2021 Final Report Summary Sheet

Grantee Information

Project Title: Reducing P Loss in Southern Illinois: Producers, Practices, and Productivity

Institution: University of Illinois

Primary Investigator: R. Christianson

NREC Project # 2018-4-360340-646

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:
Primary issues for plot establishment were related to wet weather and COVID. Having the Ewing Demonstration Center limited our ability to quickly access and problem solve in a time-efficient manner with limited personnel.

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:
Phosphorus loss work due to cover crop freeze-thaw was presented at the Dudley Smith Initiative Winter Field Day in February 2021. In May of 2021, we filmed a researcher superhero segment.

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.**

Summary

The major goal of this work is to evaluate and promote practices to reduce P loss in Illinois' unglaciated areas. The practices under evaluation are no-till/conservation tillage, cover crops, and edge-of-field P-removing filters. Work is being done on the Ewing Demonstration Center Figure 1, private farms, and on-campus. Because improvements in soil health qualities such as infiltration rate and water holding capacity are practical metrics that resonate with producers, these will be evaluated as a proxy for reduced runoff risk at both private farms and the Ewing Demonstration Center. Questions about cover cropping P tradeoffs will be answered in controlled, on-campus studies (paper currently under review).

Cover crop impact on yield was evaluated at the Ewing Demonstration Center, with initial results showing no-till and no-till in combination with other treatments (i.e., cover crop) do not significantly reduce soybean yields, rather the full tillage no-cover crop treatment has the lowest yields when considering soybeans in 2021 and 2019 (Tukey's Honest Significant Difference) (Figure 2). In 2021, soybeans were planted on May 27th at 143k seeds/ac. In 2021, the average cover crop biomass produced across cover crop treatments was 1.1 tons per acre for cereal rye and 1.0 tons per acre for annual ryegrass. No statistically significant differences were observed in total phosphorus concentrations or total suspended sediment concentrations (individual paired t-tests). That said, the highest observation came from a full tillage plot.

Cover crop costs were estimated using seed cost and planting cost. Soybeans were planted into the standing green cover crop, which was terminated along with typical pre-emergence herbicide application used for the no-till operation (no cost compared to no-till). The resulting cost was approximately $56 per acre for cereal rye and $52 per acre for annual ryegrass. The ryegrass and filter strip combination cost was estimated based on seed and planting as well as a portion of the plot out of production. Cost recovery was conservatively estimated using sales of fescue hay with one cutting per year at 2 tons per acre. The resulting cost of the filter strip treatment was $161 per acre. Since our full tillage control was managed differently, there was a separate $27 per acre cost associated with two passes of a tandem disc on those plots.

To date, results have reached scientists and other stakeholders via conference presentations and outreach, including research results at field days and an interactive sand table to show the impact of topography and land management decisions on runoff.

a)

b)

Figure 1. Run-off plot setup at the Ewing Demonstration Center (before spring tillage) (a). No-till treatment plots with monitoring setup (b).

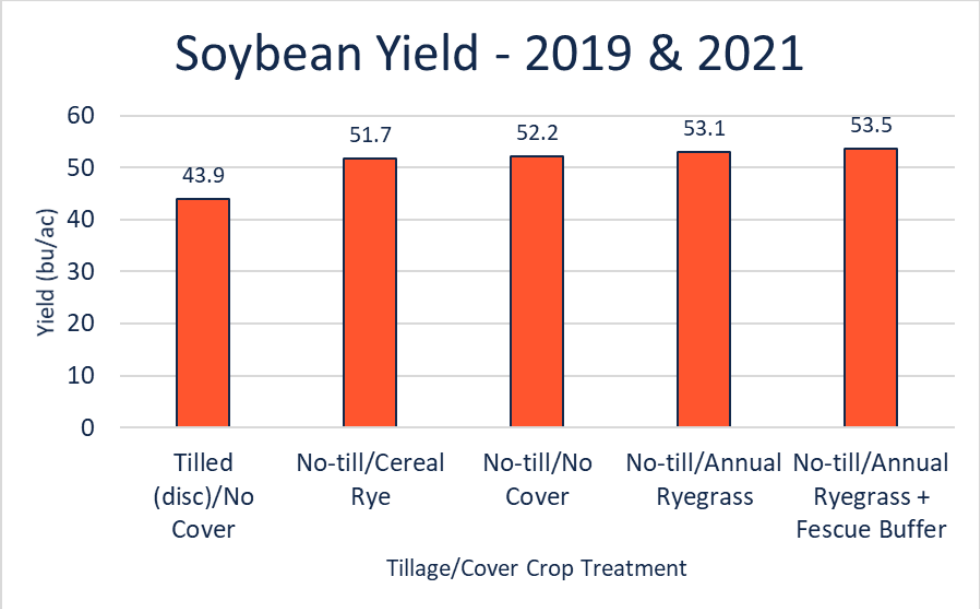

Figure 2. Yield response to treatments at the Ewing Demonstration Center. Soybean yield for the "Tilled (disc)/No Cover treatment was significantly lower than all other treatments (Tukey's HSD test at alpha = 0.05).

