2021 Final Report Summary Sheet

Grantee Information

Project Title: Knowledge is power: Powering up bioreactors and saturated buffers in Illinois

Institution: University of Illinois

Primary Investigator: Laura Christianson

NREC Project # 2021-3-360498-144

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:

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:

NREC December 2021 1.0 Year Report

Knowledge is power: Powering up bioreactors and saturated buffers in Illinois

NEC Project #2021-3-360498-144

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-PIs: Dr. Reid. Christianson and Dr. Richard Cooke

Summary:

This NREC project graciously supplies a significant portion of required matching funds for a USDA NRCS Conservation Innovation Grant. Work has proceeded on the three objectives that will allow: improved N removal with innovative bioreactors and saturated buffers built in the field (**Obj. 1**); systematic analysis of existing adoption-scaling limitations for these two practices across Illinois (**Obj. 2**); and evaluation of new monitoring methods to that could lead to market-based water quality solutions (**Obj. 3**).

An existing bioreactor on a private farm was retrofit with a pump in fall 2021 to test the "pumped bioreactor" concept (**Obj. 1; Figure 1**). Initial monitoring in underway, but a short-term intensive sampling test will be done in early 2022 (for example, sampling every 3 hours for 6 days) to determine the best sampling frequency for long-term monitoring. The solar powered pumps will pump during the day meaning the bioreactor will stop flowing at night. This will give the water in the bioreactor a very long retention time at night (that is, a long treatment time) so sampling needs to be designed to capture both day and night appropriately.

Real-time, continuous nitrate sensors (**Obj. 3)** have been deployed at the UIUC ACES Dudley Smith Farm bioreactor and at a bioreactor on a private farm. Nitrate data from these sensors are currently streaming to a password-protected website (**Figure 2**). Final data quality control processes and checks that are essential prior to public release of the data are planned for early 2022.

Figure 1. The Christianson IDROP Team installing pumps and solar panels at a ditch-diversion bioreactor in fall 2021.

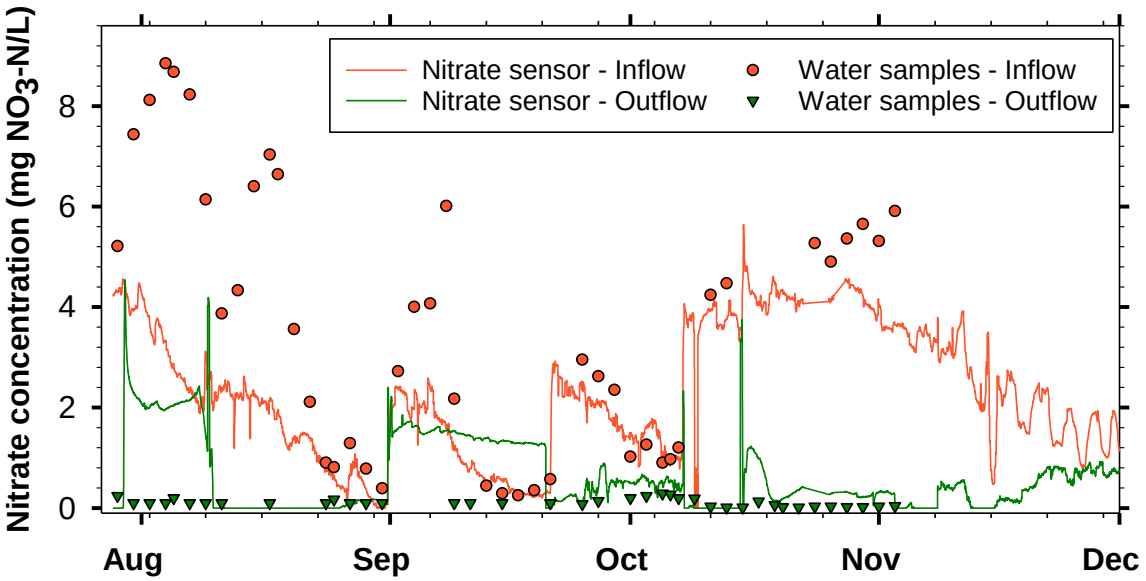

Figure 2. Bioreactor inflow and outflow nitrate concentrations as collected by autosamplers and with high-frequency sensors at the UIUC ACES Dudley Smith Farm (Pana, Illinois). *These data are preliminary and not for public distribution* as there is a clear discrepancy between sampled and sensed nitrate concentrations. Further quality control and assessment will be performed in 2022.

