# Environment and Natural Resources Trust Fund

2027 Request for Proposal

## General Information

**Proposal ID:** 2027-177

**Proposal Title:** Duckweed for Clean Water and Sustainable Bioproducts Production

## Project Manager Information

**Name:** Veluchamy Chitraichamy

**Organization:** U of MN - WCROC

**Office Telephone:** (320) 589-1711

**Email:** chitr012@umn.edu

## Project Basic Information

**Project Summary:** This project will develop and demonstrate an integrated duckweed based treatment system that recovers nutrients from swine wastewater and produces a valuable protein rich biomass for sustainable bioproducts development.

**ENRTF Funds Requested:** $688,000

**Proposed Project Completion:** June 30, 2030

**LCCMR Funding Category:** Water (B)

## Project Location

**What is the best scale for describing where your work will take place?**

Statewide

**What is the best scale to describe the area impacted by your work?**

Statewide

**When will the work impact occur?**

During the Project and In the Future

## Narrative

**Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.**

In Minnesota, intensive swine operations across 3,225+ farms generate large volumes of manure wastewater more than 1.3 Million gallon per day that contain high concentrations of nitrogen and phosphorus. Without effective treatment these nutrients may pose significant environmental risks to nearby watersheds and degrading water quality. Traditional manure management systems, such as anaerobic lagoons and holding ponds, can reduce suspended solids but have limited capacity to remove dissolved nutrients. As a result, there is a growing need for alternative treatment systems that not only treat manure wastewater but also recover valuable nutrients from swine manure wastewater. Duckweed has emerged as an alternative promising nature based solution due to its rapid growth rate, minimal land and input requirements, and high nutrient uptake efficiency. Its ability to uptake nitrogen and phosphorus makes it a strong selection for nutrient recovery from swine wastewater. This proposal will develop an integrated duckweed based swine wastewater treatment system for sustainable bioproducts development. The proposed system will be designed to reduce nutrient runoff, recover valuable nutrients, improve water quality, and generate usable biomass. By integrating duckweed based nutrient recovery for swine wastewater could be a sustainable alternative treatment that aligned with Minnesota's nutrient reduction strategy.

**What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.**

Our proposed solution will be the development of an integrated duckweed-based wastewater treatment system that transforms nutrient rich swine manure wastewater into a valuable protein rich biomass that could use as a food, feed, biofuel, and other bioproduct development.

We will design, and construct a novel photobioreactor, and evaluate a scalable integrated treatment system that uses fast-growing duckweed to recover excess nutrients particularly nitrogen and phosphorus from swine manure wastewater. The designed novel system will consist of pre-treatment solids separation, controlled duckweed cultivation bioreactors, and biomass harvesting units to ensure improved effluent quality prior to discharge or reuse. Identified duckweed species will be capable of rapid nutrient uptake and produce a high-protein content biomass. Our designed system will simultaneously remove excess nutrients that contribute to runoff and eutrophication, reduce risks to downstream water bodies, improve overall water quality and produce a protein-rich biomass.

Unlike conventional lagoon or mechanical treatment systems, this approach integrates nutrient recovery with biomass production and valorization. Rather than treating swine manure as waste, we used to cultivate duckweed and convert into circular bioresource bioproduct. This aligns with climate-smart agriculture principles and nutrient recycling strategies promoted by MN nutrient reduction strategy and MN climate smart food systems.

**What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?**

This project will protect, conserve, and enhance Minnesota's natural resources by reducing nutrient pollution from swine wastewater before it reaches lakes, rivers, and groundwater systems. By recovering nitrogen and phosphorus through duckweed cultivation, the system will decrease nutrient runoff that contributes to harmful algal blooms, eutrophication, and oxygen depletion in surface waters. Improved effluent quality will support watershed protection goals and strengthen ecological health.

The long-term goal of this effort is to protect the state's land and water resources, and create sustainable renewable bioproducts, aligning with the public mission of environmental protection and resource conservation.

## Activities and Milestones

### Activity 1: Development of an integrated system to recycle and more effectively utilize nutrients in swine wastewater to reduce agricultural runoff.

