2021 Final Report
Summary Sheet

Grantee Information

Project Title: Evaluating Nutrient Loss Reduction Strategies: Longer rotation with cover crops and bioreactor

Institution: University of Illinois at Urbana-Champaign

Primary Investigator: Lowell Gentry

NREC Project # 2015-5-360350-374

[redacted]

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:

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:
We can demonstrate proof of concept that a more divers rotation (C-S-W with double crop soybean after wheat and cereal rye after corn) can compete financially with conventional C-S production while reducing tile nitrate by more than 30%.

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:
We had an article in Prairie Farmer about the bioreactor recharge and I have presented data from this study 6 times in the past year. Dr. Tony Studer was successful as the PI on a NIFA grant meant to "reinvent Extension" and Eric Miller's site was showcased in the text and will be part of addressing one of the major goals of the study. Our research group will receive two continuous-recording nitrate sensors to show the dramatic effect of management (i.e. cover crops vs. fall N application) on tile nitrate across one farm (Eric Miller's farm), ultimately real time tile nitrate would be available to the public. extreme difference in tile nitrate. This could have major implications for how the University conducts Extension and Outreach at the nexus of agriculture and water quality.

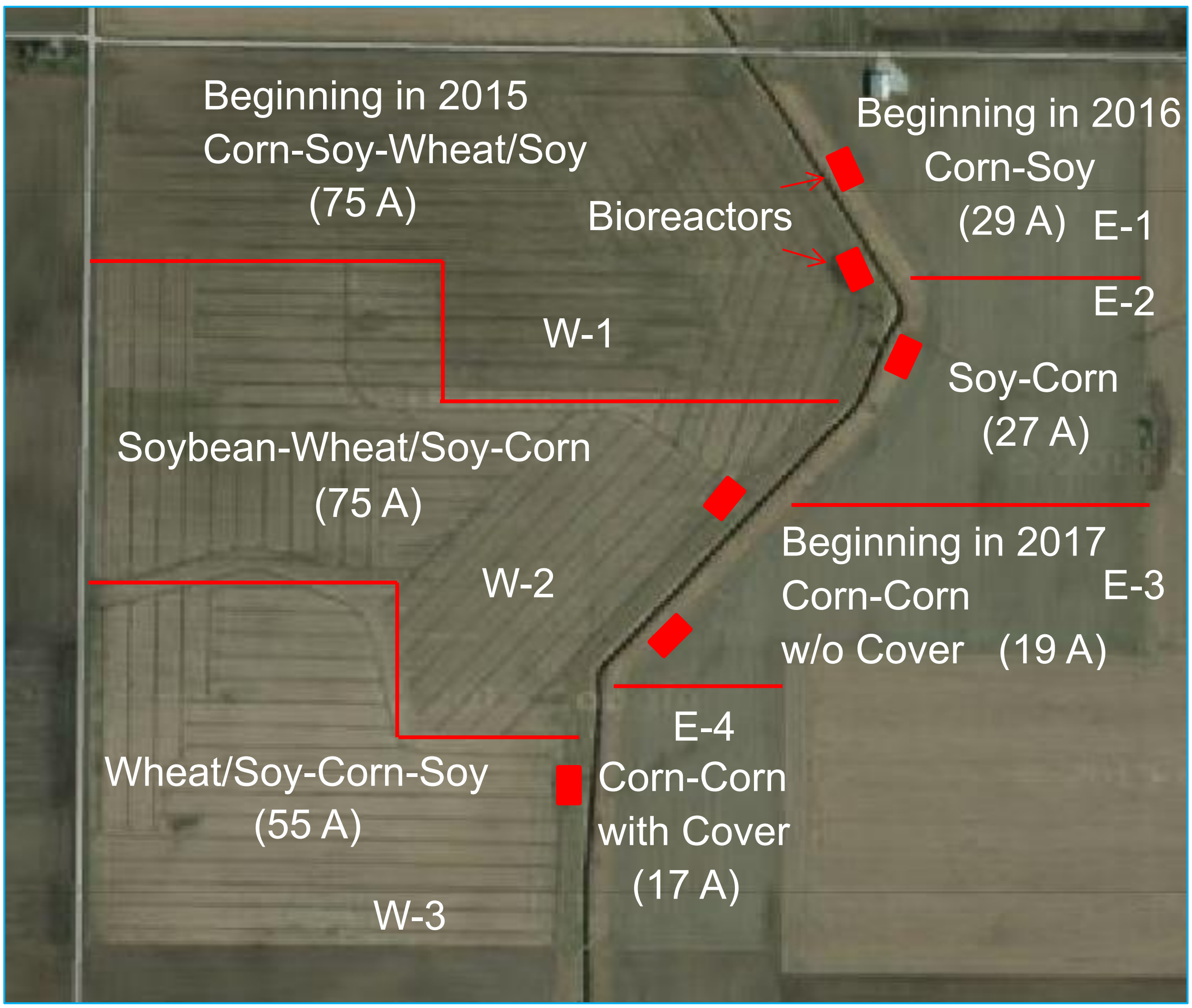
Please write a detailed summary report that includes: Details of each objective and the progress made towards its competition, planned research activities for 2022, major accomplishments, any preliminary findings or data relevant to the project, relevant budgeting, and any publications or outreach accomplished from the research. Please **include a one page summary with relevant data tables or graphs and pictures related to the project that you would like included in the NREC end of the year report.**