Cooperators

- **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-PIs**:
  - Dr. Richard Cooke, Ag. and Biological Engineering, University of Illinois
  - Dr. Reid Christianson, Department of Crop Sciences, University of Illinois
- **Postdoctoral Associate**:
  - Dr. Carolina Díaz-García
- **Staff**:
  - Mr. Ronnie Chacón, Research Specialist responsible for field data collection
  - Mr. Mike Wallace, Research Specialist performing sample analysis
- **Private farm landowners/operators**

Locations

- Ditch diversion bioreactor retrofit with a pump – Private Farm in Livingston County
- Paired bioreactor + saturated buffer combination (location TBD)
- Bioreactor #1 instrumented with real-time nitrate sensors – University of Illinois ACES Dudley Smith Farm at Pana, Illinois
- Bioreactor #2 instrumented with real-time nitrate sensors – Private Farm in Peoria County

List of objectives

The specific assessable objectives are to:

- OBJECTIVE 1: **Design**, **build/retrofit** and **monitor** novel denitrifying bioreactors (2) and a saturated buffer (1) in Illinois.
- OBJECTIVE 2: **Create** and **analyze** a database of existing full-size bioreactors and saturated buffers in Illinois to assess current designs and performance with the aim of improving the NRCS design standards and outreach activities for these practices.
- OBJECTIVE 3: **Use novel monitoring techniques** (3a: real-time nitrate sensors; 3b: inexpensive thin-film "nitrate disks") at existing bioreactors and saturated buffers to explore avenues toward market-based drivers for adoption of these practices.
- OBJECTIVE 4: "*To include a final report at the conclusion of this project to address each of the objectives stated above*."

Length of project - number of years completed: 1.0 years (of 3.0 years)

Accomplishments

1. OBJECTIVE 1: **Design**, **build/retrofit** and **monitor** novel denitrifying bioreactors and saturated buffers
    a. An existing ditch-diversion bioreactor on a private farm (construction and initial monitoring funded by "*Bioreactors for Illinois*…" NREC 2017-4-360498-302) was retrofit with a pump in October 2021 (**Figure 1**). Monitoring is underway.
2. OBJECTIVE 2: **Create** and **analyze** a database of existing full-size bioreactors and saturated buffers: We are awaiting personnel hiring at our partner institutions to proceed with database development.
3. OBJECTIVE 3: **Use novel monitoring techniques** at existing bioreactors and saturated buffers
    a. Real-time nitrate sensors (EcoN sensors, Ott HydroMet) are streaming data to a log-in protected private site while Dr. Reid Christianson provides initial data quality and process control.
        i. One set of sensors was deployed at the UIUC ACES Dudley Smith Farm bioreactor, which leverages funding from a former NREC project ("*Assessing synergies and tradeoffs of recommended BMPs to reduce nutrient losses*", NREC 2016-01797) (**Figure 2**).
        ii. The second set of nitrate sensors was deployed at a bioreactor on a private farm.
    b. Initial trial runs to build the low-cost nitrate disks required notable trouble-shooting with international colleagues in New Zealand and Sweden. Dr. Carolina Díaz-García achieved early success at the end of 2021 with a working nitrate disk prototype. This prototype will be further developed with detailed testing (for example, tested with different nitrate concentrations, deployment times, water temperatures) in 2022.

4. Results from this work were presented during this period at/in:
    a. **Díaz García, C., J. Chandrasoma**, T. Berkshire, P. Davidson, R. Cooke, R. Christianson, and L. Christianson. 2021. University of Illinois Crop Sciences Agronomy Days 2021: Tours 3. Saturated Buffers 101: Learning the basics of an emerging conservation practice. 05 August 2021. ≈55 in attendance.
    b. **Christianson, L. and IDROP Lab Team**. 2021. Farm Progress Show UIUC College of ACES Tent: Saturated Buffer model. Decatur, Illinois. 31 August – 02 September 2021. ≈400 stopped by the model.
5. Publications during this reporting period
    a. Díaz García, C., T. Berkshire, J. Chandrasoma, P. Davidson, R. Cooke, R. Christianson, and L. Christianson. 2021. Saturated buffers 101: "Buffing up" water quality. University of Illinois Extension factsheet CSWQ-0121. Available at: https://go.illinois.edu/BuffingUp.
        i. This represents leveraged funding with another NREC project: *NREC 2017-4-360498-168: Drainage water management and saturated buffers for achieving NLRS goals*. See that project's annual report for the factsheet in the Appendix A.

