Illinois Nutrient Research & Education Council

2017 Final Report Summary Sheet

Grantee Information

Project Title: Assessing synergies and tradeoffs of recommended BMPs to reduce nutrient loss

Institution: University of Illinois

Primary Investigator: Pittelkow

NREC Project # 2016-4-360276-980

Is your project on target from an IMPLEMENTATION standpoint? ☒ **Yes** ☐ **No**

If you answered "no" please explain:

Is your project on target from a BUDGET standpoint? ☒ **Yes** ☐ **No**

If you answered "no" please explain:

Based on what you know today, will you meet the objectives of your project on-time and on-budget? ☐ **Yes** ☒ **No**

If you answered "no" please explain:

The timeline is essentially delayed one year. This has been discussed with NREC and an amended timeline has been approved.

Have you encountered any issues related to this project? ☐ **Yes** ☒ **No**

If you answered "yes" please explain:

Have you reached any conclusions related to this project that you would like to highlight? ☐ **Yes** ☒ **No**

If you answered "yes" please explain:

Have you completed any outreach activities related this project? Or do you have any activities planned? ☒ **Yes** ☐ **No**

If you answered "yes" please explain and provide details for any upcoming outreach:

An overview of the project was presented at two field days at the site in 2016, UIUC Agronomy Day 2016, one field day at the site in 2017. A presentation by Pittelkow also introduced this research at the Annual Farm Bureau meeting in Chicago in December 2017. An analysis of the spatial variability of tile drainage N losses, soil N_2O emissions, early season crop N uptake and yield was presented in a poster at the ASA-CSSA-SSSA meetings in October 2017.

Additional Notes: See below for project accomplishments and updated timeline

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Illinois Nutrient Research & Education Council
2017 Final Report
February 9, 2018

Project Assessing synergies and tradeoffs of recommended BMPs to reduce nutrient losses

Participants Cameron Pittelkow, Laura Christianson, Rabin Bhattarai

Length 4 years (January 1, 2016 – December 31, 2019)

Summary This project completed its second year of funding. Tile drainage was successfully installed at the site in Sept/Oct 2016, along with a bioreactor. Project activities occurred as proposed in 2017, with a focus on collecting baseline data under uniform crop management practices. Following the 2017 harvest, the cereal rye cover crop was drilled and fall N treatments were applied with strip tillage. Bioreactor monitoring occurred throughout 2017 and the bioreactor reduced nitrate moving through it by 76%. All 16 individually drained plots are now implemented with automatic water samplers for continuous water quality monitoring. Soil N_2O emissions were measured weekly during the growing season, along with soil and crop N dynamics at key growth stages within each plot. The initial project delay has been discussed with NREC and the approved, updated timeline and budget are included below.

1. Objectives

The overall goal of this project is to evaluate whether current BMPs for reducing nitrate loss may also result in agronomic and environmental tradeoffs that have not been previously considered (e.g. negative impacts on crop productivity, nutrient utilization, tile drainage P losses, and/or N_2O emissions). A replicated tile drainage research site combining in-field and edge-of-field practices has been established at the UIUC Dudley Smith Research Farm near Pana, IL to address the following objectives:

1. Determine the effects of combining recommended water quality BMPs on tile drainage nutrient losses, field N and P balances, and fertilizer use efficiencies.

2. Considering a best case scenario (e.g. 4R nutrient stewardship + cover crops + bioreactor), assess whether synergies are occurring among practices, and/or there is an upper limit to nutrient loss reductions.

3. Using plots without fertilizer inputs as a baseline, assess the relative contribution of soil vs. fertilizer sources to annual N and P losses for continuous corn production systems.

4. Evaluate whether recommended BMPs reduce nitrate losses but increase N_2O emissions.

5. Evaluate whether cover crops and bioreactors reduce nitrate losses but increase tile drainage P losses under certain conditions.

6. Assess crop yields and relative cost efficiencies of recommended BMPs.

7. Evaluate (through modeling) how environmental tradeoffs can be managed at the landscape and/or watershed-scale using different combinations of BMPs.

8. Communicate results to agricultural community stakeholders through field days and extension events.

9. Include a final written report at the conclusion of this project to address each of the objectives stated above.

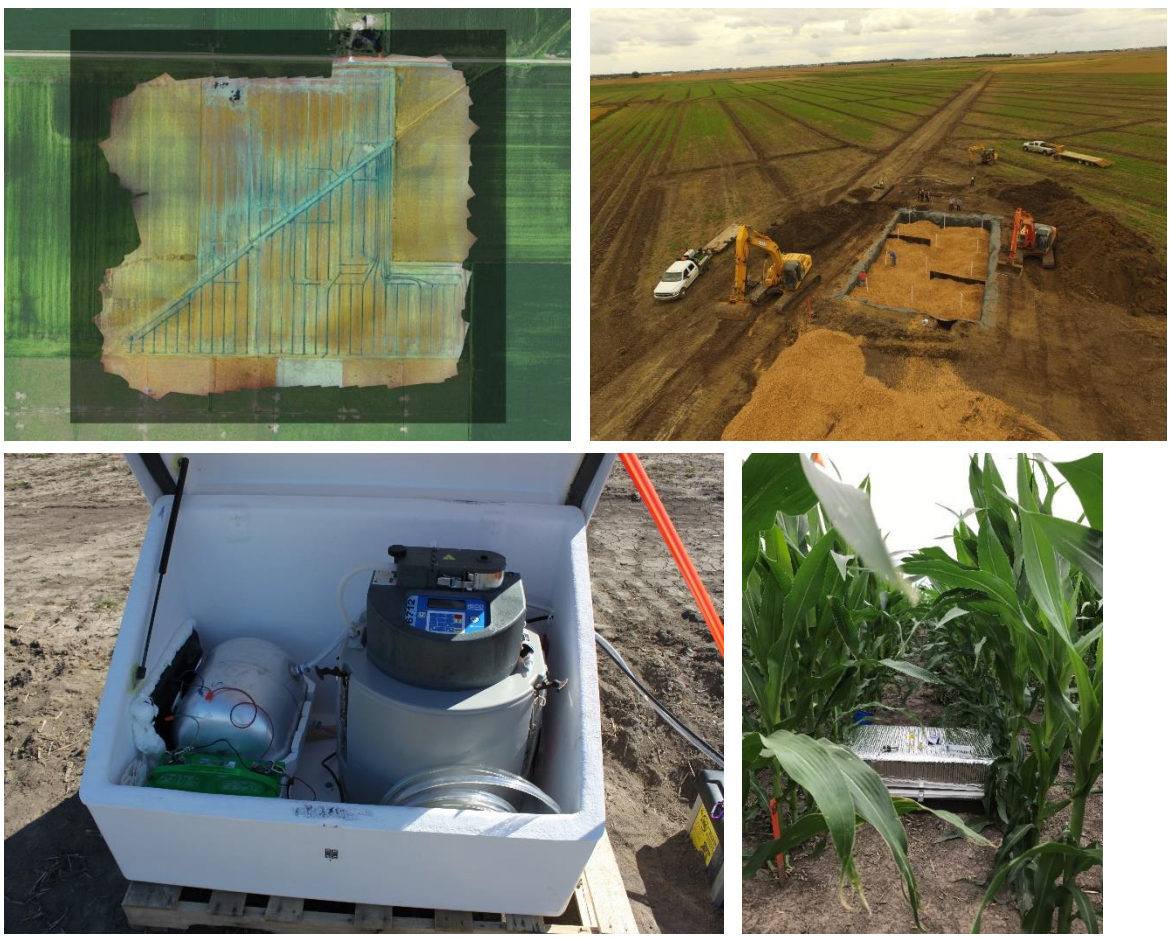

Figure 1. Aerial photographs of Dudley Smith experimental site showing individually replicated tile drainage plots approximately 2 acres in size (upper left) and bioreactor installation (upper right). Baseline data collection occurred during the 2017 growing season under uniform crop and soil management practices. Automatic water samplers were used to monitor tile drainage nitrate losses (lower left), and greenhouse gas chambers were used to measure soil N_2O emissions (lower right).

