Impacts of 4R Nitrogen Management on Crop Production and Nitrate-Nitrogen Loss in Tile Drainage
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I. Background

Corn and soybean producers in Iowa and throughout much of the U.S. Corn Belt are increasingly challenged to maximize crop production to supply feed, fiber, and more recently biofuels (especially ethanol from corn) while at the same time managing soils by utilizing fertilizers and animal manures efficiently and minimizing negative impacts on water quality. In particular, there is concern about nutrient export from subsurface drainage and surface water runoff to water systems in Iowa and the Gulf of Mexico. In addition to local impacts on receiving waters, nitrogen (N) and phosphorous (P) loads from U.S. Corn Belt are suspected as primary drivers of hypoxia in the Gulf of Mexico (Dale et al., 2010). The EPA SAB's 2007 hypoxia reassessment identified both N and P as major contributors to Gulf hypoxia and the 2008 Action Plan called for a dual nutrient strategy of 45% reductions in both N and P loads. Relative to N loss, nitrate-N is the predominant form in many agricultural watersheds due to subsurface drainage or shallow subsurface flow (Baker et al., 2008). Nitrate-N loading from the Mississippi River is suspected to be a main contributor to the hypoxic zone in the Gulf of Mexico (Rabalais et al., 2001), and the main source of nitrate-N in the Mississippi River Basin has been linked to subsurface drainage in the Midwest (Lowrance, 1992; Keeney and DeLuca, 1993; David et al., 1997; Zucker and Brown, 1998). Based on the need for nitrate-N reductions to meet water quality goals, new management practices are needed that have the potential to significantly reduce nitrate-N losses at minimal cost and/or provide economic benefits. Practices are needed that will address the right source at the right rate in the right place. In addition, there is a need to quantify the water quality and crop yield impacts of some traditionally recommended best nutrient management practices such as timing of N application. The Iowa Nutrient Reduction Strategy Science Assessment has indicated nitrate-N loss improvement with certain practices, such as time of application (spring versus fall) and nitrification inhibitor. However, the published data available for the science assessment was limited for those practices, especially from Iowa research. Also, the practice of split or in-season application had indication of limited benefit to tile drainage nitrate-N reduction.

II. Project Objectives

As part of this field research and demonstration project, we are evaluating various promising N management methods and technologies by documenting the nitrate-N export and crop yield from several systems (Table 1). The specific objectives of this project are to:

1. Determine the effects of N fertilizer application and N fertilizer application timing on nitrate-N leaching losses.
2. Determine the effects of N fertilizer application and N fertilizer application timing on crop yield.

3. Disseminate project findings through peer-reviewed journal articles, Extension fact sheets, Extension presentations, and other outlets as appropriate; and provide needed scientific information for on-going review and adjustment of the Nutrient Reduction Strategy Science Assessment.

The project began on January 1, 2015 and runs through December 31, 2017.

Table 1. Treatments at the Northwest Research Farm drainage facility.

Treatment Number	**Tillage**	**Nitrogen Application Time**	**Nitrogen Application Rate (lb N/acre)**
1	Conventional tillage	Fall (anhydrous ammonia with nitrapyrin)*	135
2	Conventional tillage	Spring (anhydrous ammonia)	135
3	Conventional tillage	Split with variable N at sidedress (40 lb/acre of urea 2x2 starter at planting plus in-season agrotain treated urea)	135
4	Conventional tillage	None	0

*In fall of 2014 freezing conditions occurred early and prevented fall application. Application occurred in early spring 2015.

III. Project Methods

The project objectives are being implemented at a new drainage facility in northwest Iowa (near Sutherland, Iowa, Figure 1). The site had tile drainage installed in 2013 (Figures 2 and 3). In 2014, the study site was uniformly cropped, with treatments implemented for the 2015 growing season.