Evaluating Nutrient Loss Reduction Strategies: Longer rotation with cover crops and bioreactor

PI: Lowell Gentry, Principal Research Specialist in Agriculture, Department of Natural Resources and Environmental Sciences, University of Illinois, W-503 Turner Hall, 1102 S. Goodwin Ave., Urbana, IL 61801. (217) 333-1769. lgentry@illinois.edu.

Collaborators: Eric Miller, (Landowner and operator of the production farm where the research will be conducted) and **Dan Schaefer** (IFCA)

Location: Eric Miller's farm in Piatt County IL. We monitor outlets from 7 separate tile drainage systems where 6 of them flow through a bioreactor. At this site, we can simultaneously compare and contrast tile nitrate loss from four management systems consisting of 1) a maize-soy-wheat rotation with cover crops, 2) a conventional maize-soy rotation, 3) continuous maize, and 4) continuous maize with cereal rye. The size of the site offers the opportunity to conduct a large-scale evaluation of each cropping system in adjacent fields that are composed of the same soil type and exposed to the same weather conditions (**see map of site below**).



Objectives:

The overall **goal** of this study is to **test the effectiveness of a longer rotation with cover crops in combination with a bioreactor** to decrease tile nitrate loss and directly examine this potential nutrient loss reduction scenario on a field-scale production system.

Specific objectives are to:

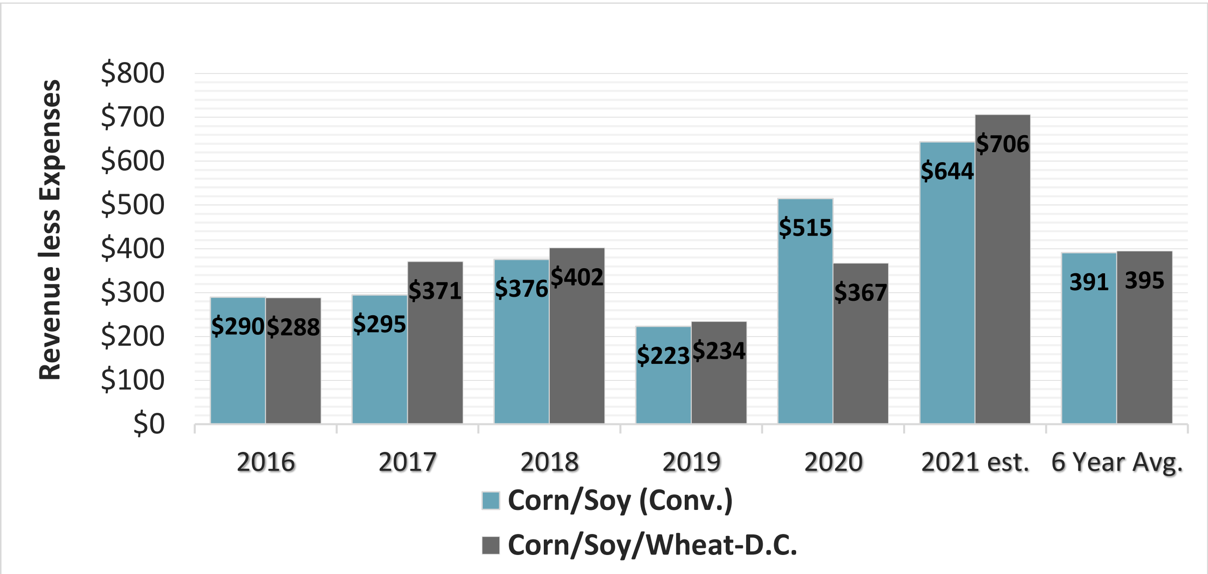
1. Determine the effect of a C-S-W rotation with cover crops on crop yields, nutrient cycling, field hydrology, and nitrate leaching on field scale plots.
2. Examine the role of cover crops in N cycling and nitrogen availability.
3. Perform economic evaluation of the four cropping systems on this farm.
4. Compare yield curves, maximum yields and EONR of corn in N rate trials in both C-S-W and C-S systems.
5. Monitor and evaluate bioreactor performance (See NREC project 2022-1-360350-404)

Crop Yields, Economic Analysis, and Tile Nitrate:

Table showing crop yields and flow weighted mean nitrate concentrations of tiles draining associated fields from 2015 through 2021.