2. Accomplishments

Research infrastructure at the site including the individually replicated tile drainage research plots and a bioreactor were successfully installed at the Dudley Smith farm in Sept/Oct 2016 (**Figure 1**). This represented a delay in the project compared to the original timeline, which was largely caused by purchasing logistics at UIUC. Tile installation costs were covered by the College of ACES, and the cost estimate was large enough that the contract had to go out for public bid. The ACES Office of Research remained very dedicated to this project throughout this process, particularly through the leadership of Dr. Vickie Jarrell. With their support, the bid/procurement steps were successfully navigated, and tile drainage and bioreactor installation occurred rapidly following bid approval at the institutional level.

Due to this delay, the project timeline has shifted one year, meaning the 2017 growing season was a baseline data collection year. Following the 2017 harvest, cover crops and N management treatments were imposed, thus the 2018 growing season will represent the first full year of data collection assessing treatment impacts. An updated timeline reflecting this change is shown in **Figure 2**. Otherwise, project setup and implementation has been consistent with the originally proposed plan, with the following accomplishments in 2017:

- In March 2017 a meeting was held between the faculty research team, UIUC extension, and the tenant farmers operating the DS farm to discuss crop management logistics and research and field sampling plans. Together the group decided to create a new gate and field entryway that would facilitate access to the sampling stations. To meet the long-term goals of the project, it was also decided that a shed would be installed on the site.
- Funds from **the successful proposal** collaborating with the Christian County Farm Bureau (2017 Illinois Farm Bureau Nutrient Stewardship Grant) were used to purchase heated enclosures for the automatic water samplers.
- Research on the bioreactor began in early spring. Results indicate the water sampling equipment monitoring bioreactor in-flow and out-flow is operating well (**Figure 3**). As expected, denitrification activity is high in the first year after construction.
- The 40 acre experimental site was planted on April 26, 2017.
- A drone flight was conducted to map the layout of tile drains in early May (**Figure 4**), followed by two flights during early corn growth and midseason to assess in-field variability.
- A **field day** providing an update of project activities was conducted at the site on June 25th. All three project PIs were present and the team received good questions and feedback (**Figure 5**).
- The novel bioreactor design was **featured in the Spring 2017 AdvanCES in Research magazine**: "*Bioreactors are ready for the big time*" (Quinn, L.; pp. 48-49), available at: http://research.aces.illinois.edu/sites/research.aces.illinois.edu/files/reports/2017_AdvanCES_in_Research.pdf.
- Meetings occurred with different stakeholder to define representative 4R nutrient stewardship and cover crop practices that are recommended for reducing nutrient losses while maintaining or increasing yield in continuous corn systems. A description of the four treatments imposed in this study starting in Fall 2017 is included in **Table 1**.

- Two new PhD students have started on the project. Giovani Preza-Fontes will work on nutrient cycling and water quality with Laura Christianson and Cameron Pittelkow. Shailendra Singh will work on crop modeling and geospatial upscaling of results with Rabin Bhattarai.
- Baseline sampling for N_2O emissions and water quality was conducted throughout 2017 (see **5. Preliminary Results** below).
- Following harvest in 2017, a cereal rye cover crop was drill seeded in the cover crop plots.
- In early December 2017, strip tillage was performed on the whole field and fall N was applied to the conventional N management plots.

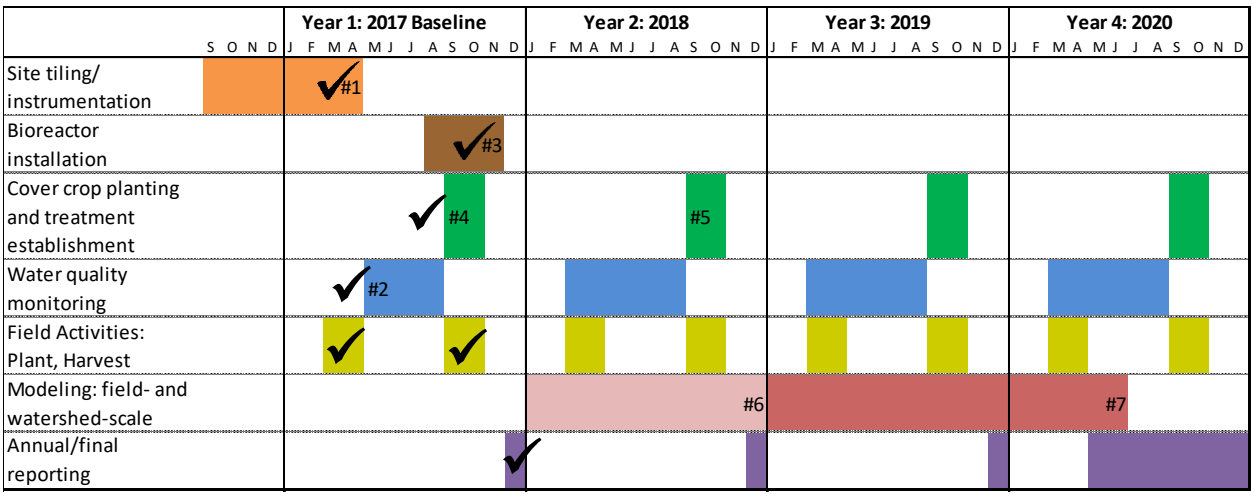

Figure 2. Four year project timeline detailing site installation, field agronomic practices, water quality monitoring, and crop modeling activities. While 2020 is not included in the current budget, unused funds for 2016 will be allocated towards data collection in 2020 by applying for a no-cost extension at the conclusion of the project. Numbers in the figure indicate the following milestones, #2 growing season for baseline water quality and soil N2O monitoring, #4 cover crop and N treatments first imposed, #5 first annual assessment of N and P losses under different treatments, #6 first annual assessment of N2O emissions under different treatments, #7 modeling portion with calibration and validation of field- and watershed- scale models.

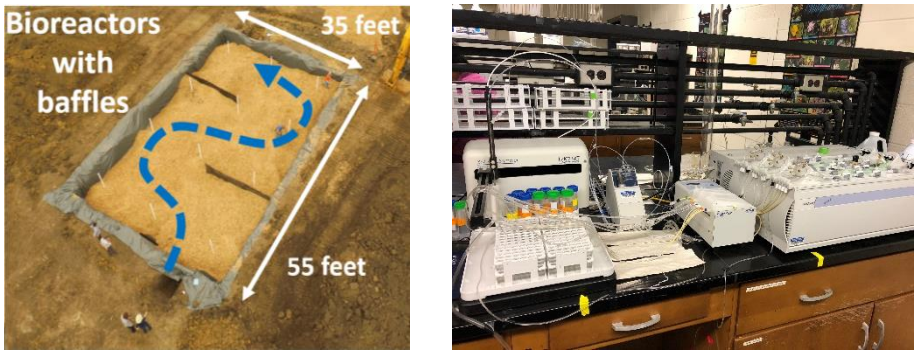

Figure 3. Bioreactor design with baffles to route water flow through the bioreactor (left) and laboratory equipment for analysis of nutrient concentrations in drainage water (right).

Figure 4. Aerial image showing the layout of tile drainage system (red lines). A drone flight was conducted shortly after crop emergence in May 2017.

Figure 5. Project leaders present an update at the June 25th, 2017 field day at the Dudley Smith experimental site. Dr. Laura Christianson (left) provides an overview of water quality monitoring and Dr. Rabin Bhattarai (right) discusses how field data will be incorporated into the modeling portion of the project.

Treatment	N rate	P and K mgmt.	Cover crop	Strip till	Fall N	N at planting	Sidedress N
Unfertilized control				X			
Conventional	MRTN	Broadcast		X	120 lb N (NH_3)	80 lb N (UAN)[1]	
4R management	MRTN	Broadcast		X		80 lb N (UAN)[2]	120 lb N (UAN) [2]
4R + cover crop	MRTN	Broadcast	Cereal rye	X		80 lb N (UAN)[2]	120 lb N (UAN) [2]

Table 1. Description of N fertilizer and cover crop treatments implemented starting in Fall 2017. The MRTN rate for continuous corn in central Illinois is 200 lb N/acre. All plots were strip tilled in the fall. [1]For the conventional treatment, UAN will be applied at planting as an herbicide carrier or 2x2 with the planter. [2]For the 4R treatments, a portion of N applied at planting or sidedress may either be UAN or a stabilized N source such as Agrotain.