**Activity Budget:** $157,949

**Activity Description:**
We will focus on developing and optimizing the controlled integrated duckweed cultivation systems to maximize nutrient recovery from swine manure wastewater under Minnesota climatic conditions. We start with the characterization of influent swine wastewater (nitrogen, phosphorus, solids, pH, temperature), establishing the inoculum duckweed growth units, and conducting different loading rates, photoperiods, biomass density optimization and dilution strategies for swine wastewater to rapid nutrient uptake to maximize the duckweed biomass production. We will screen different duckweed species and identify the strains that are best suited for high nutrient uptake and rapid biomass production from varied swine wastewater strength. We will monitor and identify the system performance through water quality testing to measure nutrient removal efficiency, biomass productivity, and system stability at different swine wastewater concentration. Operational parameters such as hydraulic (hydraulic retention time, flow rate, and water depth), water quality (nitrogen and phosphorous concentration, pH, DO, temperature) and biological parameters (biomass density, harvesting frequency, growth rate) will be evaluated to improve nutrient uptake rates while maintaining healthy duckweed growth and minimizing operational challenges like overcrowding. This activity will generate technical performance data needed for the system design in activities 2 and 3.

**Activity Milestones:**

| Description | Approximate Completion Date |
|---|---|
| Identify and select the duckweed species that suits wastewater and establish a inoculum-batch growth unit | September 30, 2027 |
| Develop and optimize parameters for the integrated facility to remove the residual nitrogen and phosphorus | January 31, 2028 |
| Evaluate the nutrient removal efficiency, water quality, and biomass yield of selected duckweed species | April 30, 2028 |

### Activity 2: Engineering design and construction of a lab-scale integrated duckweed treatment system to remove the nitrogen and phosphorus in swine wastewater

**Activity Budget:** $250,995

**Activity Description:**
We will do engineering design, fabrication, and operation of a lab-scale integrated duckweed treatment system for rapid nutrient uptake from swine manure wastewater. The designed integrated system will combine pre-treatment unit (solids separation and flow equalization), controlled duckweed cultivation unit, harvesting device and a polishing step to improve final effluent quality. We will perform the engineering tasks on hydraulic modeling, sizing of treatment components, material selection, and construction and development of monitoring and control systems to regulate flow rates, retention time, and other environmental parameters such as temperature, strength of wastewater, and mixing etc. The design will prioritize modularity and scalability to ensure that operational and performance data can inform upcoming pilot and farm-scale deployment. After construction the designed system will undergo flow calibration, and operational validation to confirm proper functionality to increase the nutrient uptake and maximize biomass production. Periodically samples will be collected from the water inlet and outlet pipes of lab-scale integrated system to enable continuous monitoring of nutrient concentrations (carbon, nitrogen, crude protein, phosphorus, starch, amino acid

content content), and biomass samples will be collected and analyzed biomass density, starch accumulation, and overall treatment efficiency (recovery rate and removal rate).

**Activity Milestones:**

| Description | Approximate Completion Date |
|---|---|
| Develop process flow diagrams and engineering design specifications for integrated duckweed treatment system | July 31, 2028 |
| Fabrication of designed lab-scale integrated duckweed treatment system | November 30, 2028 |
| Establish baseline operational conditions of lab-scale integrated duckweed bioreactor | February 28, 2029 |

## Activity 3: Evaluate the pilot-scale integrated wastewater treatment system and conduct duckweed feeding demonstrations with swine

**Activity Budget:** $254,054

**Activity Description:**
We will perform the construction and operation of a pilot-scale integrated duckweed-based treatment system at the West central Research and Outreach Center, Morris to evaluate performance under real-world conditions representative of Minnesota conditions. We will use all the lab-scale results from previous activity to build the pilot system. The pilot scale system will be designed to operate under seasonal temperature variations typical of Minnesota, allowing assessment of performance across changing environmental conditions for higher biomass productivity, system stability, and overall nutrient recovery efficiency. We will implement a highly productive selected strain to conduct outdoor cultivation. Selection of most suitable duckweed species will include their capacity for growth, biomass yield, and nutritional composition. Samples will be collected for analysis of dry matter, crude protein, starch, and neutral detergent fiber as well as calcium, phosphorus and heavy metals.
We will also evaluate duckweed as a feed ingredient for swine by incorporating it at inclusion levels of 5–10% of the diet. Feeding trials will be conducted to assess palatability, intake, and overall acceptability. Few swine at a time with three replications are used to determine if swine prefers the taste of duckweed added to starter grain using the sequential elimination procedure.