In 2013, the site was instrumented for replicated studies of drainage water quality. The site has 32 individually subsurface drained plots for subsurface drainage water quality evaluation. Drainage lines from individual plots were directed to separate sumps within culverts. Drainage water is pumped through plastic plumbing fitted with a common plated sprayer orifice nozzle and a water meter. Back pressure created by the meter forces a small constant fraction of all drainage to be diverted to a glass sampling bottle so that a flow-proportional water sample is collected. Subsamples (125 ml) will be collected from the composite water samples in glass jars during each drainage period and volume measurements will be recorded as dictated by actual drainage patterns. Additional information on this sampling strategy is described in Lawlor et al. (2008). Samples will be preserved by acidification with sulfuric acid and analyzed for nitrate-N using second derivative spectroscopy (Crumpton et al., 1992). Based on the nitrate-N concentration of the water sample, and the volume of water during the period from when water was collected, a mass of nitrate-N loss will be computed. While the water quality focus of this proposal is on documenting nitrate-N loss, we will analyze the water samples for total phosphorus (TP) and total reactive phosphorus (TRP). TRP is determined using the ascorbic acid method originally described by Murphy and Riley (1962) and TP is determined by converting to orthophosphate by persulfate digestion.

In addition to sampling and quantifying nitrate-N loss we will also document crop yield for each treatment. Grain samples will be collected at harvest and will be analyzed for N to evaluate N export with the grain and to assess N use efficiency by N inputs, nitrate-N outputs and N outputs with grain. To measure residual nitrate-N present in the soil, soil cores will be sampled after corn or soybean harvest in late fall. In each plot, twenty push-probe (2cm) soil samples will be extracted at three depths (0-30, 30-60, and 60-90cm) with samples from each depth being composited. Nitrate-N will be extracted from soil samples and measured by a colorimeter (Lachat QuickChem 8000 Automated Ion Analyzer, Milwaukee, WI). To assess the corn N status, an active canopy sensor (model yet to be determined) will be used to determine NDVI and/or chlorophyll index, no later than mid-vegetative corn growth stage, and possibly multiple determinations in the early growing season. This sensing will also be used to help determine the variable in-season adjusted sidedress N rate application. Also, lower plant corn stalk samples will be collected at the end of the growing season to determine the concentration of nitrate-N in the lower corn stalk (20cm segment from 15 to 35 cm above the ground), specifically to determine if excess N had been applied in each system studied. Fifteen segments will be collected and composited from each plot.