Cooperators and Locations

A. PI: Dr. Reid Christianson, Research Assistant Professor, Department of Crop Sciences, University of Illinois, S318 Turner Hall, 1102 S Goodwin Ave., Urbana, IL 61801. (240) 344-8144. ReidDC@illinois.edu. Dr. Christianson has fifteen years of experience focused on water quality and land use management. As PI, he will supervise all project work.
    a. Co-PI: Dr. Laura Christianson, Assistant Professor, Department of Crop Sciences, University of Illinois, S322 Turner Hall, 1102 S Goodwin Ave., Urbana, IL 61801. Dr. Christianson has nine years focused on agricultural water quality. As Co-PI, she will oversee all water sample analysis and supervise a graduate student performing the on-campus cover crop study.
    b. Co-PI: Dr. Andrew Margenot, Assistant Professor, Department of Crop Sciences, University of Illinois, 1011 Plant Sciences Laboratory, 1201 S Dorner Dr., Urbana, IL 61801. Dr. Margenot has six years of experience focused on soil phosphorus management. As Co-PI, he will coordinate soil sampling and supervise a graduate student evaluating phosphorus sorbing materials.
    c. Co-PI: Dr. Talon Becker, Commercial Agriculture Educator, University of Illinois Extension, 1212 Route 14 West, Benton, IL 62812. Dr. Becker has ten years of experience in agricultural research, with approximately three years focused on nutrient management. As Co-PI, he will coordinate activities at the Ewing Demonstration Center.
    d. Mr. John Pike, Pike Ag, LLC, 14453 Canaville Road, Marion, IL 62959. Mr. Pike is a professional agronomist and with several decades of extensive experience in production agriculture. He will be responsible for identifying and coordinating with the private farms for infiltration and water holding capacity testing.
B. Graduate Students on the project: Taylor Berkshire, MS in Crop Sciences – successfully defended in 2021 and is now working on a PhD; Ariana Munoz, MS in Crop Sciences – successfully defended in 2021 and is now working for and agricultural conservation non-profit in Maryland.

Restate Objectives

A. The major goal of this work is to evaluate, refine, and promote both recommended and novel practices to reduce phosphorus (P) losses in unglaciated areas of Illinois. The practices under evaluation are no-till/conservation tillage, cover crops, and edge-of-field P filters. Specifically:
    a. **Install surface runoff monitoring plots to measure runoff and P loss** from five in-field treatments (Ewing Demonstration Center) and evaluate P loss.

b. **Measure infiltration and water holding capacity** as a proxy for runoff (private farms and Ewing Center).
c. **Design and construct a novel P-removal filter** (On-campus and Ewing Center).
d. **Perform rainfall simulations** on a cover crop to evaluate runoff and leaching P loss reduction under freeze/thaw conditions (On-Campus).
e. **Assess soil P** for vulnerability to run-off losses with multiple, complementary measures of P availability and soil loading
f. Perform an **economic evaluation** and **promote these effective P practices**.
g. Per the RFP, the final objective is "*to include a final report at the conclusion of this project to address each of the objectives stated above*."

Findings and Continued Work Plan

In short, the three practices of no-till/conservation tillage, winter cover crops, and edge-of-field P-filters will each be studied in at least two locations (private farms, the Ewing Demonstration Center, and/or on-campus). To add additional redundancy, each type of testing (soil P assessments, rainfall simulations and runoff measurement, infiltration, and water holding capacity tests) will also be done in at least two of the three locations.

A. *Sequence of specific project tasks*

a. **Install surface runoff monitoring plot infrastructure to measure runoff and P loss** from five in-field treatments at the Ewing Demonstration Center (Objective 1; Years 2-4).
    i. The Ewing Demonstration Center in Southern Illinois has fifteen total plots (*n* = 3; 45 m long x 6 m wide) installed and separated with plastic sheeting. An in-ground sump, small pump, and flow meter are at the bottom of each plot, which allows continuous runoff volume measurement whenever runoff occurs. This also serves as the water sampling location.
        1. In 2019, all treatments had significantly higher soybean yields than the tilled control. In 2020, all of the cover crop treatments has significantly lower corn yield compared to the tilled control and the no-till no-cover crop treatment. Combining the 2019 and 2021 soybean yields, the tilled control had significantly lower yields.
    ii. The five triplicate treatments are:
        1. No-till without a cover crop.
        2. No-till with a cereal rye cover crop, fully terminated in the spring.