3. Benefits to environment, crop production, and economics of Illinois Agriculture

Results from this project will provide much-needed information on the potential positive and negative impacts of water quality BMPs that growers are being encouraged to adopt as part of the IL NLRS. This experiment is the first of its kind spanning in-field nutrient management, in-field cover crop management, edge-of-field remedial practices, and modeling to provide a holistic assessment of promising pathways for reducing nutrient losses while maintaining crop production goals and economic profitability in Illinois agriculture.

4. Summary of activities during the 2017 growing season

For the baseline monitoring year (2017), research was focused on evaluating the within-field variability of crop growth, tile drainage discharge and N concentrations, and soil N2O emissions to verify that few underlying differences existed among treatment plots which may override treatment effects in future years of the experiment. Hence, corn was grown under the same management practices across the field. Pre-plant tillage was done using an S-tine field cultivator to prepare the seed bed. Corn was planted on April 26, with a target seeding rate of 80,000 plants ha^{-1}. Seed was placed at a depth of 2.5 to 3.5 cm with 76-cm row spacing. Nitrogen fertilizer management consisted of two applications using 28% UAN: pre-plant on April 25 (168 kg N ha^{-1}) and side-dress on June 14 (135 kg N ha^{-1}).

Drainage flow was continuously monitored using a water level data logger (Hobo® U20L-04, Onset Computer Corporation, Boume, MA) only on plots 3, 7, 9, 10, 13, and 15. Drainage flow rates were calculated using the V-Notch Stoplog Flow Equation. Drainage flow monitoring started on April 18 and water samples collection started on May 2. Water samples were only collected when drainage flow was occurring.

Measurements of N_2O were done using the closed-static chamber method according to the USDA-ARS GraceNET Project Protocol. Gas samples were taken weekly from planting to August. After side-dress N application, gas samples were taken twice a week for two weeks. From September to corn harvest, gas samples were taken twice a month.

Aerial imagery was collected using an unmanned aerial vehicle (3DR® Drone Site Scan, Berkeley, CA) equipped with a multi-spectral sensor (Parrot Sequoia®, Paris, France) on June 14 2017 when corn was approximately at the V5-V6 growth stage. The spatial resolution of aerial imagery was 15 × 15 cm. The Normalized Difference Vegetation Index (NDVI) and NDRE (Red-edge NDVI) were calculated from reflectance measurements in the red, red-edge, and near infrared portion of the spectrum, according to the following equations:

$$NDVI = \frac{NIR - Red}{NIR + Red} \quad \text{Eq. 1}$$

$$NDRE = \frac{NIR - Red\ edge}{NIR + Red\ edge} \quad \text{Eq. 2}$$

Twenty spots in the field were randomly selected for collecting plant biomass samples after the first drone flight. Plant biomass samples were collected from a 0.76 m^2 area. The plants were clipped at the ground level, dried at 60º C in a forced-air oven for 7 days, and subsamples were analyzed for tissue nitrogen concentration.

After corn physiological maturity, grain yield was estimated by hand harvesting corn ears from a 7 m^2 area near the gas chamber. Grain moisture was measured with a grain analyzer (Model GAC 2000, DICKEY-John Corp., Springfield, IL), and grain yields were corrected to 15% moisture content.

The aerial images were processed and analyzed (NDVI and NDRE) using Pix4D Software (Pix 4D S.A., Switzerland). All the maps were created using ArcMap Software (ESRI®). The NDVI and NDRE values of each cell within the sampling area were extracted using the Pixel Inspector tool. The interpolation of raster surfaces from points (soil N2O emissions and grain yield) was done using the Kriging Spatial Analyst tool. The summary statistic of both NDVI and NDRE for each plot and growth stage was obtained using the Zonal Statistical as Table Spatial Analyst tool.

5. Preliminary results

Despite differences in magnitude among plots, the temporal behavior of discharge volume followed a similar pattern (Figure 6). Cumulative tile drainage discharge volume increased rapidly during the first month of monitoring (May) in all plots, and remained stable thereafter. Drainage flow also occurred after two rainfall events on July 27 (78.8 mm) and October 11 (51.1 mm) in most of the plots. Plot 15, 3, and 9 had consistently greater discharge volume compared to the other plots, with discharge volume greater than 300 mm. On the other hand, tile drainage discharge volume was very similar on plots 7, 10, and 13, with discharge volumes ranging from 205 (plot 7) to 230 mm (plot 13).

Tile drainage discharge volume among plots had a coefficient of variation (CV) of 25%, indicating moderate within-field variability. It is important to note that this variability does not correspond to the entire field, since only 6 out of the 16 plots were monitored. In addition, drainage is affected by several factors such as soil physical properties, topography, drain spacing and depth, and soil/crop management. Thus, the CV of drainage can be dictated by many sources of variation. However, because corn was grown under the same management and the drainage system was uniform across the field, it is plausible that the different soil types contributed to the variability observed. In addition, this was the first year of drainage following tile installation and differences in drainage flow may decrease over time. Figure 7 shows the within-field variability of soil types.

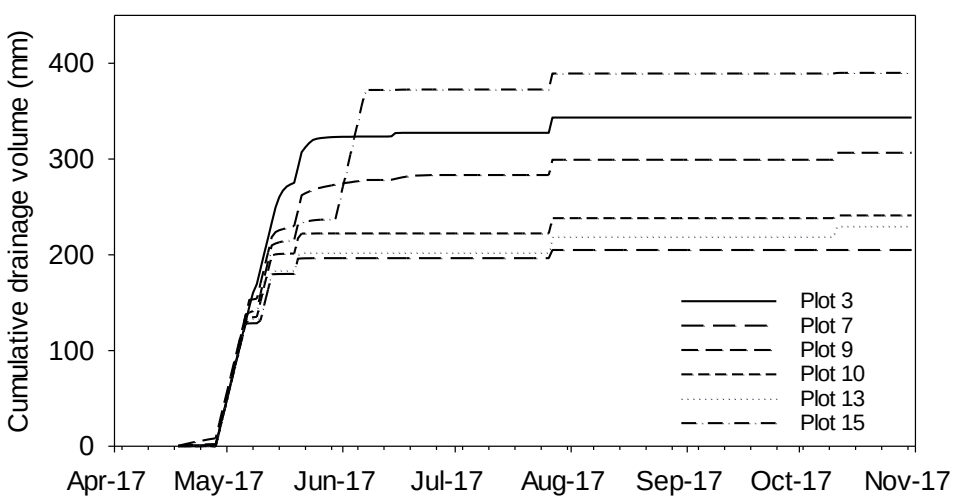

Figure 6. Cumulative discharge flow during the 2017 growing season (from April 18 to October 31st).