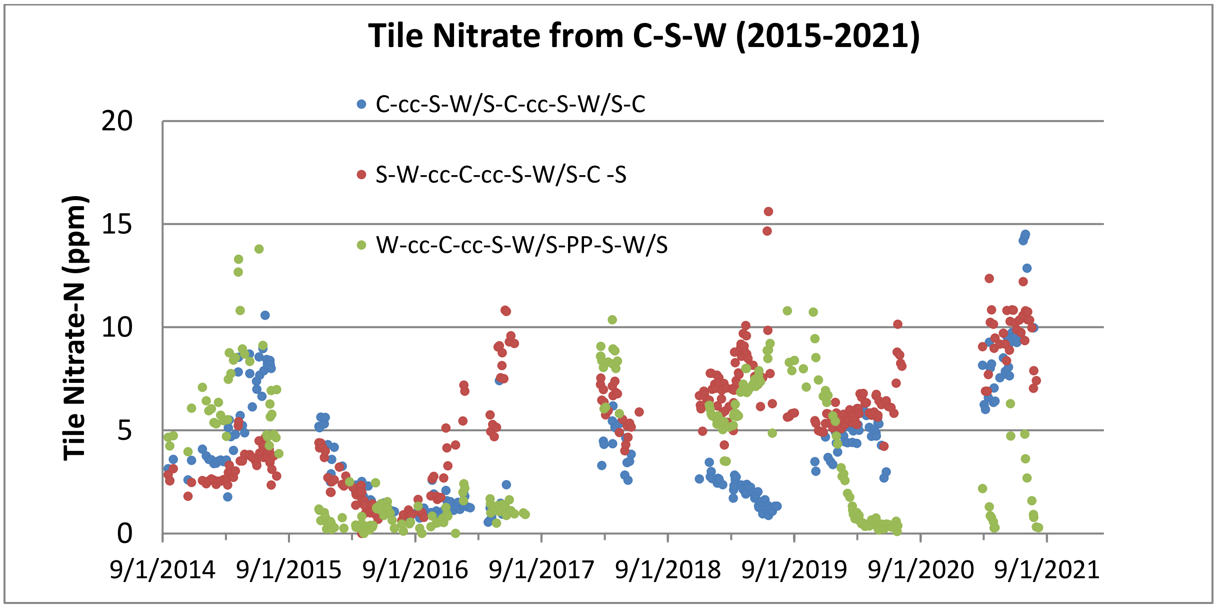
Fields	2015	2016	2017	2018	2019	2020	2021
W-1	**Corn**	**Soy**	**Wheat/Soy**	**Corn**	**Soy**	**Wheat/Soy**	**Corn**
Yield (bu/A)	253	75	98/55	265	75	92/20	241
Tile NO_3 (ppm)	7.7	2.2	2.2	4.7	1.9	4.5	8.7
W-2	**Soy**	**Wheat**	**Corn**	**Soy**	**Wheat/Soy**	**Corn**	**Soy**
Yield (bu/A)	83	101	259	97	102/25	231	84
Tile NO_3 (ppm)	3.8	2.3	7.5	6.7	8.2	6.4	9.1
W-3	**Wheat**	**Corn**	**Soy**	**Wheat/Soy**	**Prevent**	**Soy**	**Wheat/Soy**
Yield (bu/A)	77	206	80	88/52	-	71	106/53
Tile NO_3 (ppm)	7.3	0.8	1.2	8.7	7.0	1.5	2.1
E-1		**Corn**	**Soy**	**Corn**	**Soy**	**Corn**	**Soy**
Yield (bu/A)		219	79	271	83	217	80
Tile NO_3 (ppm)		7.2	5.0	9.4	7.8	8.9	5.5
E-2		**Soy**	**Corn**	**Soy**	**Corn**	**Soy**	**Corn**
Yield (bu/A)		86	242	86	221	80	228
Tile NO_3 (ppm)		7.0	7.3	5.8	12.1	5.1	11.6

In general, crop yields were excellent this past year for both C-S-W and C-S. Corn and soybean yields in C-S-W were greater than in C-S, and winter wheat with double crop soybean was the most productive system (wheat = 106 bu/A and soybean = 53 bu/A) and produced the greatest net return of any phase of the rotation in 2021.



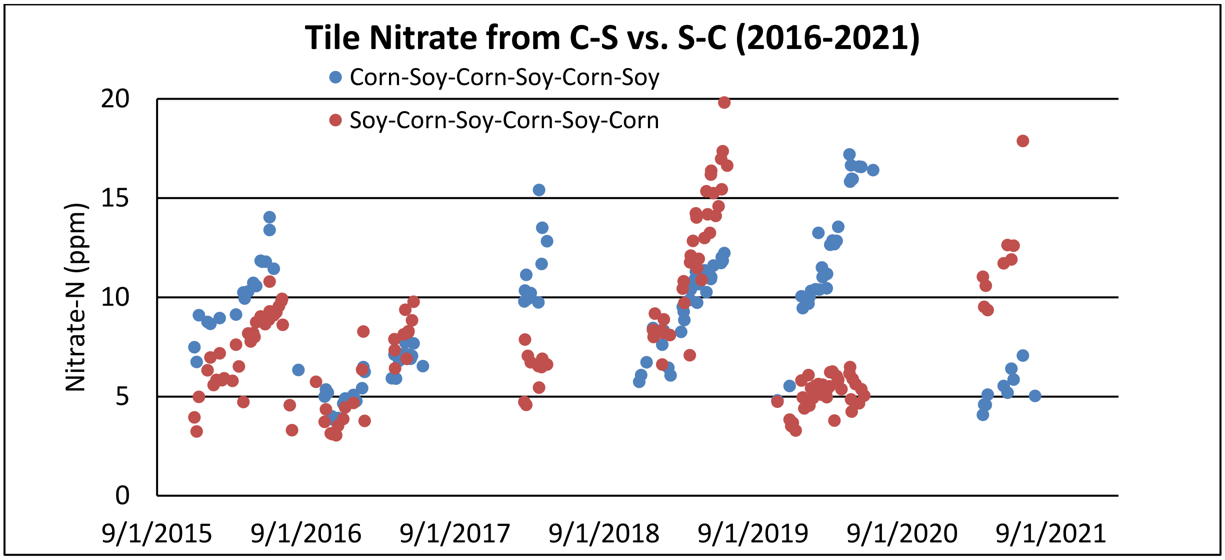
Six-year economic evaluation of C-S-W vs. conventional C-S averaged across all crop phases of each rotation every year.