3. No-till with an annual ryegrass cover crop, fully terminated in the spring.
4. No-till with an annual ryegrass cover crop with a 12 m fescue buffer at the bottom of the field.
5. Control: Conventional tillage without a cover crop (on an adjacent farm).

iii. Runoff testing and P loss assessment will be performed under natural and simulated rainfall conditions.
1. No statistically significant differences were observed in total phosphorus concentrations or total suspended sediment concentrations (individual paired t-tests). The highest observation came from a full tillage plot.
2. Runoff monitoring has been plagued with issues such as plugged flow meters, short circuiting of wiring due to large current draw, rodents, and floating sumps. Our typical field staff was not able to keep everything working all the time, so the farm staff is starting to help maintain and keep charged the batteries, which has been the primary issue. Though monitoring is sparse, we were able to compare the treatments using events collected in 2020 and 2021. The runoff range was between 0.10 inches and 0.33 inches, though these were not statistically different.
3. A summary of precipitation over the study period using the new Army Crops of Engineers Antecedent precipitation Tool shows that over the study period, 35% of the days were wetter than normal, with only 6% drier than normal. This trend was starkly different than the previous year, in which 44% of the days were drier than normal and 5% were wetter than normal.
4. Continued monitoring and rainfall simulation on-site will commence in 2022.

b. **Measure infiltration and water holding capacity** as a proxy for runoff at private farms and the Ewing Demonstration Center (Objective 2; Years 2 and 3). Soils with greater water infiltration rates and water holding capacity will result in less surface runoff than soils with lower infiltration and water holding capacity. Thus, these two tests will be done as follows:

i. Saturated Hydraulic Conductivity Testing:
1. Measured saturated hydraulic conductivity was between 1.0 inches per hour up to 18 inches per hour. Expected, based on the USDA Soil Water Characteristics calculator, would be around 0.63 inches per hour.
2. Measurements will be made again in 2022.

ii. Water Holding Capacity Measurement (volume of water held per volume of soil).
1. These tests will be performed at:
a. The Ewing Demonstration Center

i. Approximately 33% to 34% of the soil volume can hold water, though wilting point is 11%, making the effective available water between 22% and 23%.

b. Up to 32 privately-owned fields in Southern Illinois. Fields will be recruited to broadly replicate treatments being tested at the Ewing Center (*n* = 5-8 sites for each treatment; up to 32 sites total). Private farm treatments will be:
   i. Conventional tillage
   ii. Long term no-till
   iii. Never cover cropped
   iv. Long term cover crop

1. Mr. John Pike, who has several decades of experience working with farmers in Southern Illinois, will be the point-person with these cooperators. Nearly 50 locations have been identified, though soil sampling was delayed due to the onset of Covid-19 in the spring of 2020. Soil sampling will commence in communication with John Pike and sentiment of partnering farmers.

c. **Design and construct a novel P-removal filter** at the Ewing Center (Objective 3). A P-removal filter will intercept and treat surface runoff and tile drainage which culminates at the SE corner. This will require two sub-objectives:
   i. Initial design has been done with an expected capacity of ~28,000 gallons per hour. Materials tested in the lab may be replaced with materials tested by the USDA ARS in Indiana to ensure performance. Installation will occur in 2022.

d. **Perform rainfall simulations on a cover crop** to evaluate runoff and leaching P loss reduction under freeze/thaw conditions (Objective 4). This focused experiment will answer the question about DP release due to plant cell rupture upon freeze/thaw conditions.
   i. This experiment was completed in winter/spring of 2019. This work was presented at the ASA-CSSA-SSSA International Meeting in November of 2020, and the presentation by Ariana Muñoz won first prize in the Nutrients and Environmental Quality Community student competition. This work is currently under review as a journal manuscript.
   ii. This concept has been extended to a field trial at the Dudley Smith Farm in Christian County.

e. **Assess soil P loading and loss risk** at the Ewing Center and private farms (Objective 5; Years 1-4 and 1-2, respectively).
   i. Soil samples at both the Ewing Center and private farms will be analyzed for three P measures providing complementary data on P crop availability and run-off risk, which will include Bray P, water-extractable P and degree of phosphorus saturation (DPS) (Measured as the ratio of P to iron (Fe) and aluminum (Al)

extractable by the Mehlich test). This represents the amount of available P relative to potential binding sites in the soil, and as such, can be used to measure the P loading status of soils.