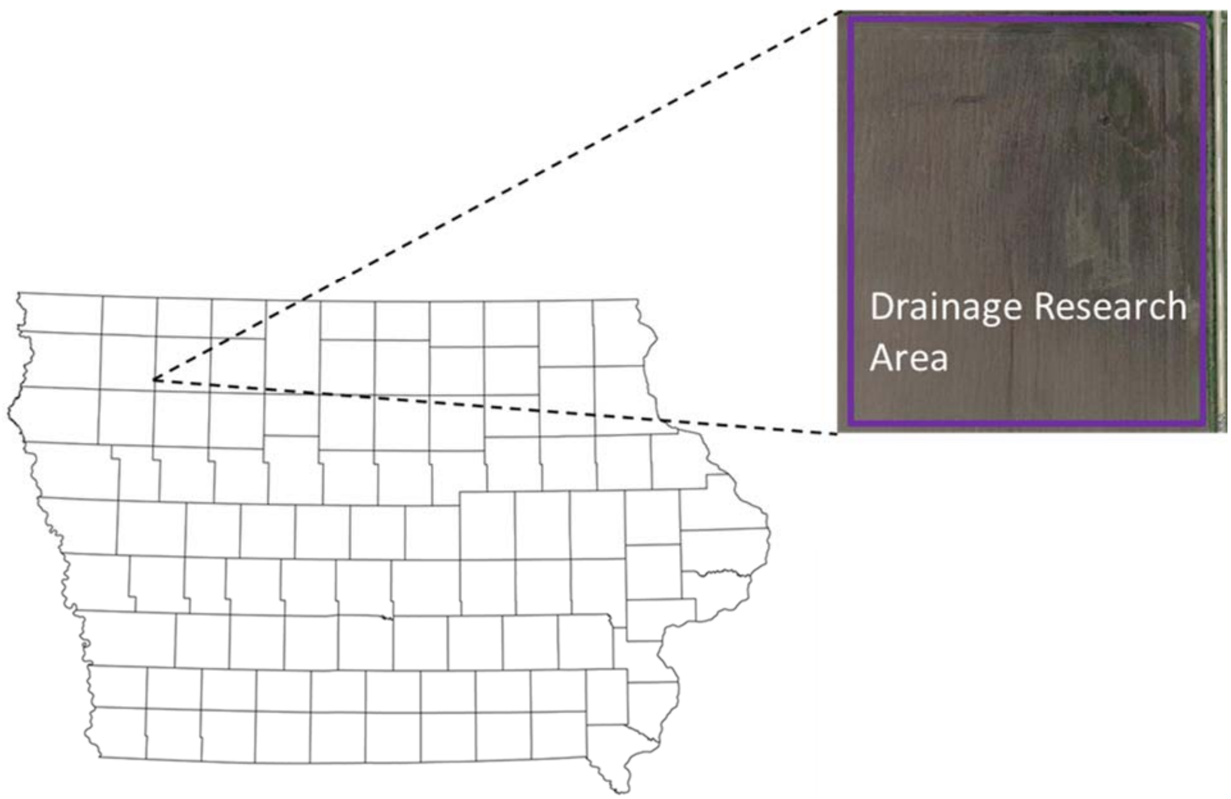

Figure 1. Study site near Sutherland, Iowa.