**Activity Milestones:**

| Description | Approximate Completion Date |
|---|---|
| Evaluate the technical and environmental impact of the swine wastewater remediation system | January 31, 2029 |
| Construct and operate pilot-scale system for higher nutrient removal efficiency, and better effluent quality | May 31, 2029 |
| Harvest and conduct biomass nutritional analysis, processing and valorization for multiuse. | July 31, 2029 |
| Evaluate the potential of produced duckweed from a pilot-scale as a feed to swine | November 30, 2029 |

## Activity 4: Educate producers and consumers about technology to recycle nutrients, prevent runoff and add value to nutrients in swine wastewater

**Activity Budget:** $25,002

**Activity Description:**
We build connections with swine industry stakeholder and farmers to highlight research results and support commercialization of developed technology. We will also work with the extension professional to share the finding and to educate producers, swine professionals, and other stakeholders on the implementation of duckweed based swine manure wastewater treatment system through multiple activities. Information and final reports will be made available

to any stakeholder or interested party. We will be maintaining a web page within the University of Minnesota research group websites throughout the project and beyond. Dissemination and engagement efforts will also focus on hosting field days or webinars or in-person meetings and development of informational materials highlighting the project goal and results. Such fact sheets will target specific audiences or stream types. Finally, we will present experimental study results at extension and professional conferences in the state and region. For all outreach activities, we will solicit feedback using standard survey documents, and these surveys will determine the impacts of our activities on audience knowledge and swine farmers' behaviors related to adopting practices that reduce runoff of swine wastewater to lakes and streams.

**Activity Milestones:**

| Description | Approximate Completion Date |
|---|---|
| Conduct workshops, webinars, and a WCROC field day each year of the integrated facility for | December 31, 2029 |
| Prepare the Extension factsheets to inform stakeholders of the demonstration sites. | April 30, 2030 |
| Update the WCORC website every 6 months with an update on the swine wastewater project | June 30, 2030 |

## Project Partners and Collaborators

| Name | Organization | Role | Receiving Funds |
|---|---|---|---|
| Yuzhi Li | University of Minnesota-WCROC | Collaborator - assist the research efforts, mentor the graduate research assistant | Yes |
| Lee Johnston | UMN - WCROC | Collaborator - assist the research efforts, mentor the graduate research assistant | No |

## Dissemination

**Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.**
The project team will implement a comprehensive dissemination and data-sharing strategy to ensure that project findings, data, products, and outcomes are accessible to stakeholders, researchers, policymakers, and the public while fully complying with ENRTF Acknowledgement Requirements and Guidelines. Findings on nutrient recovery performance, duckweed production, nitrogen, phosphorus and potassium mass balance, and water quality improvements will be shared through peer-reviewed journal publications, conference presentations, technical reports, and stakeholder workshops targeting swine producers, watershed managers, and conservation professionals. Annual and final reports will be submitted to ENRTF as required, and plain-language summaries, fact sheets, and webinars will be developed to reach non-technical audiences. All datasets including water quality monitoring data, nutrient analyses, and recovery efficiency results will be quality-controlled, documented with metadata, and made publicly available through a UMN supported repository, with any confidential farm-level information anonymized. Recovered duckweed biomass products and related documentation may be shared for research and demonstration purposes where appropriate. All publications, presentations, outreach materials, and digital content will prominently acknowledge support from the Environment and Natural Resources Trust Fund using the required funding statement and official logo, ensuring full adherence to ENRTF acknowledgement policies.

## Long-Term Implementation and Funding

**Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this work be funded?**
The results will be implemented through pilot-scale demonstrations at the West Central research and outreach center in Morris. Proposed demonstration will include field days, workshops and targeted outreach activities to strengthen industry collaboration and facilitate knowledge transfer. Swine producers will be actively engaged to promote system adoption, supported by technical guidelines and economic feasibility analysis. Ongoing efforts will seek funding through federal grants, industry partnerships, and private investments. Future research will focus on system optimization and commercialization. Additional work will be pursued through competitive grants (USDA, NSF), corporate sponsorships, and collaborations with agricultural innovation centers to ensure long-term sustainability impact.