1. The first round of soil test phosphorus at the Ewing Demonstration Center showed high spatial variability across the plots, indicating there are likely no pre-project biases among treatments. Further, indications are that soil phosphorus concentrations show classic increases as we approach the toe slope due to soil movement down the hill.
2. Soil samples will continue to be collected at Ewing in each plot (0-3 in depth) to assess soil P availability, loading, and susceptibility to loss via run-off. Prior to sampling, potential hotspots and overall spatial heterogeneity in soil P that may confound assessments will be screened with limited disturbance in the field using a portable XRF spectrometer. By exposing soils to the same, controlled rainfall rate (Objective 1b), simulations will enable accurate comparisons of the relationships between soil P tests and run-off P, which is often not possible in field settings. The Ewing Demonstration Center installed a water main to the farm to facilitate rainfall simulation. Because DPS risk thresholds need to be empirically developed for a given soil type and cropping system, an added benefit of this work lies in relating P run-off concentrations with DPS measurements. This will be a first step toward developing Illinois-specific DPS interpretations and recommendations.

f. Perform an **economic evaluation** and **promote these P practices** (Objective 6).
    i. Economic Evaluation
        1. Cover crop costs were estimated using seed cost and planting cost. Soybeans were planted into the standing green cover crop, which was terminated along with typical pre-emergence herbicide application used for the no-till operation (no cost compared to no-till). The resulting cost was approximately $56 per acre for cereal rye and $52 per acre for annual ryegrass. The ryegrass and filter strip combination cost was estimated based on seed and planting as well as a portion of the plot out of production. Cost recovery was conservatively estimated using sales of fescue hay with one cutting per year at 2 tons per acre. The resulting cost of the filter strip treatment was $161 per acre. Since our full tillage control was managed differently, there was a separate $27 per acre cost associated with two passes of a tandem disc on those plots.
    ii. Promotion: A mobile augmented reality sandbox was designed and constructed in the fall of 2018 and spring of 2019. This tool allows

discussion surrounding how topography and land management can influence erosion and phosphorus loss risk. The augmented reality sand table was demonstrated at the 2020 Nutrient Stewardship Virtual Field Day hosted by LaSalle County Farm Bureau and other events (see below).

Impact of the Research

Ultimately, this work will serve to help support the use of conservation practices across Illinois by evaluating environmental impacts and interactions while also showcasing these activities generally to the public as well as directed towards farmers.

A. Several presentations have been made with data generated from this work:
    a. Berkshire, T., Christianson, L., Christianson, R., Margenot, A.J. Media Selection for Edge-of-Field-Phosphorus Filter. American Society of Agronomy. Nov 4-7, 2018. Baltimore, MD. (poster)
    b. Berkshire, T., Christianson, L., Christianson, R., Margenot, A.J. Media Selection for Edge-of-Field-Phosphorus Filter. Illinois Nutrient Loss Reduction Symposium. Nov 13, 2018. Urbana, IL. (poster).
    c. Berkshire, T., Christianson, L., Christianson, R., Margenot, A.J. Phosphorus Sorption Material Characterization for Selection of Edge-of-Field Phosphorus Filter. Society of America Meeting. Jan 9-12, 2019. San Diego, CA.
    d. Berkshire, T., Christianson, L.E., Christianson, R.D., Margenot, A.J. Reducing Phosphorus Loss. Ewing Demonstration Day, Ewing, IL July 25, 2019.
    e. Berkshire, T., Christianson, R., Christianson, L., Margenot, A.J. Using the portable X-ray fluorescence spectrometer (pXRF) to determine phosphorus saturation of P sorbing materials in edge-of-field P filters. Soil Science Society of America Meeting. Nov 10-13, 2019. San Antonio, TX.
    f. Berkshire, T., Christianson, L., Christianson, R., Margenot, A.J. Removing Dissolved Phosphorus with Edge-of-Field Phosphorus Filters. Illinois Nutrient Loss Reduction Symposium. Dec 3, 2019. Springfield, IL. (poster)
    g. Christianson, L., R. Cooke, R. Bhattarai, R. Christianson, and P. Davidson. 2020. Illinois state update. NCERA-217 multi-state meeting/Ag Drainage Management Taskforce meeting. Held virtually due to Covid-19. 03-04 June 2020.
    h. Berkshire, T., Christianson, L., Christianson, R., Margenot, A.J. Removing Dissolved Phosphorus with Edge-of-Field Phosphorus Filters. Illinois Nutrient Research and Education Symposium. Feb 13, 2020. Urbana, IL. (poster)
    i. Berkshire, T., Christianson, L.E., Christianson, R.D., Margenot, A.J. Reducing Phosphorus Loads from Non-Point Sources. ILMA-Lakes Conference, Champaign, IL March 13, 2020.
    j. Muñoz, A., L. Christianson, R. Christianson, L. Alves de Oliveira. 2021. Nutrient Leaching from Packed Soil Columns with Cover Crops Exposed

