2019 Final Year-End Report Summary Sheet

Grantee Information

Project Title: Bioreactors for Illinois: Smaller, Better, Faster Cereal Ry

Institution: University of Illinois

Primary Investigator: Laura Christianson

NREC Project # 2017-4-360498-302 2017-3-3

Is your project on target from an IMPLEMENTATION standpoint and what % was planted? ☒ 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: It is likely we will request a one-year no-cost-extension later in 2020 if the NREC Board is amenable to that. As long as funds remain, it seems prudent to continue monitoring to collect as many site-years of N-removal performance as possible.

How has this year's weather effected this project, and to what extent? ☐ 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 provide details/dates for any upcoming outreach activities so that NREC staff can attend and possibly provide media exposure. See section 3b for previous outreach activities from this reporting period.

Please provide a 3-paragraph summary of this project to be shared in an NREC update bulletin. Please include any pictures or relevant tables or graphs. *See next page*.

NREC January 2020 3.0 Year Report

Bioreactors for Illinois: Smaller, Better, Faster

PI: Dr. Laura Christianson, Assistant Professor of Water Quality, Department of Crop Sciences, University of Illinois, S322 Turner Hall, 1102 S Goodwin Ave., Urbana, IL 61801.
Co-PI: Dr. Richard Cooke, Agricultural and Biological Engineering, University of Illinois

Three paragraph summary:

The most significant advancement for this project this past year has involved the Heat-Enhanced Bioreactor site. The solar panel and electrical configuration for the bioreactor heating pads is operational with the first set of temperature data pending as this report is being written. A second bioreactor also installed in 2018 was constructed with insulation boards, but without heating pads. Two additional "control" bioreactors at the site were re-charged this past fall to provide more complete controls for this current study. The recharged bioreactors have no heat source and no insulation. Mary Auth provided coverage of this recharging process in October 2019 (NREC Field Notes Oct 09).

Monitoring at the other bioreactors for this project is ongoing as has been previously communicated. The extremely wet spring followed by a dry summer created challenges for conservative tracer testing, but this work is planned to continue this spring/early summer (2020). For the tracer testing, a new bromide sensor will be trialed in addition to the conventional method of sampling the bioreactor outflow and analyzing those samples in the lab for bromide. It is thought the deployable bromide sensor will allow us to more consistently capture the bromide tracer peak without having to estimate the bioreactor flow rate and *in situ* retention time as closely to successfully program the autosamplers. This has been especially challenging at bioreactors that are distant from campus.

These bioreactor designs and some preliminary results have been communicated to a variety of groups including Illinois' NRCS engineering team and at a specialty bioreactor conference in Cartagena, Spain. Results and design ideas will also be presented in New Zealand and Australia this spring. It is abundantly clear that farmers around the world are seeking practical solutions to reduce nitrate loss that allow continued in-field agricultural productivity. This work in Illinois is truly novel within this global context for its full-scale evaluation of concepts that advance bioreactor science and engineering.

1. List of objectives

The specific assessable objectives are to:

1. **Design** and **build** four new types of denitrifying bioreactors in Illinois:
    a. Two Ditch Bioreactors (Private Farm)
    b. One High-Flow Booster Bioreactor (Monmouth Farm, UIUC)
    c. One Heat-Enhanced Bioreactor (South Farm, UIUC)
2. **Compare** the nutrient removal efficiency and hydraulic performance of these novel bioreactors to existing conventional bioreactors
3. Perform an **economic evaluation** ($ per acre treated and $ per pound of nitrogen removed).
4. 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*."

2. Length of project - number of years completed: 3.0 years (of 4.0 years)

Figure 1. Solar panel and battery configuration for the Heat-Enhanced Bioreactor at the Agricultural Engineering Farm (Urbana, Illinois) (left) with the initial power and voltage read-out interface (right).

3. Accomplishments
    a. Bioreactors
        i. Two Ditch Bioreactors (Private Farm): Monitoring continues successfully, and tracer testing is planned for spring/summer 2020.
        ii. One High-Flow Booster Bioreactor (Monmouth Farm, UIUC): Monitoring continues successfully, and tracer testing is planned for spring/summer 2020.
        iii. One Heat-Enhanced Bioreactor (South Farm, UIUC): Monitoring continues successfully, and tracer testing is planned for spring/summer 2020.
            1. This bioreactor provided an added-value opportunity for a student (Ms. Mary Foltz, Environmental Engineering) to investigate nitrous oxide emissions both from the bioreactor surface and in the dissolved form in the bioreactor outflow in summer 2019.
    b. Results from this work were presented during this reporting period at (presenter in bold):
        i. **Christianson, L. and IDROP Lab Team**. Illini Fest: Bioreactor demonstrations. Chicago, Illinois. 18 July 2019. ≈100 stopped by booth.
        ii. **Christianson, L. and IDROP Lab Team.** Farm Progress Show Conservation Partners Tent: Bioreactor demonstrations. Decatur, Illinois. 27-29 August 2019. ≈100 stopped by the bioreactor model.
        iii. **Zucher, F**., A. Sanchez, R. Chacon, and L. Christianson. 2019. Tracer testing highlights design and operational differences in denitrifying woodchip bioreactors. Tri-Societies Annual Meeting SASES undergraduate poster competition. San Antonio, Texas. 10-13 November 2019. Poster #1032.
        iv. **Christianson, L.** 2019. Soil Science Society of America Invited Session: Coupling and feedback of phosphorus and nitrogen in soil and ecosystem. Nitrogen, phosphorus, and

tile drainage, oh my! A case for edge-of-field practices. Tri-Societies Annual Meeting. San Antonio, Texas. 10-13 November 2019. Abstract # 206-1.