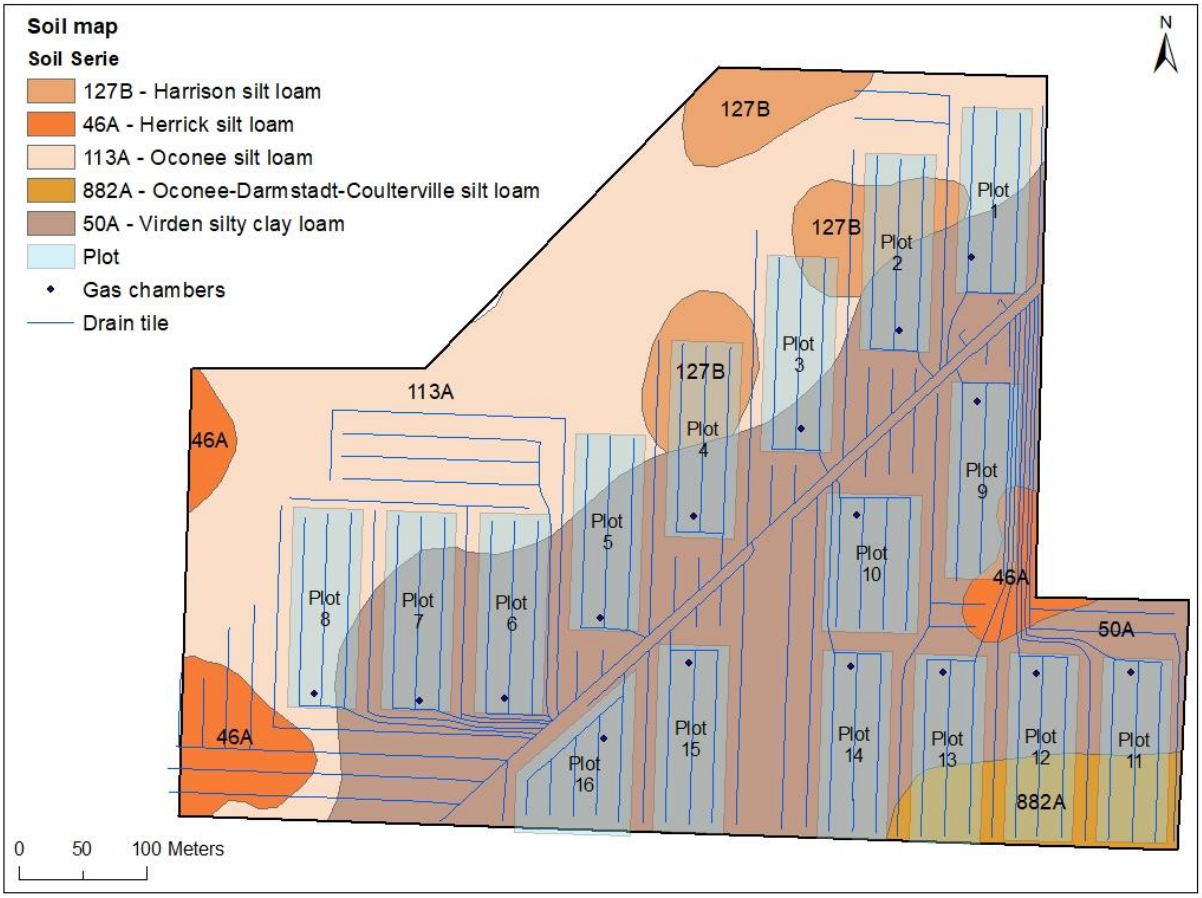

Figure 7. Layout of experimental plots and tile drainage design, including gas chamber location and soil types at the Dudley Smith Farm.

Tile drainage NO_3-N concentration varied among plots during the growing season (Figure 8A). For instance, in the first sampling date, NO_3-N concentration ranged from 2.9 (plot 11) to 16.6 mg NO_3-N L^{-1} (plot 5), with a CV of 49.8%. Moreover, the CV of daily NO_3-N concentration was above 40% throughout the growing season.

Spikes of NO_3-N concentration were also seen on May 17 on plots 8 and 13, and on June 16 on plot 5 (2 days after side-dress N application). Total nitrate load at the end of the growing season was considerably higher on plot 3 compared to the other plots (Figure 8B). In addition, NO_3-N load ranged from 5.8 to 13.7 kg NO_3-N ha^{-1}, with a CV of 31.7%.

Nitrate is very mobile in the soil due to its negative charge, so it moves freely with water. In this sense, tile drainage NO_3-N concentration is expected to increase after N fertilizer application, particularly if the N fertilizer source contains N in the form of nitrate and in years with high precipitation. Although the monitoring of water samples started on May 2nd, it is possible that tile drainage NO_3-N concentration was high due to the pre-plant N application of 168 kg N ha^{-1} as UAN coupled with high precipitation events (33.3 and 31.7 mm of rain on May 11 and June 15, respectively).

In situations like this, tile drainage NO_3-N concentrations can easily exceed the 10 mg L^{-1} maximum contaminant level established by the US-EPA for drinking water purposes.

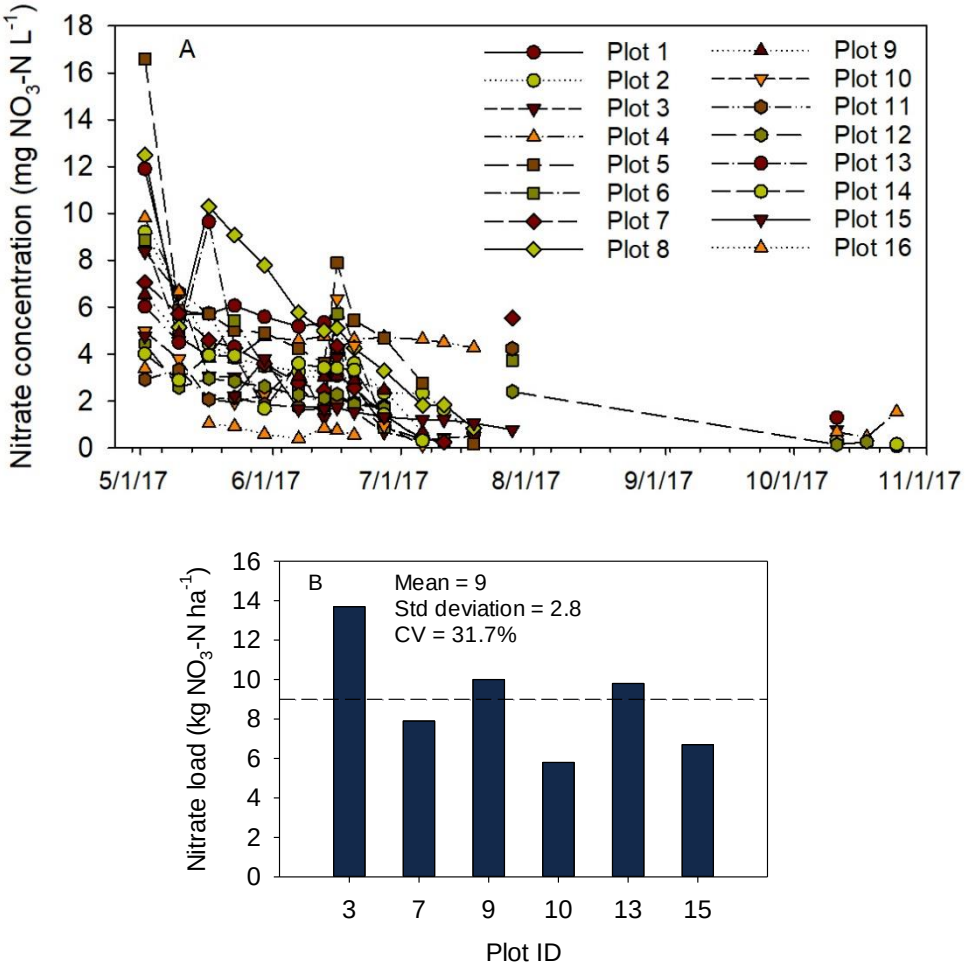

Figure 8. Daily nitrate concentrations for experimental plots (A) and total nitrate load for plots with continuous monitoring of drainage discharge (B) for the 2017 growing season at Dudley Smith Farm.

The bioreactor was monitored throughout 2017 and its performance in removing nitrate was high, as expected (Figure 9A). Nitrate exiting the bioreactor was generally much lower than entering the bioreactor, resulting in a 76% reduction in nitrate in the water that was treated in the bioreactor over the entire growing season. During heavy precipitation events, bypass flow occurred where some water leaving the field did not enter the bioreactor (see orange lines on graph). Thus, in total the bioreactor removed around 50% of the total nitrate load exiting the field (Figure 9B) (that is, the treated water plus the untreated bypass during heavy precipitation events in the spring of 2017).