It is clear that the 3-year rotation (with double crop soybean after winter wheat and cereal rye after corn) can compete financially with convention C-S production at this latitude.



Tile nitrate concentrations from each cropping sequence within the C-S-W rotation from the fall of 2014 through the 2021 drainage season.

Following wheat/double crop soybean in 2020, tile flow weighted mean (FWM) nitrate concentration (8.7 ppm) was greater than usual possibly due to warm fall conditions that promoted N mineralization (blue dots). In addition, tile FWM nitrate concentration (9.1 ppm) was elevated following corn in 2020 (red dots) possibly because EONR was 30 lbs/A less than the applied rate of 180 lbs/A and because the cereal rye biomass did not attain the 0.5 tons/A threshold needed to reduce tile nitrate. After the "unintentionally" large cereal rye cover crop (2.75 tons/A) ahead of soybean in 2020, tile FWM nitrate concentration (2.1 ppm) remained much lower than the other two phases of the rotation in 2021 (green dots).



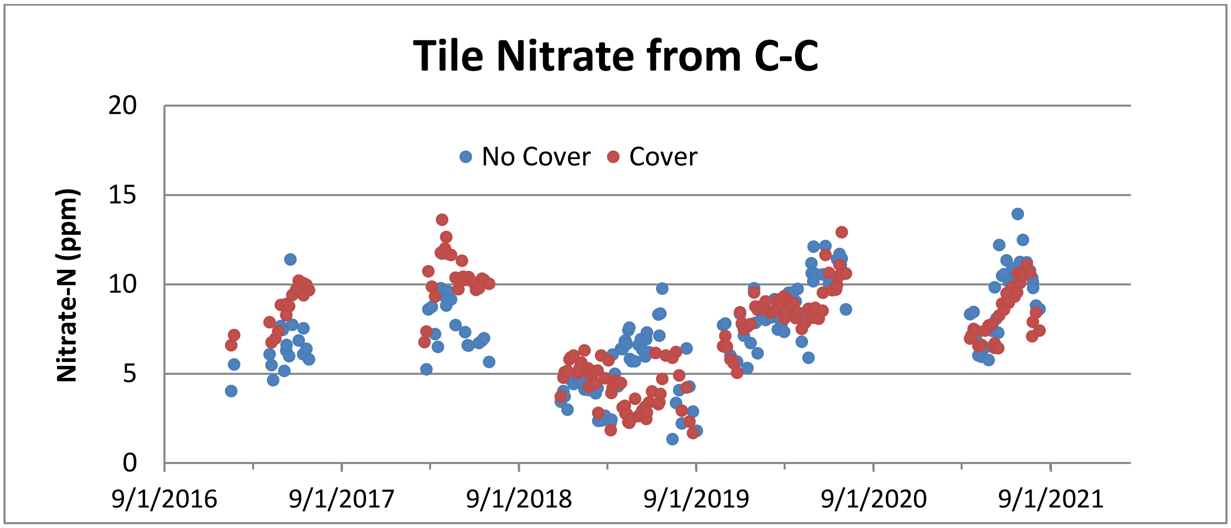
Tile nitrate concentrations from both cropping sequences within the C-S rotation from the fall of 2014 through the 2021 drainage season.