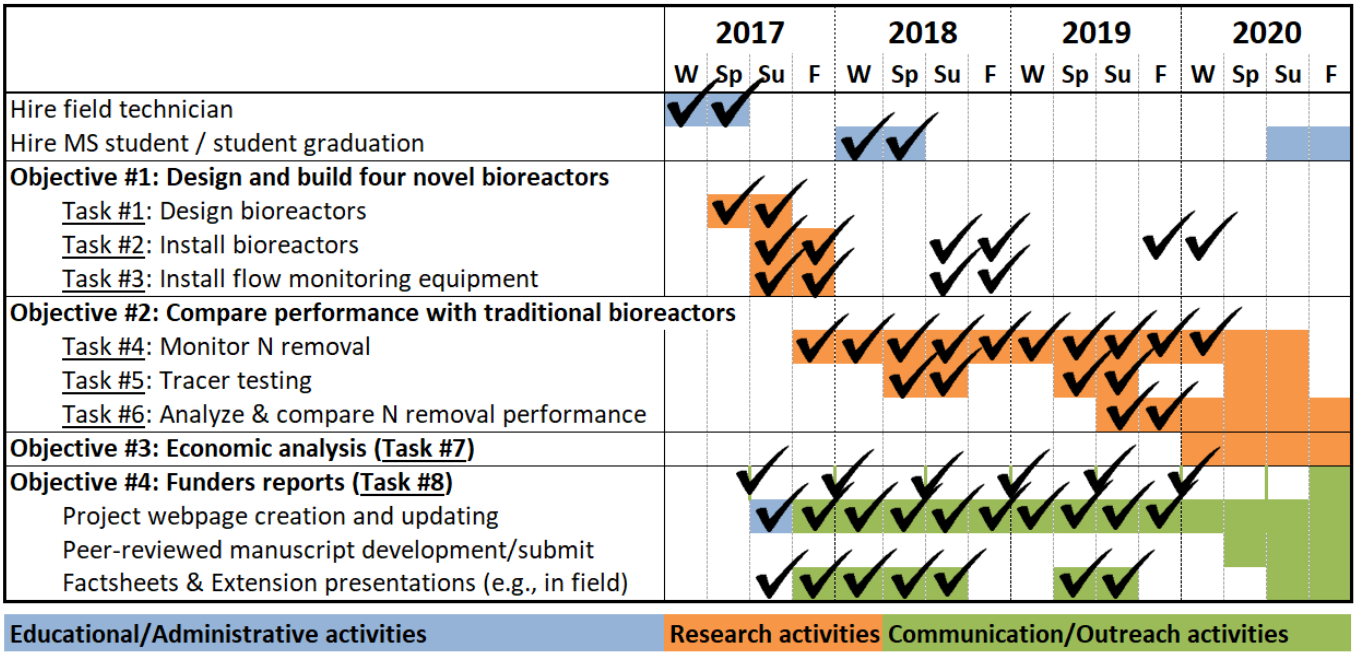
v. **Christianson, L.** 2019. Denitrifying woodchip bioreactors: A view from the field. Invited keynote, Jornada Técnica Internacional "Uso De Biorreactores Con Madera Y Humedales Para La Desnitrificación De Efluentes Agrícolas" (International Technical Conference "Use of Bioreactors with Wood and Wetlands for the Denitrification of Agricultural Effluents). Universidad Politécnica de Cartagena. Cartagena, Spain. 03 December 2019.

vi. **Christianson, L.** 2019. Denitrifying woodchip bioreactors: Current status, next steps, and scaling for the future. 2019 Illinois Natural Resources Conservation Service (USDA NRCS) state-wide meeting. Springfield, Illinois. 10 December 2019. ≈30 in attendance.

How will the research benefit the environment and/or crop production, etc.?

As investments in drainage systems continue to be made across Illinois, there is an increasing need to provide landowners practical edge-of-field options to reduce drainage N loss without negatively affecting yields. Trialing novel bioreactor designs at the field scale facilitates broad leaps in knowledge for bioreactor science and for demonstration efforts to encourage bioreactor adoption. This work positions Illinois as a global leader in bioreactor innovation. Better bioreactors through modifications as being studied here will enhance water and environmental quality, allow strong in-field agronomic production, and allow economically cost-effective achievement of NLRS goals.

Table 1. Up-to-date timeline for "*Bioreactors for Illinois…*" project



All proposed bioreactors have been constructed and monitoring is either on-going or being initiated (**Table 1**). Tracer testing and N-removal and economic analyses are the next most important tasks that needs to be completed.

New questions created by this work: None in this reporting period.

Table 2. Budget analysis showing expenditures aligned with budget categories.

	Budgeted	Spent through 12/2019
A. Personnel	$128,089	$123,882
B. Fringe Benefits	$40,476	$13,102
C. Travel	$14,498	$8,903
D. Equipment	$9,000	$0
E. Supplies	$40,018	$24,950
F. Contractual Services	$65,800	$46,855
G. Other (Investment income, Expense budget pool)	$6,140	$0
H. Indirect Charges	$33,095	$48,707
TOTAL COST (Year 3.0)	**$337,116**	**$266,399**
BALANCE REMAINING	***$70,717***	