## Project Manager and Organization Qualifications

**Project Manager Name:** Veluchamy Chitraichamy

**Job Title:** Research Assistant Professor

**Provide description of the project manager's qualifications to manage the proposed project.**
Dr. Veluchamy Chitraichamy is a Research Assistant Professor in the College of Food, Agricultural and Natural Resources Science at the University of Minnesota, Twin Cities. Dr. Chitraichamy finished his post-doctoral training at the University of Guelph Canada on various research project that focus on biomass valorization, waste management and resource

recovery, and environmental sustainability. He earned PhD in Civil Engineering specialized in Environmental Engineering at the Indian Institute of Technology Guwahati, India and B.Tech degree in Agricultural Engineering from Tamil Nadu Agricultural University, India. Dr. Chitraichamy has 9 years of research experience in sustainable waste management and resource recovery from various bioresource waste materials. His interdisciplinary research program focuses on integration of renewable bioenergy with agriculture and the environment. He has successfully conducted interdisciplinary research projects by collaborating with various academic institutions, industry stakeholders, and government agencies. Dr. Chitraichamy has guided students in laboratory research, experimental design, data analysis, fostering a collaborative and productive research environment that ensures rigorous project oversight and effective knowledge transfer to team members and stakeholders. His current and past research projects include the conversion of organic wastes into biofuel and value-added byproduct development, bioreactor designs, development of kinetic model and evaluating techno-economic analysis (TEA), evaluating novel farm-scale technologies, determining the fate of various contaminant and pathogens, monitoring greenhouse gas emissions and developing decision support guidance. He has a proven track record of publishing peer-reviewed journals, presenting research findings at national and international conferences. He advocates dissemination of science to the public through research outreach and extension activities, public talk and social media.

**Organization:** U of MN - WCROC

**Organization Description:**
In the College of Food, Agricultural and Natural Resources Sciences (CFANS) at the University of Minnesota, we look at the bigger picture. When we envision a better tomorrow, it includes disease- resistant crops, products that protect our health, lakes free from invasive species, and so much more. We use science to find answers to Minnesota and the world's grand challenges and solve tomorrow's problems.

The Department of Bioproducts and Biosystems Engineering (BBE), in CFANS, discovers and teaches solutions for the sustainable use of renewable resources and the enhancement of the environment. We discover innovative solutions to address challenges in the sustainable production and consumption of food, feed, fiber, materials, and chemicals by integrating engineering, science, technology, and management into all degree programs.

The UMN West central Research and Outreach Center (WCROC), located at Morris, will serve as the primary project location. The WCROC is a 1,100-acre, one of the University's living laboratories where agricultural research can be demonstrated at scale, and it serves as a regional center for agricultural stakeholders to discuss current issues in agriculture. The faculty and staff have considerable experience in developing and effectively implementing applied research, outreach, and extension programs at the applied farm-level.