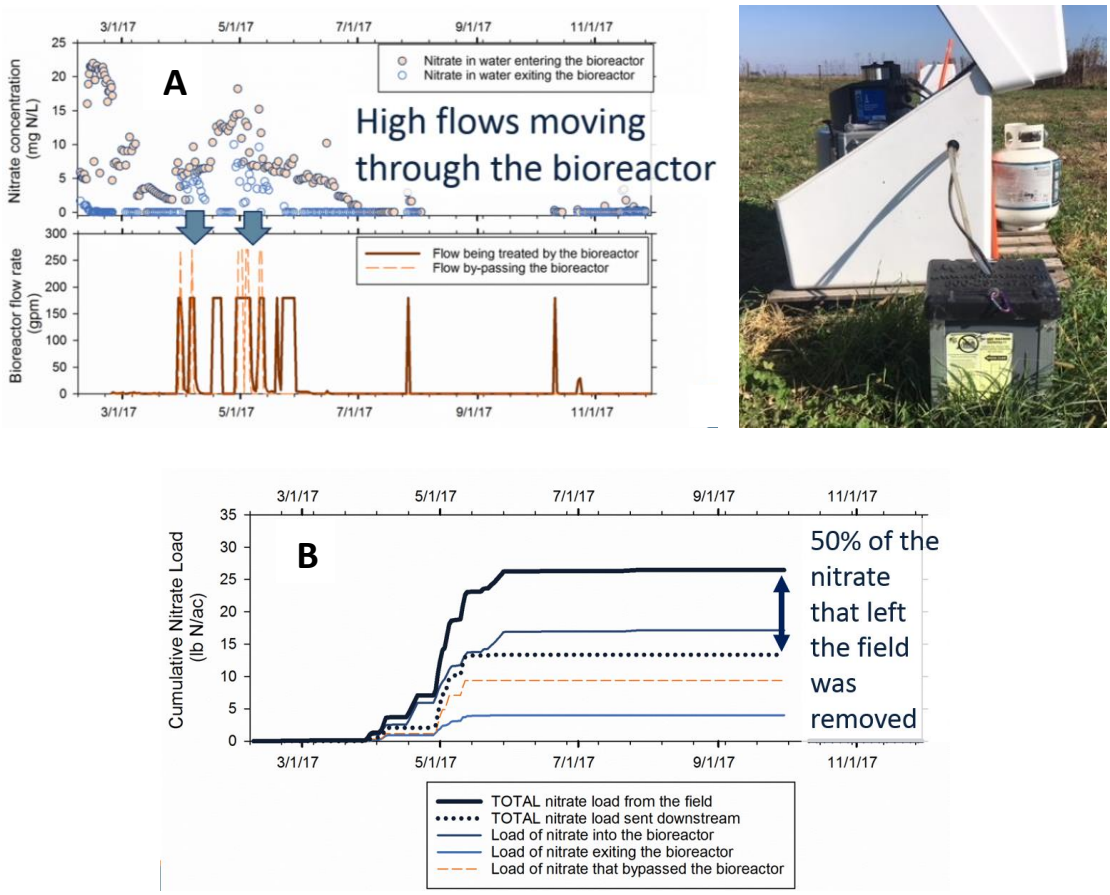

Figure 9. Nitrate concentrations in water entering and leaving the bioreactor, and the flow rate of water entering the bioreactor and by-passing the bioreactor (A). The resulting cumulative load of nitrate entering, leaving, and by-passing the bioreactor (B).

Higher spatial variability of NDVI was observed within-field at V6 when compared to R1 (Figure 10). The CV ranged from 10 to 28.1% for NDVI at V6 compared the range of 1.4 to 6.8% at R1 (Table 2). When averaged per plot, NDVI ranged from 0.462 (plot 4) to 0.668 (plot 13), with a CV of 12.8%. A similar pattern was observed for NDRE, with higher variability early in the growing season (V6) in comparison to when corn was at R1.

The high values of CV at V6 also indicate a high variability within-plot (Table 2). The dark red spots (low NDVI) across the field were likely due to poor seed germination and plant emergence. Excessive rainfall within 10 days after planting (177 mm) caused long periods of ponding across the fied, leading to corn being replanted in some of these areas.

NDVI has been successfully used to monitor plant biomass and N status throughout the growing season. Generally, greater leaf area and greener plant biomass result in higher NDVI values. However, NDVI values tend to saturate later in the growing season. This is because at the end of the vegetative stage, the canopy is closed and the sensor cannot capture light reflectance from the soil. Thus, there is a peak of absorption in the red light wavelength and NDVI become less sensitive to changes in plant biomass, and consequently this results in smaller differences in NDVI values. In contrast, NDRE is more

sensitive to changes in biomass after a certain biomass density that occurs at the end of the vegetative stage. Therefore, NDRE can be used to make inferences of plant biomass and N status later in the season, as shown in Figure 11.

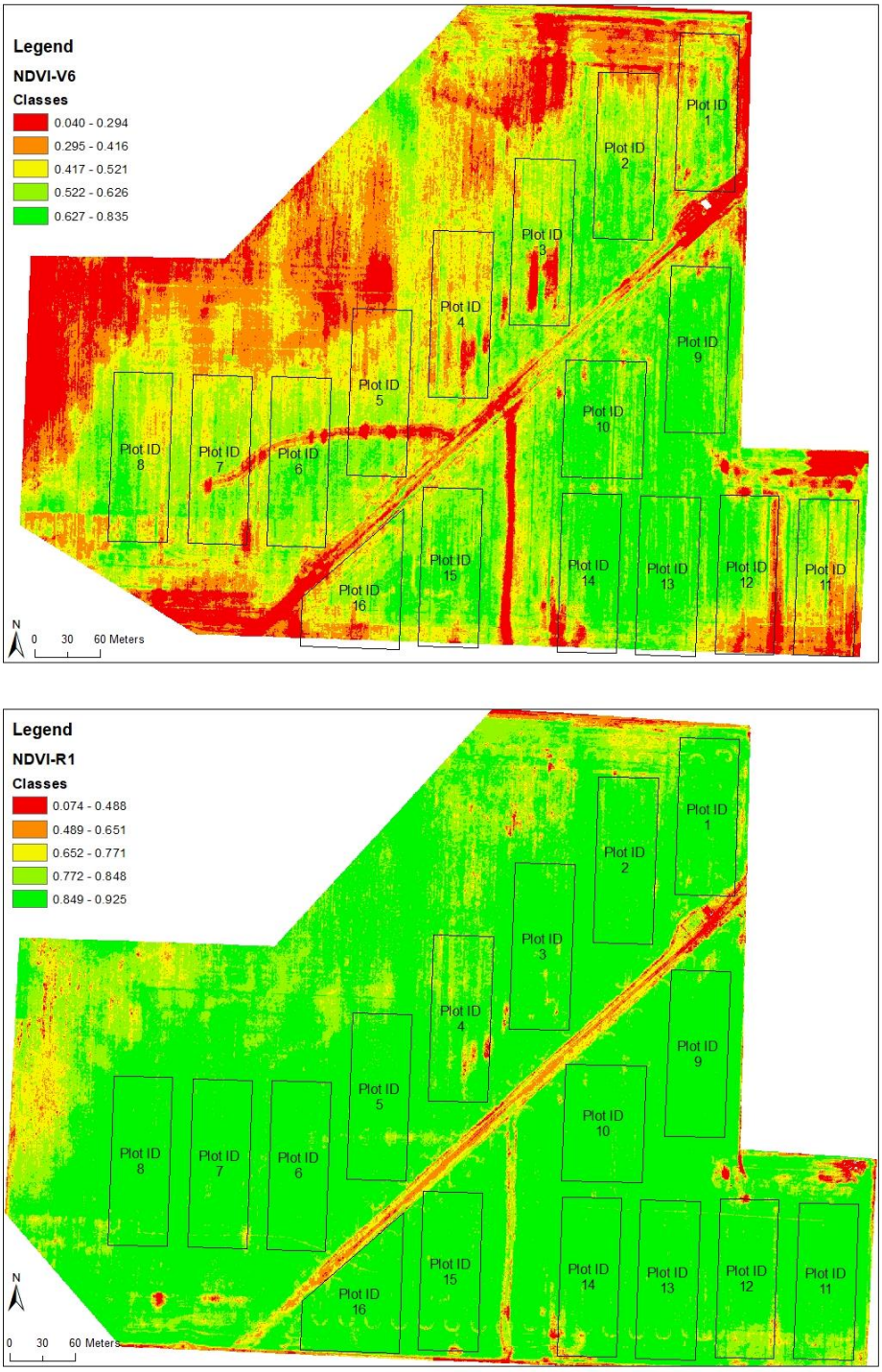

Figure 10. Normalized Difference Vegetation Index (NDVI) of corn at growth stage V6 (top) and R1 (bottom) during the 2017 growing season at Dudley Smith Farm.