Table 1. Up-to-date timeline for "*Knowledge is power…*" project

	2021				2022				2023			
	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F
OBJ 1: Design, build/retrofit and monitor novel bioreactors and sat. buffers												
Task #1a: Design/build/retrofit pumped bio. (Y 1) and bio+SB combo (Y 2)	✓	pumped bio.					bio. + sat. buff.					
Task #1b: Monitor/compare N removal performance of novel designs				✓								
OBJ 2: Create and analyze a database of existing bioreactors and saturated buffers												
Task #2a: Information compilation and database creation												
Task #2b: Database synthesis												
OBJ 3: Use novel monitoring techniques at bioreactors and saturated buffers												
Task #3a: Instrument and monitor real-time nitrate data at bioreactors			✓									
Task #3b: Live-stream bioreactor data to create the *"Internet of Bioreactors"*				✓								
Task #3c: Build and calibrate inexpensive nitrate disks for sat. buffers			✓	✓								
Task #3d: Deploy and compare nitrate disks to conventional monitoring												
Outreach events and activities: field days, live streaming bio. data			✓	✓								
Scientific outputs: conference attendance, database publication, journal articles												

Planned activities for 2022

- OBJECTIVE 1: Monitoring will continue at the pumped bioreactor at a private farm. A short-term intensive sampling test is planned (for example, sampling every 3 hours for 6 days) to determine the best sampling frequency for long-term monitoring. The solar powered pumps will pump during the day meaning the bioreactor will stop flowing at night. This will give the water in the bioreactor a very long retention time at night (that is, a long treatment time) so sampling needs to be designed to capture both day and night appropriately.
- OBJECTIVE 1: Site selection and design for the paired bioreactor + saturated buffer.
- OBJECTIVE 2: Database development will progress as other personnel across the multi-state team are identified.

- OBJECTIVE 3: Real-time nitrate sensor data for at least one bioreactor will be made public in 2022. Final data quality control processes and checks that are essential prior to public release are planned for January/February 2022.
- OBJECTIVE 3: Dr. Carolina Díaz-García will further develop her nitrate disk prototype with detailed testing (for example, tested with different nitrate concentrations, deployment times, water temperatures) in 2022.

Project Synopsis *(as originally proposed)*

Edge-of-field practices like woodchip bioreactors and saturated buffers provide targeted and cost-effective nitrogen (N) loss reduction in tile-drained areas of Illinois. Three proposed objectives will allow: improved N removal with innovative bioreactors and saturated buffers built in the field (**Obj. 1**); systematic analysis of existing adoption-scaling limitations for these two practices across Illinois (**Obj. 2**); and evaluation of new monitoring methods to that could lead to market-based water quality solutions (**Obj. 3**). The innovative designs will consist of a bioreactor that receives water pumped from the nearby ditch so it will operate under a consistent flow rate and a paired bioreactor + saturated buffer treatment system (**Obj. 1**). In addition to novel designs, creation and analysis of a database of currently installed bioreactors and saturated buffers will allow a methodical approach to better understand differences in the variety designs with the aim of improving the NRCS design standards and outreach activities for these practices (**Obj. 2**). Finally, continuous web-streaming nitrate sensors and inexpensive "nitrate disks" will be trialed at existing bioreactors and saturated buffers in Illinois (**Obj. 3**). Cost effectiveness of the new designs and monitoring methods will be reported along with a variety of deliverables that stretch beyond peer-reviewed publications (extension presentations; publicly available database; live-streaming bioreactor N data). This work will be impactful because it builds on previous NREC funding successes to "power up" these practices via improved knowledge toward accelerated adoption.