## Budget Summary

| Category / Name | Subcategory or Type | Description | Purpose | Gen. Ineligible | % Benefits | # FTE | Classified Staff? | $ Amount |
|---|---|---|---|---|---|---|---|---|
| **Personnel** | | | | | | | | |
| 1 Research Assistant Professor, 9 month appointment, seeking summer salary | | Principal Investigator, coordinate the research efforts, design experiments, mentor the postdoc researcher, graduate research assistant and undergraduate and write project reports | | | 36.6% | 0.3 | | $45,401 |
| Professor, 9 month appointment, seeking summer salary | | Collaborator - assist the research efforts, mentor the graduate research assistant | | | 36.6% | 0.15 | | $28,798 |
| Post Doc/ Researcher | | Scientific staff, working on experiment design, data collection and analysis, manuscript preparation, research dissemination, supervise graduate and undergraduate student | | | 26.1% | 2 | | $165,285 |
| 2 Graduate Research Assistant (stipend and tuition fee) | | Conducting the experiments, data collection, validation of results as proposed, research dissemination, work with undergraduate student. | | | 24.2% | 6 | | $332,876 |
| One undergraduate students ($17.46 per hour, 10 hour per week, and 20 weeks each year; 3% increase in each year afterwards) | | Receive research training and collect experimental data | | | 0% | 0.9 | | $10,847 |
| | | | | | | | **Sub Total** | **$583,207** |
| **Contracts and Services** | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | **Sub Total** | **-** |
| **Equipment, Tools, and Supplies** | | | | | | | | |
| | Equipment | A lab-scale ($15,000) and pilot-scale ($30,000) integrated duckweed based wastewater treatment system for enhanced nutrient recovery and a protein rich biomass production will be built in the second and third year. The components include two: lab-scale and pilot scale integrated reactors, pumps, tubing and valves, control and monitoring system (temperature controllers, pH sensors, data logger, photo meter), regulator and pressure sensors. | This lab scale and pilot scale reactor will enable us to test our proposed process in the real swine farm. The components for integrated wastewater treatment system include solid liquid separator, duckweed cultivation system, harvesting devise, gas measuring devises, air compressor, insulation, pumps for moving water and wastewater throughout the system at the WCROC. | | | | | $45,000 |
| | Tools and Supplies | Funds ($14,000 in Year 1, $19,000 in Year 2, and $18,613 in Year 3) are requested for experimental chemicals and analytical supplies, and PPE. Analytical supplies for conducting experiments and nutrient analysis of replicated samples. Supplies for the system include bags, pvc piping, compressor, heat sealer, filters, chemicals, metal racks, pumps, lights, electrical wiring, pH monitoring and control, CO2 sparging equipment and storage at the WCROC, Morris. | These chemicals and analytical supplies are need to carryout the proposed experimental work. | | | | | $51,613 |
| | | | | | | | **Sub Total** | **$96,613** |
| **Capital Equipment** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| **Acquisitions and Stewardship** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| **Travel In Minnesota** | | | | | | | | |
| | Conference Registration | One conference trip on second and third year for PI and 2 student per year, $250 registration per person ($750 total per year), 500 miles per year | PI and graduate student each year will present and share research results in | | | | | $4,180 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Miles/ Meals/ Lodging | ($300), lodging for 3 persons and 2 nights ($900), and meals ($620 for 3 persons, two days per year) | in-state conferences, and network with peers. | | | | | |
| | | | | | | | **Sub Total** | **$4,180** |
| **Travel Outside Minnesota** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| **Printing and Publication** | | | | | | | | |
| | Publication | Open-access journal publication cost | Publish research results in open-access journal, about $3,000 per year for one paper | | | | | $4,000 |
| | | | | | | | **Sub Total** | **$4,000** |
| **Other Expenses** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| | | | | | | | **Grand Total** | **$688,000** |

## Classified Staff or Generally Ineligible Expenses

| Category/Name | Subcategory or Type | Description | Justification Ineligible Expense or Classified Staff Request |
|---|---|---|---|

## Non ENRTF Funds

| Category | Specific Source | Use | Status | Amount |
|---|---|---|---|---|
| **State** | | | | |
| | | | **State Sub Total** | **-** |
| **Non-State** | | | | |
| | | | **Non State Sub Total** | **-** |
| | | | **Funds Total** | **-** |

**Total Project Cost: $688,000**

**This amount accurately reflects total project cost?**

Yes

## Attachments

### Required Attachments

*Visual Component*

File: 3b2a1749-cb3.pdf

*Alternate Text for Visual Component*

The graphical abstract describes the integrated duckweed-based wastewater treatment system that transforms nutrient rich swine manure wastewater into a valuable protein rich biomass that could use as a food, feed and used as a raw material for biofuel, bioplastics and other bioproducts development....

### Supplemental Attachments

*Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other*

| Title | File |
|---|---|
| Letter of Authorization to Submit | 51210370-28d.pdf |

## Administrative Use

**Does your project include restoration or acquisition of land rights?**

No

**Do you understand that travel expenses are only approved if they follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?**

Yes, I understand the UMN Policy on travel applies.

**Does your project have potential for royalties, copyrights, patents, sale of products and assets, or revenue generation?**

No

**Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?**

N/A

**Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?**

N/A

**Does your project include original, hypothesis-driven research?**

Yes

**Does the organization have a fiscal agent for this project?**

No

**Does your project include the pre-design, design, construction, or renovation of a building, trail, campground, or other fixed capital asset costing $10,000 or more or large-scale stream or wetland restoration?**

No

**Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services (as defined in Minnesota Statutes section 299C.61 Subd.7 as "the provision of care, treatment, education, training, instruction, or recreation to children")?**

No

**Provide the name(s) and organization(s) of additional individuals assisting in the completion of this proposal:**

Wendy Moylan, University of Minnesota

**Do you understand that a named service contract does not constitute a funder-designated subrecipient or approval of a sole-source contract? In other words, a service contract entity is only approved if it has been selected according to the contracting rules identified in state law and policy for organizations that receive ENRTF funds through direct appropriations, or in the DNR's reimbursement manual for non-state organizations. These rules may include competitive bidding and prevailing wage requirements**

N/A