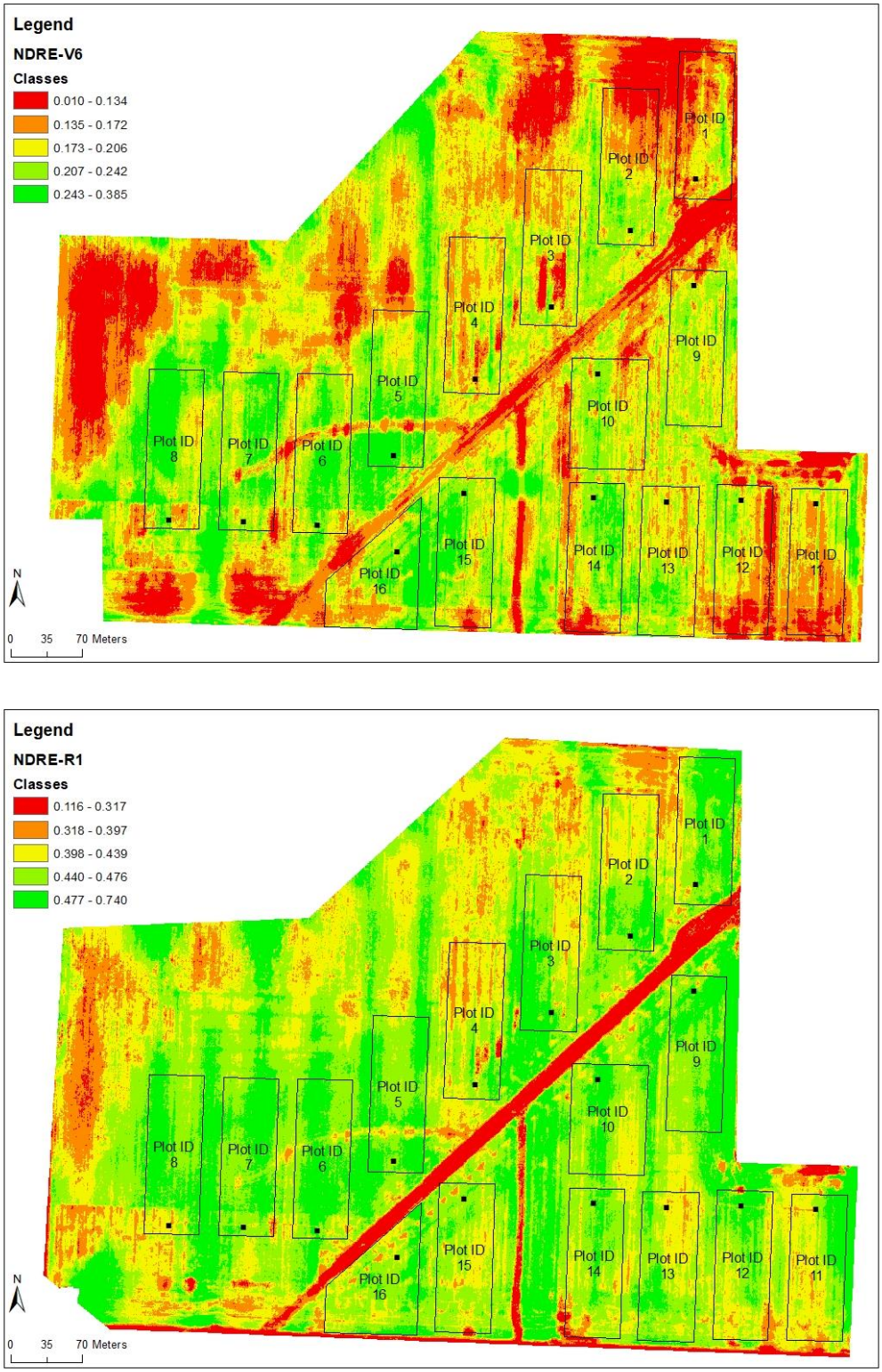

Figure 11. Red-edge Normalized Difference Vegetation Index (NDRE) of corn at growth stage V6 (top) and R1 (bottom) during the 2017 growing season at Dudley Smith Farm.

Table 2. Summary statistics of NDVI and NDRE of corn at growth stage V6 and R1.

	NDVI – V6						NDVI – R1					
Plot	Min	Max	Range	Mean	STD	CV (%)	Min	Max	Range	Mean	STD	CV (%)
1	0.154	0.794	0.640	0.515	0.110	21.3	0.381	0.918	0.537	0.876	0.034	3.9
2	0.217	0.784	0.567	0.557	0.090	16.2	0.629	0.903	0.274	0.873	0.015	1.7
3	0.158	0.753	0.594	0.503	0.119	23.6	0.423	0.912	0.489	0.878	0.022	2.6
4	0.158	0.755	0.597	0.462	0.084	18.3	0.348	0.908	0.560	0.845	0.057	6.8
5	0.146	0.711	0.565	0.481	0.099	20.7	0.628	0.914	0.286	0.877	0.017	2.0
6	0.172	0.731	0.558	0.547	0.084	15.3	0.719	0.911	0.192	0.885	0.013	1.5
7	0.144	0.707	0.563	0.519	0.081	15.6	0.625	0.909	0.284	0.883	0.016	1.8
8	0.237	0.786	0.549	0.546	0.081	14.8	0.698	0.910	0.212	0.881	0.014	1.5
9	0.206	0.807	0.601	0.665	0.071	10.7	0.568	0.921	0.353	0.891	0.012	1.4
10	0.216	0.811	0.595	0.640	0.070	11.0	0.612	0.912	0.300	0.885	0.014	1.6
11	0.148	0.763	0.615	0.470	0.116	24.7	0.471	0.921	0.450	0.875	0.028	3.2
12	0.134	0.807	0.673	0.532	0.149	28.1	0.262	0.912	0.650	0.859	0.043	5.0
13	0.376	0.820	0.444	0.668	0.067	10.0	0.604	0.905	0.301	0.878	0.014	1.5
14	0.149	0.815	0.666	0.623	0.124	19.9	0.268	0.909	0.640	0.874	0.044	5.0
15	0.188	0.794	0.606	0.594	0.083	13.9	0.311	0.905	0.593	0.874	0.026	3.0
16	0.158	0.804	0.646	0.503	0.105	20.9	0.362	0.908	0.545	0.874	0.031	3.6
	NDRE – V6						**NDRE – R1**					
Plot	Min	Max	Range	Mean	STD	CV (%)	Min	Max	Range	Mean	STD	CV (%)
1	0.065	0.264	0.199	0.164	0.036	22.1	0.232	0.574	0.342	0.469	0.036	7.7
2	0.073	0.273	0.200	0.180	0.040	22.0	0.353	0.529	0.176	0.448	0.029	6.4
3	0.099	0.274	0.175	0.181	0.030	16.5	0.275	0.540	0.265	0.456	0.034	7.4
4	0.109	0.292	0.183	0.183	0.026	14.2	0.217	0.523	0.306	0.425	0.037	8.6
5	0.113	0.330	0.217	0.225	0.036	16.0	0.328	0.540	0.213	0.471	0.023	4.8
6	0.105	0.307	0.202	0.220	0.035	15.7	0.357	0.534	0.177	0.475	0.022	4.6
7	0.092	0.312	0.220	0.226	0.031	13.6	0.259	0.527	0.268	0.474	0.022	4.6
8	0.121	0.357	0.235	0.235	0.042	17.9	0.349	0.528	0.179	0.470	0.024	5.2
9	0.075	0.262	0.187	0.201	0.022	10.9	0.345	0.543	0.198	0.472	0.021	4.4
10	0.054	0.279	0.225	0.201	0.027	13.6	0.243	0.530	0.287	0.458	0.025	5.5
11	0.091	0.283	0.192	0.170	0.029	17.1	0.253	0.545	0.292	0.442	0.035	7.9
12	0.073	0.275	0.203	0.174	0.037	21.4	0.263	0.542	0.279	0.450	0.031	6.8
13	0.125	0.291	0.167	0.203	0.027	13.2	0.351	0.518	0.167	0.447	0.026	5.9
14	0.077	0.290	0.212	0.205	0.040	19.4	0.203	0.514	0.311	0.448	0.033	7.4
15	0.091	0.327	0.236	0.217	0.036	16.8	0.224	0.499	0.275	0.444	0.024	5.5
16	0.094	0.344	0.250	0.209	0.040	19.3	0.210	0.524	0.314	0.451	0.029	6.4

