6	c	8.86	b	6.93	c	5.89	b	7.21	c

Table 2. Annual tile nitrate load and flow weighted mean nitrate-N concentration (FWMC) from six corn N treatments during the soybean production phase of the 2-yr rotation in 2016, 2017, 2018, and 2019. **Note:** Annual data presented on a water year basis (Oct. 1 of the previous year through Sept. 30 of the named year). Significance at P<0.05.

Soybean																
N treatment	Mean annual tile NO_3-N load (lbs/A)								Mean NO_3-N FWMC (mg/L)							
	2016		2017		2018		2019		2016		2017		2018		2019	
75% Spring	19.3	ab	12.7	b	9.6	a	6.6	a	7.89	ab	4.67	bc	3.90	a	2.10	ab
100% Fall	24.9	a	20.3	a	13.7	a	8.4	a	10.22	a	6.98	a	6.22	a	2.42	ab
50%/25%/25%	24.3	a	21.4	a	13.6	a	9.0	a	9.20	a	7.47	a	5.51	a	2.84	a
100% Spring	26.9	a	13.1	b	11.1	a	8.0	a	10.53	a	5.34	b	4.86	a	2.53	ab
50%/50%	21.7	a	15.7	ab	10.1	a	7.7	a	8.66	a	6.15	ab	5.12	a	2.83	a
50%/50%/Cover	12.8	b	11.1	b	8.3	a	6.8	a	5.25	b	3.59	c	4.50	a	1.80	b

Tile flow (expressed as inches of runoff) averaged across the 36 tiles was 9.3 inches in 2018 and 15.3 inches in 2019 (data not shown). This represents approximately 22% and 37% of the annual precipitation. The large amount of rainfall in March and April in 2019 produced much more tile flow than the large events of 2018 that occurred during the growing season.

Tile load results from 2019 were previously shown in Figures 5 and 6, but here in Tables 1 and 2 we show all tile loads and flow weighted mean nitrate concentrations (FWMC) for the past 4 years. In general, for the corn phase, the major source of significant difference for tile nitrate loads is the comparison of fall N treatments to the other 4 treatments (Table 1). For the soybean phase, there are fewer significant differences found among the treatments in any given year, except for the effect of cereal rye during the soybean phase of the study (Table 2).

Tile FWMC 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 during March and April of 2018 were abnormally cold, likely limiting soil N mineralization.

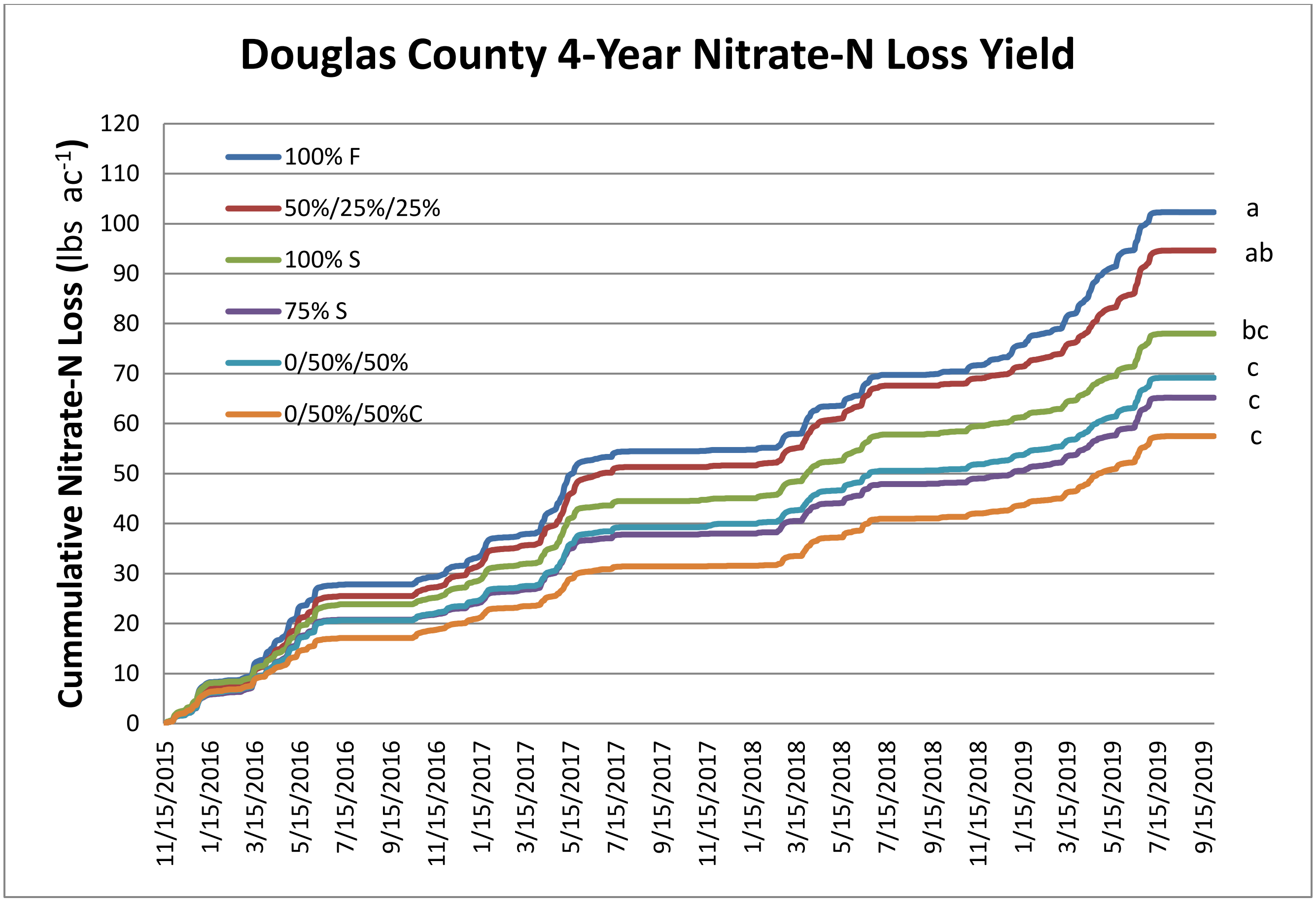

Figure 10. Cumulative daily tile nitrate load from the fall of 2015 through the summer of 2019 for each of the six corn N treatments averaged over both phases of the rotation.