to Freeze-Thaw Events. Dudley Smith Winter Field Day. University of Illinois Extension. Held virtually due to Covid-19. February 9, 2021.

B. Papers:
    a. Margenot, A.J., Kitt, D., Gramig, B.M., Berkshire, T., Chatterjee, N., Hertzberger, A., Aguiar, S., Furneaux, A., Sharma, N., Cusick, R. 2019. Toward a regional phosphorus (re)cycle in the U.S. Midwest. Journal of Environmental Quality. 48(5):1397-1413. https://doi.org/10.2134/jeq2019.02.0068
    b. Muñoz Venture, A., R. Christianson, R. Bhattarai, L. Christianson. Runoff and drainage tradeoffs from cover crops exposed to freeze-thaw events. Under review.

C. The augmented reality sand table serves as a platform to quickly engage audiences of all ages surrounding the topic of water movement, erosion, phosphorus loss risk, and land management in an interactive and thought-provoking way. Several outreach events have been attended with the augmented reality sand table, including
    a. Video production for social media in the spring of 2019
    b. Crop Sciences Agronomy Day in the summer of 2019
    c. Farm Progress Show in the summer of 2019
    d. Ewing Demonstration Center Field Day in the summer of 2019.
    e. Career Spark in the fall of 2019.
    f. Field and Furrow student club at UIUC in the fall of 2019.
    g. Introduction to Crop Sciences Class lab at UIUC in the fall of 2019.
    h. Nutrient Stewardship Virtual Field Day hosted by LaSalle County Farm Bureau in the summer of 2020.

Date of Initiation (Jan 2018) and Completion (Nov 2022)

Due to staffing changes in spring 2018, weather in both fall 2018 and spring 2019, and Covid-19 in 2020, much of the fieldwork was delayed. That said, the sand table and on-campus rainfall simulation components are done with one manuscript under review. The original timeline was modified (Figure 3) to account for delays in the field and the no-cost extension to this project. Also, testing of the phosphorus sorption media has gone well, which prompted additional lines of inquiry, which were pursued, resulting in two additional manuscripts being developed now. The timeline for the phosphorus sorption media was extended to account for this.

		2018				2019				2020				2021				2022			
		W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F
Obj. #1: Install runoff plots and measure P loss	Install plot infrastructure at Ewing Center				✓	✓	✓	✓	✓	✓	✓										
	Obj. 1a: Monitor P loss under natural rainfall								✓			✓	✓	✓	✓	✓	✓				
	Obj. 1b: Monitor P loss under rainfall simulations																				
Obj. #2: Measure infiltration and water holding capacity	At the Ewing Demonstration Center						✓														
	On private farms (up to 32 sites)								✓												
Obj. #3: Design and construct a novel P-removal filter	On-campus testing and selection of P-removal media	✓	✓	✓	✓	✓	✓	✓	✓												
	Design and build full-size P-removal filter								✓						✓						
	Monitor P removal by full-size P-removal filter (Ewing)																				
Obj. #4: Test cover crop with rainfall simulation	On-campus rainfall simulation of cover crop runoff/leaching, including soil analysis				✓	✓	✓	✓													
Obj. #5: Assess soil P	At the Ewing Demonstration Center						✓														
	On private farms (up to 32 sites)																				
Obj. #6: Economic analysis and practice promotion	Economic evaluation ($/ac treated; $ per lb P saved)																✓				
	Design and build aug. reality sand table				✓	✓	✓	✓													
	Present at field days; Display aug. reality sand table			✓					✓	✓											
	Factsheet development, printing, and distribution										✓										
Obj. #7: Funders reports	Peer-reviewed manuscript development/submit								✓					✓	✓	✓	✓				

Figure 3. Revised timeline due to weather and staffing - with progress indicated by checks. This figure has also been extended based on the no-cost extension to this project.