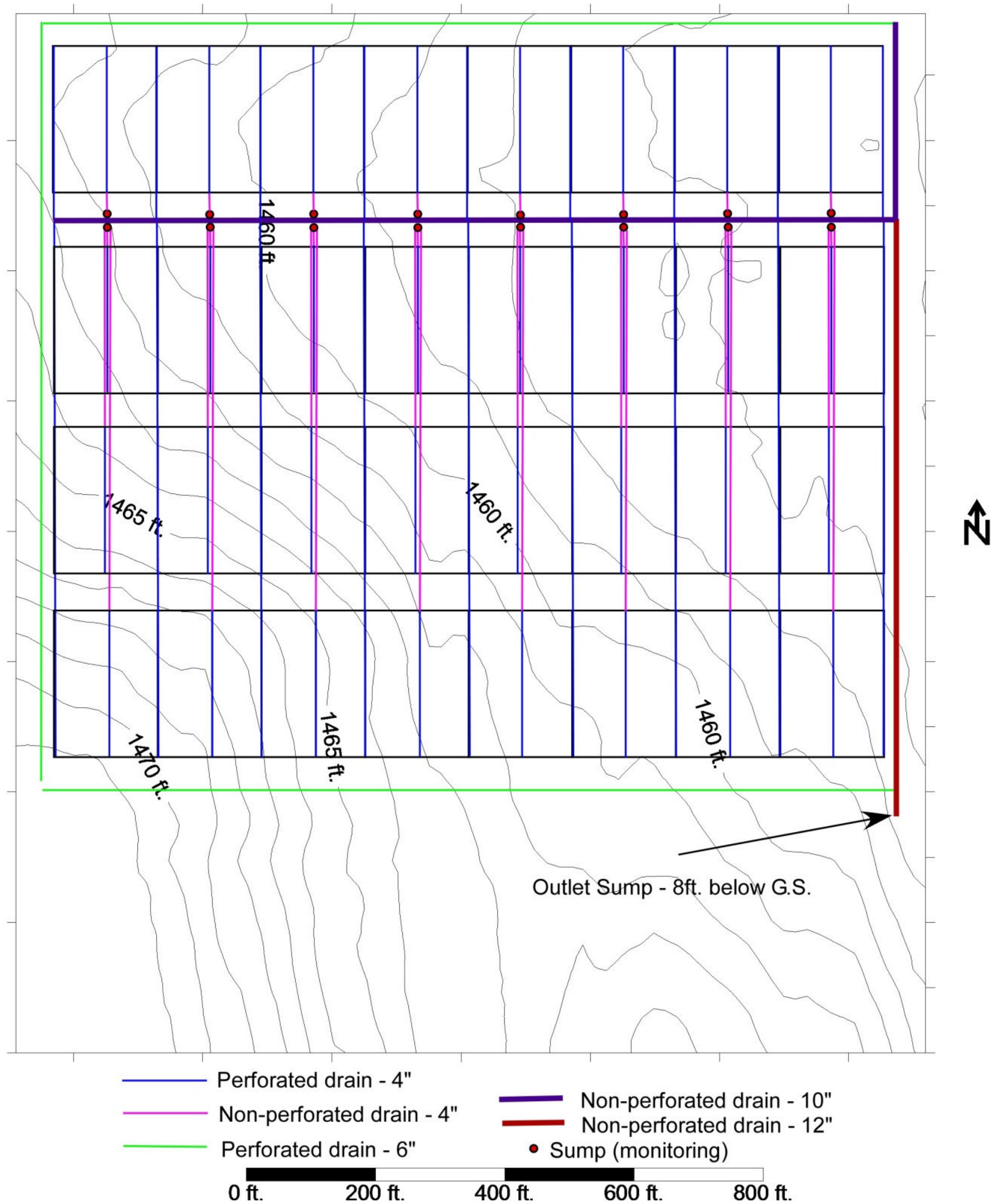

Figure 2. Example subsurface drainage layout for study site

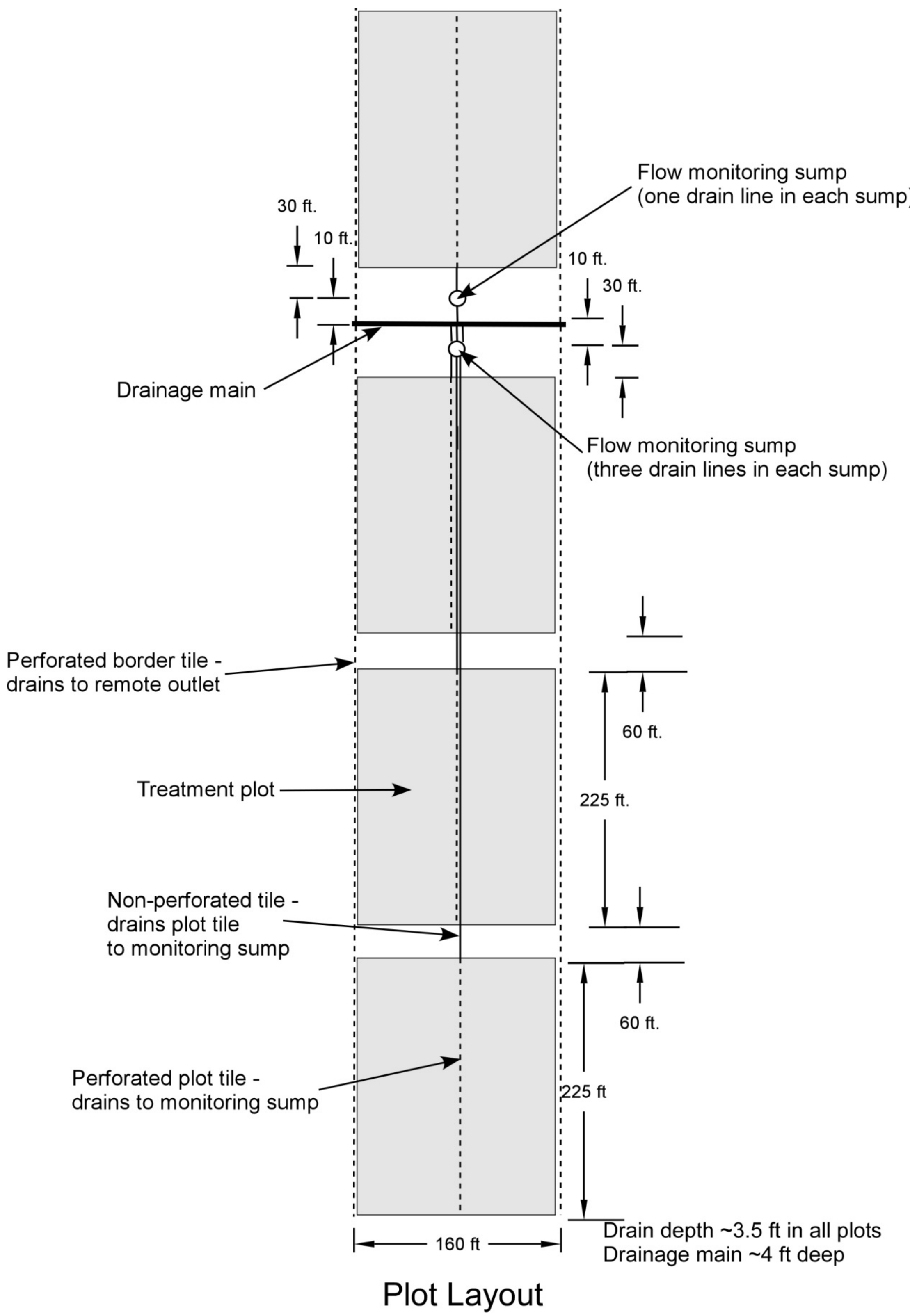

Figure 3. Example subsurface drainage layout for four plots

IV. 2015 Results

Except for the early fall 2014 freezing conditions which prevented the fall anhydrous ammonia application (completed early spring 2015), agronomic operations were completed in a timely manner in 2015. The 2015 year was characterized by greater precipitation in late summer and fall than would be normal for this geographic area (Table 2) and overall greater yearly precipitation than the 30-yr average precipitation (Cherokee, IA weather station which is about 10 miles south pf the project site).