Cumulative tile nitrate loads over the past four years ranged from a high of 102 lbs/A (25 lbs/A/yr) with the full rate of fertilizer N in the fall (100% F) to a low of 57 lbs/A (13 lbs/A/yr) with the split pre-plant and side-dress plus cover crops (0/50%/50% C) (Figure 10).

It is interesting to note that after four years, cumulative tile nitrate loads for the reduced N rate treatment (75% S) and the 2-way split application treatment of the full rate (0/50%/50%) were similar (65 vs. 69 lbs/A). Although N deficiency has limited corn yields in the 75% N treatment; nitrate continued to leach from these plots during the non-growing season. 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.

The oat and radish cover crop appeared to have little or no effect on tile nitrate concentration. There was a beneficial carryover from the large cereal rye crop of 2016, which lowered tile nitrate concentrations throughout the winter of 2016-2017 until spring fertilizer N was applied to corn in 2017 (Table 1).

Overall, these data suggest that there can be 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.

Outreach

In 2019, Mr. Gentry was invited to present results from this study (and the Piatt County Study) at 15 meetings or conferences. These outreach activities included speaking at the annual Illinois Fertilizer and Chemical Association Conference in Peoria on January 29; the Ohio Agribusiness Association in Columbus on Feb. 1; the Crop Management Conference in Mt. Vernon, Springfield, Champaign, and Malta on Jan. 22, Jan. 30, Feb. 6, and Feb. 20; the Midwest Cover Crop Council meeting in Springfield on Feb. 21; the Central States Water Environment Association 2019 Government Affairs Seminar held jointly with AWA Mini Conference on March 27; the Nitrogen Management Workshop for AFT and the Vermillion Headwaters Watershed Partnership on July 23; the FFAR 4R Nutri-net meeting on November 10; the American Society of Agronomy annual meetings in San Antonio TX on November 11; the Coles County Cover Crop and Soil Health Field Day on November 14; the Research Showcase at the NLRS Partnership Conference on December 3; the Illinois Certified Crop Advisor Conference/Ag Masters Conference on December 5; and the IL 4R Indoor Field Day at IFCA on December 12.

Mr. Gentry also presented a Soil Fertility Webinar on Feb. 28. This webinar was turned into a CCA short course for U of I Extension. In addition, Mr. Gentry has been serving on the Salt Fork Steering Committee, the STAR Science Committee, the Illinois Sustainable Ag Partnership Science Committee, and the MCCC tool selector committee. Assisted in the update of the NREC cover crop guide published in September and provided two research summaries for NREC Field Notes articles. Based on data from this site and the Piatt County site, two articles were published in Prairie Farmer in August and October.

And finally, we have reached out to other U of I researchers and invited their participation including Kaiyu Guan (Process-based modelling) and Yuji Arai (Soil Chemistry) from NRES and Nick Seiter (Entomology) and Andrew Margenot (Soil Science) from Crop Science. Combining and layering their expertise on our 5-year baseline of information at this site will allow for a more thorough examination of nutrient cycling, availability, and loss as we strive for greater nutrient use efficiency on tile drained land.

Summary Conclusion

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.**

Project Budget (Jan.1 through Dec. 31)

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

Personnel:	**Salary**	**Fringe benefits**
Administrative/professional	58,890.78	23,462.86
Other academic (intern)	5,872.72	74.03
Wages	53,093.80	3,551.02
Total personnel	117,857.30	
Total fringe benefits	27,087.91	
Travel (domestic)	6,289.68	
Supplies	12,643.24	
Contractual services	14,841.37	
Facilities and administration	19,837.92	
Tuition		
Total expenditures	198,557.42	

Additional Summary of Highlights for 2019

We believe the unusual weather conditions this past year provided us with a clear view of one of the major sources of tile nitrate, namely soil N mineralization (especially following soybean production) (Figure 9). With the early start of tile drainage in late summer of 2018 and the late application of fertilizer N this spring, we saw the influence of soil N mineralization following soybean production without the confounding effects of preplant fertilizer N applications. Using an on-farm replicated tile drainage study in Douglas County, IL, we show that more nitrate loss occurred following soybean production than following corn this past drainage season. We were surprised by the sustained low tile nitrate concentrations throughout the drainage season following corn production at this site last year. Although it is well established that microbial decomposition of corn residue can immobilize soil N, this past year was particularly interesting as the 2018 corn crop was found to be N deficient by the end of the growing season (as indicated by very low stalk nitrate values) and its residue had a very wide C:N ratio (>70:1). We believe that immobilization of soil N during the decomposition of this C-rich (and N-poor) corn residue limited nitrate leaching and decreased tile nitrate loss. On the other hand, we speculate that the soil system is C limited after soybean production and that nitrate liberated from the decomposition of soybean residue can and does substantially add to tile nitrate loads. Over wintering cover crops may be the best strategy for addressing this type of nutrient loss.

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.