During the past 6 years in the C-S rotation, the corn phase has lost more tile nitrate than has the soybean phase, especiall in the past 3 years when the corn pahse has received N application in the fall (applied with an inhibitor). This was agin true in 2021 as FWM nitrate concentrations were 11.5 ppm for corn (red dots) and 5.5 ppm for soybean (blue dots).

Using tile nitrate data from 2017 through 2021 (period when double crop soybean followed wheat), we find an overall reduction in tile nitrate of 33% comparing C-S-W with C-S. The decrease in FWM nitrate concentrations was greater than 40% in years 2017, 2019, and 2020; 23% in 2021, and only 12% during the cold winter and spring, (especially April) of 2018.

Although not included in the Table above, FWM nitrate concentration for continuous corn (C-C) was 9.2 ppm; whereas C-C with cereal rye had a FWM nitrate concentration of 8.4 ppm. Cereal rye biomass was sampled 3 times in the spring (April 4, April 14, and April 22) to determine cover crop growth rates for testing of the cover crop growth model being developed by Jonathon

Coppess and Rabin Bhattarrai. Cereal rye biomass accumulation attained 0.12, 0.29, and 0.45 tons/A on April 4, April 14, and April 22, respectively.

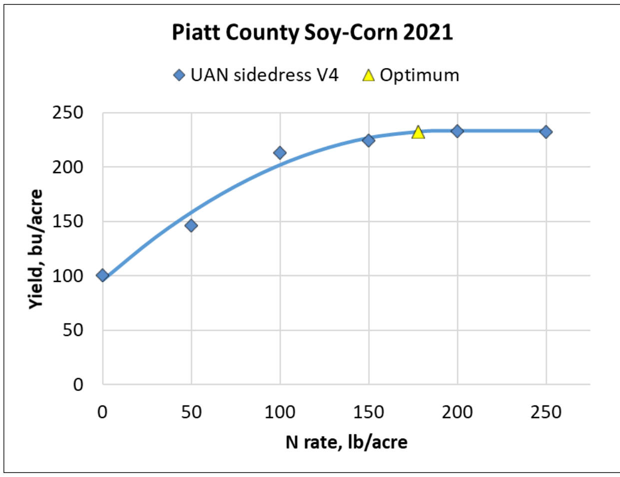


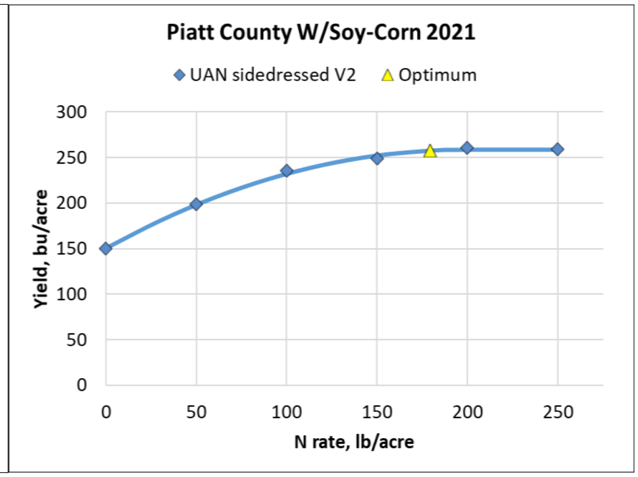
Tile nitrate concentrations from continuous corn with and without a cereal rye cover crop. Cereal rye was not planted in 2016 or 2017 to assess baseline comparison between the two tile systems.

Corn yields were similar between C-C and C-C with cereal rye; however, there was a 5 bu/A advantage with cereal rye this year (236 vs. 231 bu/A). In addition, tile nitrate was 9% less with the cereal rye in C-C.

N Rate Trials:

Each year we include an N rate trial in the corn phase of both C-S-W and C-S. We use 6 N rates of 0, 50, 100, 150, 200, and 250 lbs of fertilizer N/A.