There was a 40 bushel yield increase with the use of N in treatments 1-3 as compared to treatment 4 where no N was applied (Table 3). Of note is that oats were uniformly grown across the site in 2013 and soybean in 2014. There were no statistical differences among the soybean yields which would be expected based on the uniform previous site history, no treatments applied to soybean, and no prior-year N applications to corn. There were no statistically significant differences in flow-weighted nitrate-N concentrations between treatments where soybean was grown in 2015, which would also be expected (Table 4). In the corn phase, the treatment where no N was applied had statistically lower nitrate-N concentration than treatments where N was applied to corn. Overall, there were no statistically significant differences in total phosphorus or total reactive phosphorus concentrations between treatments (Tables 5 and 6). Nutrient loads for 2015 are not reported as we continue to evaluate plot to plot variability as the system begins to function post drainage installation.

We are continuing to summarize the crop sensing, stalk nitrate, grain N, and soil nitrate-N data that was collected in 2015.

Table 2. Monthly precipitation and drainage in 2015.

Month	**Precipitation in 2015 at the site (in)**	**30-yr Average Precipitation from Cherokee, IA (in)**	**Average Drain Flow (in)**	
			Corn	**Soybean**
January	0.1	0.6	.	.
February	0.0	0.6	.	.
March	0.6	1.9	.	.
April	3.1	3.1	0.8	0.9
May	3.5	3.9	0.9	0.5
June	2.6	5.0	0.2	0.0
July	6.8	3.9	0.2	0.1
August	6.1	3.7	0.7	0.2
September	2.8	3.5	0.5	0.2
October	1.9	2.1	0.3	0.0
November	4.9	1.5	4.6	4.3
December	1.8	0.9	3.6	2.8
Total	34.1	30.7	11.8	9.0

Table 3. Crop yields (bushel/acre) for 2015.

Treatment	Nitrogen Management for Corn	Corn	Soybean
1	Fall NH_3 With inhibitor	221 a*	62.2 a
2	Spring NH_3 (no inhibitor)	223 a	64.1 a
3	Split N (40 lb urea-N at planting + 95 lb in-season)	224 a	64.2 a
4	None	183 b	61.3 a

*Means with the same letter in the same column are not significantly different, *P*=0.05.

Table 4. Flow-weighted nitrate-N concentrations (mg/L) for 2015 calendar year.

Treatment	Nitrogen Management for Corn	Corn	Soybean
1	Fall NH_3 (with inhibitor)	16.2 a*	12.7 a
2	Spring NH_3 (no inhibitor)	15.7 a	13.4 a
3	Split N (40 lb urea-N at planting + 95 lb in-season)	12.0 ab	12.1 a
4	None	9.1 b	12.5 a

*Means with the same letter in the same column are not significantly different, *P*=0.05.

Table 5. Flow-weighted total phosphorus concentrations (mg/L) for 2015 calendar year.

Treatment	Nitrogen Management for Corn	Corn	Soybean
1	Fall NH_3 (with inhibitor)	0.022 a*	0.020 a
2	Spring NH_3 (no inhibitor)	0.026 a	0.019 a
3	Split N (40 lb urea-N at planting + 95 lb in-season)	0.022 a	0.019 a
4	None	0.020 a	0.020 a

*Means with the same letter in the same column are not significantly different, *P*=0.05.

Table 6. Flow-weighted total reactive phosphorus concentrations (mg/L) for 2015 calendar year.

Treatment	Nitrogen Management for Corn	Corn	Soybean
1	Fall NH_3 (with inhibitor)	0.022 a*	0.017 a
2	Spring NH_3 (no inhibitor)	0.024 a	0.020 a
3	Split N (40 lb urea-N at planting + 95 lb in-season)	0.026 a	0.019 a
4	None	0.021 a	0.020 a

*Means with the same letter in the same column are not significantly different, *P*=0.05.

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