STD = standard deviation
CV = coefficient of variation

Daily (dN_2O) and cumulative (cN_2O) N_2O emissions are shown in Figure 12. Despite differences in magnitude, the overall pattern of dN_2O emissions was temporally similar among plots (Figure 12A). On the second sampling date (May 23), emissions were higher (> 45 g N_2O-N ha^{-1} day^{-1}) on plots 5, 9, and 16 compared to the remaining plots, with a CV of 66.5%. Five days after N side-dress application, dN_2O emissions rapidly increased in most of the plots. For instance, dN_2O emissions increased from 4.8 and 4.2 to 70.4 and 79.6 g N_2O-N ha^{-1} day^{-1} on plots 1 and 2, respectively, resulting in a CV of 51.8%. In addition, dN_2O emissions were above 90 g N_2O-N ha^{-1} day^{-1} on plots 8 and 16 on the same date. Spikes in dN_2O emissions were also seen later in the growing season (June 25), particularly on plot 1.

Throughout the growing season, dN_2O emissions varied among plots, with CV ranging from 48 to 116%. In addition, cN_2O emissions had a CV of 42.2%. It is well accepted that N fertilization is the major factor controlling soil N_2O emissions in croplands, and emissions have been found to increase near linearly with N fertilizer rate. Considering the large amount of N fertilizer applied in the field (303 kg N ha^{-1}), it was surprising that dN_2O emissions in this study were below 100 g N_2O-N ha^{-1} day^{-1} for most of the growing season, even after N side-dress application (Figure 12A).

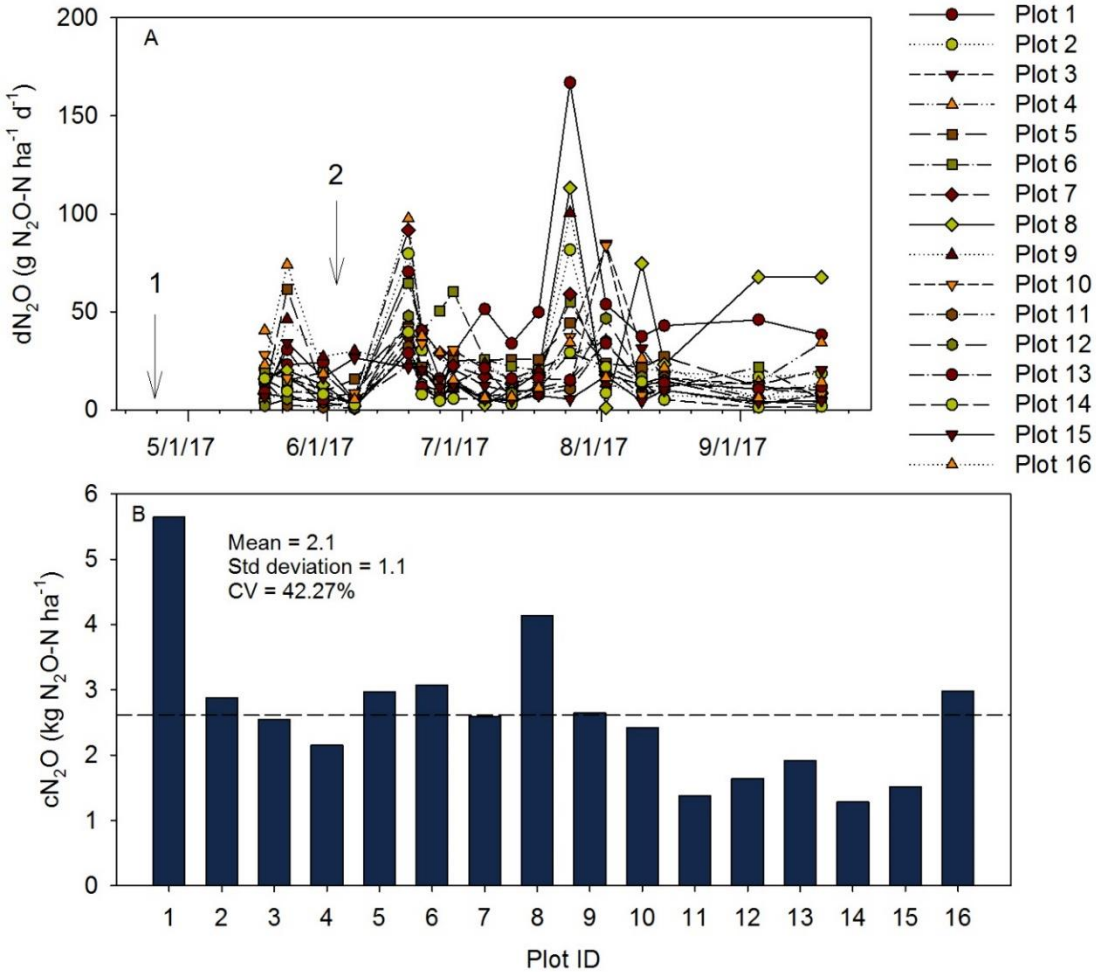

Figure 12. Daily (dN_2O) and cumulative (cN_2O) nitrous oxide (N_2O) emissions for each plot during the 2017 growing season at Dudley Smith Farm. (1 = pre-plant N application; 2 = side-dress N application; the dashed line in B indicates the mean cN_2O across plots).

High variability was also seen in terms of cN_2O emissions, with CV of 42.2% (Figure 12B). At the end of the growing season, plot 1 had the greatest cN_2O emissions (5.64 kg N_2O-N ha^{-1}) compare to the other plots. Moreover, plots 11 through 15 tended to have the lowest emissions, ranging from 1.27 to 1.63 kg N_2O-N ha^{-1}.

Figure 13 shows the distribution of cN_2O across the field as a result of the spatial analysis conducted using ArcMap. This technique allows us to divide the field in sub-areas and have a better understanding of the variability of cN_2O within-field. For instance, Figure 13 shows that the north and the west part of the field are more susceptible to losses of N via denitrification compared to the southeast part of the field. However, it must be noted that denitrification-driven N_2O emissions under field conditions are very complex and difficult to manage, as they are controlled by the interaction of many factors such as soil pH, texture, temperature, moisture, and availability of NO_3^- and soluble C. Because the spatial analysis only uses data from our selected sampling points in the field, these results need to be interpreted together with the factors mentioned above to make more confident inferences.