N rate trial yield curves and EONR for C-S and C-S-W rotations in 2021.

The economic optimum N rate (EONR) in 2021 was very similar between the two N rate trials (178 lbs/A for C-S and 180 lbs/A for C-S-W); however, maximum yield was 25 bu/A greater in C-S-W than C-S (258 bu/A vs. 233 bu/A). **It is interesting to note that the 0 lb/A rate and the 50 lb/A rate produced 50 bu/A more in C-S-W than in C-S.**

Table of corn yield and stalk nitrate for all 6 N rates in both C-S and C-S-W in 2021.

2021	C-S	C-S	C-S-W	C-S-W
N Rate	**Corn Yield**	**Stalk Nitrate**	**Corn Yield**	**Stalk Nitrate**
lbs/A	**bu/A**	**ppm**	**bu/A**	**ppm**
0	100.5	70	150.1	70
50	146.2	40	198.6	30
100	212.9	50	235.1	40
150	224.6	260	248.7	440
200	232.9	1470	260.6	2150
250	232.5	4970	258.9	6600

Stalk nitrate can be used as a proxy for plant N availability as stalk nitrate concentrations greater than 2000 ppm indicate N rates above the level of sufficiency and are considered excessive. We found greater stalk nitrate at the two highest N rates in C-S-W than in C-S**. Altogether, the combination of greater corn yields at the low end of the N rate trial along with greater stalk nitrate at the high N rates indicate there is more plant available N in C-S-W than C-S.** The first time we saw this was last year, suggesting this has taken several years to develop, consistent with the idea of carbon sequestration and accrual. However, this is the first year we saw a large increase in corn yield in C-S-W at the same EONR as in C-S. We can't wait to see what happens in 2022!

Bioreactor data:

All six bioreactors were recharged in the fall of 2021 and we have begun monitoring performance. We are using a new stoplog configuration and early performance is impressive; however, it is well established that fresh media (woodchips and carbon) causes a boost in performance due to the readily degradable nature of the C that has been recently added. Please see NREC project (2022-1-360350-404) for more details, but we are off to an excellent start with this one-of-kind replicated bioreactor study. I will be sharing the data with Dr. Laura Christianson this spring for her independent analysis of the water balance and overall performance (i.e. nutrient removal).

Importance of this study:

This project provides a real-world, on-farm evaluation of best management practices (BMP), both in-field and edge of field, to demonstrate reductions in tile nutrient losses. The University of Illinois Science Assessment which served to guide the Nutrient Loss Reduction Strategy evaluated combinations of nutrient remediation techniques to create BMP scenarios that when adopted regionally would make a significant reduction in the N and P export from agricultural runoff (overland and tile flow). Two remediation techniques that were often included in the various BMP scenarios were 1) growing winter cover crops and 2) constructing woodchip bioreactors on drainage tiles. This proactive research is demonstrating the potential of maintaining high-yielding systems with minimal nutrient losses and is directly testing "stacking" of cover crops and bioreactors in the same field.

Building on the research conducted on Eric Miller's farm in Piatt County, Dr. Tony Studer (Assistant Professor, Crop Sci.) was successful as PI on a NIFA grant meant to "reinvent Extension". The range of conservation practices and agricultural production systems (linked to tile water monitoring) on one farm under the same soil and weather conditions was showcased in the proposal and will now be part of addressing one of the major goals of the study. Our research group will receive two continuous-recording nitrate sensors to show the dramatic effect of management (i.e. cover crops vs. fall N application) on tile nitrate across one farm (Eric Miller's farm), ultimately real-time tile nitrate concentration and load would be available to the public. This could be a way to inform the public at-large about the ag industry's continued efforts in addressing water quality and demonstrate to agricultural practitioners the impact of management, weather, soil type (and a host of other factors) on nutrient loss and how to minimize losses in tile drained watersheds.