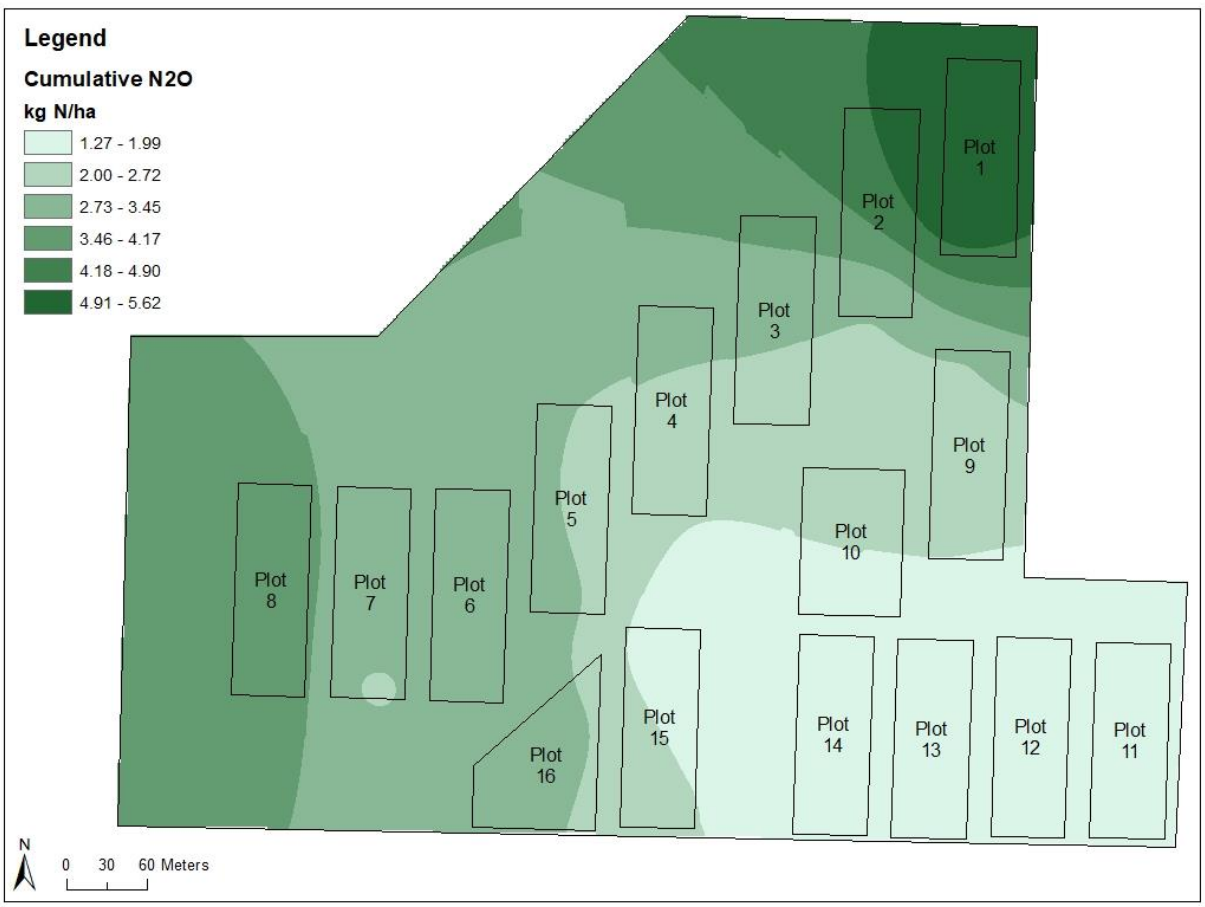

Figure 13. Within-field variability of cumulative soil nitrous oxide (N_2O) emissions at the end of the 2017 growing season at Dudley Smith Farm.

Estimations of total N uptake and corn grain yield showed low variability among plots (CV < 10%). These results are preliminary, as they are based on hand harvest areas near the GHG sampling

chambers. Total N uptake ranged from 218 (plot 16) to 322 kg ha^{-1} (plot 6), whereas grain yield ranged from 11.9 (plot 6) to 15.7 Mg ha^{-1} (plot 14). When averaged across plots, the grain yield determined by hand harvest was 14.1 Mg ha^{-1}. This is higher than the average yield of 13 Mg ha^{-1} of 2016 corn in Christian County, IL (USDA-NASS). The results from the grain yield monitor data collected at harvest are not yet available yet, but we are working with the grower and should obtain them shortly. We expect to see greater variability of yield within-field due to the high variability observed of NDRE at R1.

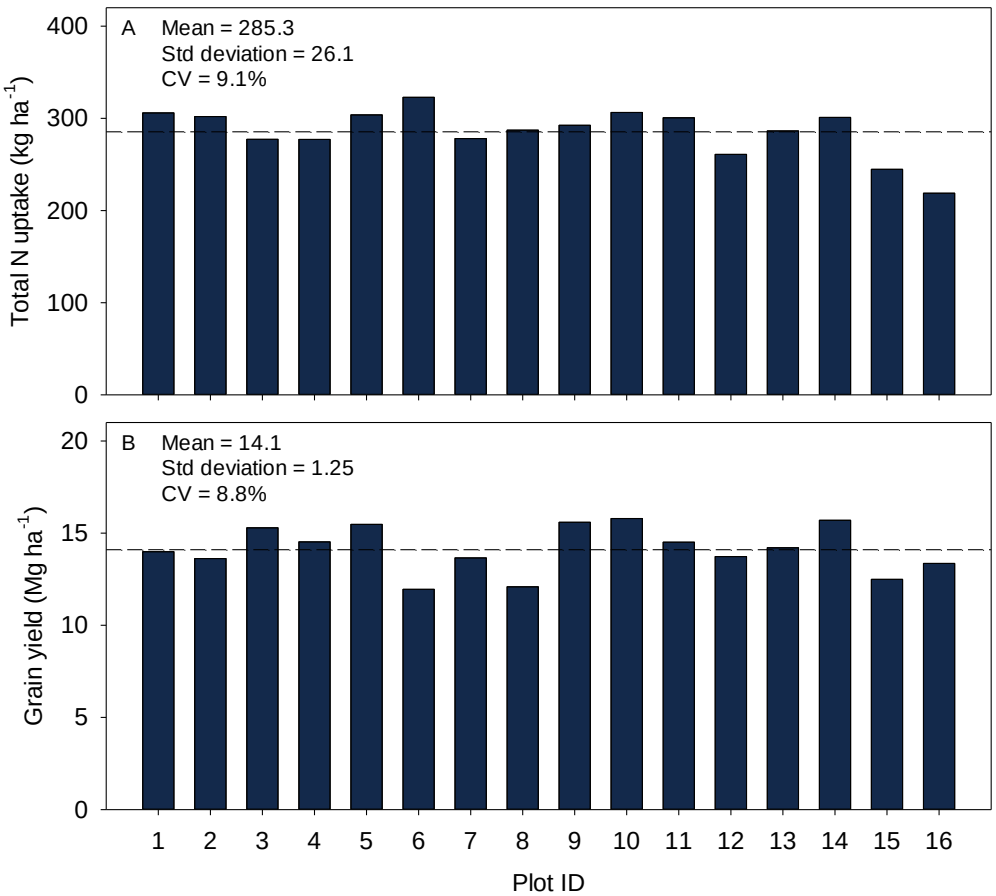

Figure 14. Estimated total N uptake (A) and corn grain yield (B) based on hand harvest areas sampled within each plot near the GHG chamber location.

5. Budget analysis

As discussed above, the timeline for the project has been delayed approximately one year. Accordingly, expenditures have been lower than the proposed budget thus far, primarily for Salary & Benefits for the first year of the project (2016). Significant project activities occurred this year in terms of trial management (strip tillage, cover crop seeding, etc.), baseline soil sampling to 90 cm at 6 locations per plot, completion of water quality monitoring setup, and GHG measurements. Therefore, funds for 2017 were largely allocated as proposed in the budget for 2017. This is a long-term experiment and it is anticipated that a no-cost extension will be applied for at the end of the project to apply the remaining

funds from 2016 (primarily labor and trial management) to data collection and trial management efforts in 2020. This has been discussed with NREC.

A preliminary budget analysis for cumulative expenses in this project (Jan 1, 2016 to Feb 5, 2018) is provided below. A finalized budget for this period will be sent from the UIUC Grants & Contracts Office to Julie Armstrong when charges are finalized in the University accounting system.

Project Budget (January 01, 2016 – Feb 5, 2018)				
Line Description	**Budget**	**Expenditures**	**Encumbrances**	**Balance**
Salaries and Wages	128,755.00	92,590.59	8,138.11	28,026.30
Fringe Benefits	43,381.00	28,618.40	2,347.63	12,414.97
Equipment	0	0	0	0
Travel	8,000.00	2,574.27	0	5,425.73
Materials and Supplies	85,944.00	82,190.59	522.71	-1
Publications and Printing	0	0	0	0
Services	15,500.00	246.21	6,764.00	-1
Total Indirect Costs	31,284.00	22,869.79	1,974.52	6,439.69
Total	313,675.14	229,089.85	19,746.97	64,838.32