Environment and Natural Resources Trust Fund

2027 Request for Proposal

General Information

Proposal ID: 2027-324

Proposal Title: Polyurethane Fertilizer Coatings to Reduce Agricultural Nutrient Runoff

Project Manager Information

Name: Prasanth Kumar Sasidharan Pillai

Organization: U of MN - College of Food, Agricultural and Natural Resource Sciences

Office Telephone: (612) 626-2296

Email: psasidha@umn.edu

Project Basic Information

Project Summary: Polyurethane-coated fertilizers derived from agricultural and food-processing byproducts will be developed to reduce nitrate leaching and phosphorus runoff from soils to water systems, improving nutrient retention and protecting water quality.

ENRTF Funds Requested: $260,000

Proposed Project Completion: June 30, 2030

LCCMR Funding Category: Small Projects (G)
Secondary 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.

Minnesota's nutrient management challenges, highlighted in watershed protection initiatives and previous LCCMR supported projects, underscore the need for innovative fertilizer technologies that reduce nutrient losses while promoting sustainable materials. LCCMR has previously supported important work on lignin based biodegradable coatings for slow nutrient release, demonstrating the potential of bio derived materials to reduce fertilizer runoff and improve water quality. Building on this progress, the proposed project complements these efforts by developing biodegradable polyurethane fertilizer coatings derived from agricultural and dairy waste streams. Unlike lignin-based coatings that primarily provide passive slow release, polyurethane chemistry enables precise control of polymer network structure, allowing polymer characteristics such as crosslink density, hydrophobicity, and molecular architecture to be engineered to tune coating permeability and nutrient diffusion rates. By tailoring these properties, the coatings can regulate the release of nitrogen and phosphorus fertilizers under Minnesota relevant soil and climate conditions. This controlled nutrient availability helps better match plant uptake, improving fertilizer use efficiency while reducing nitrate leaching and phosphorus runoff. By transforming agricultural and dairy byproducts into biodegradable coating materials, this project advances circular bioeconomy strategies while providing a scalable pathway to protect Minnesota's surface and groundwater resources and support sustainable agricultural productivity.

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 is to develop and validate fertilizer coatings made from polyurethanes synthesized from Minnesota relevant agricultural and food processing wastes, including potato peels, corn stover, and dairy whey permeate. These waste streams will be converted into polyurethane materials through oxypropylation and carbonation reactions, enabling both conventional isocyanate and non-isocyanate polyurethane pathways. The resulting waste derived polyurethanes will be applied as controlled release coatings on urea and phosphorus fertilizers. Polyurethane chemistry enables engineering of polymer networks to control crosslink density, hydrophobicity, and permeability, allowing precise tuning of nutrient diffusion and release. Polyurethane coated fertilizers regulate nutrient release through water diffusion, fertilizer dissolution, and osmotic driven diffusion across a semi permeable membrane. Release rates depend on coating thickness, crosslink density, soil temperature, and soil moisture. In this project we will tune polymer structure to achieve gradual nutrient release over 60 to 90 days aligned with crop uptake while minimizing early season losses. Environmental performance will be evaluated using soil column and simulated tile drainage experiments representing Minnesota conditions. The project targets 30 to 50 percent lower nitrate leaching and 20 to 40 percent lower phosphorus runoff while improving fertilizer efficiency and protecting Minnesota waters.

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?

The project will reduce nitrogen and phosphorus losses from agricultural soils, helping protect Minnesota's surface waters and groundwater from nutrient contamination. By targeting a 30 to 50 percent reduction in nitrate leaching and a 20 to 40 percent reduction in dissolved phosphorus runoff, the proposed waste derived polyurethane coatings will decrease nutrient loading to lakes, rivers, and tile drainage systems that contribute to harmful algal blooms and groundwater impairment. At the same time, controlled nutrient release will improve fertilizer efficiency and ensure adequate nutrient availability for crop cultivation. These outcomes improve water quality and protect Minnesota's natural resources.

Activities and Milestones

Activity 1: Synthesis of waste derived polyurethane precursors and coating formulation development

Activity Budget: $90,000

Activity Description:
Agricultural and food processing wastes including potato peels, corn stover, and dairy whey permeate will be sourced from Minnesota industry partners and converted into polyurethane precursors through oxypropylation and carbonation reactions to develop biodegradable coating materials. Both conventional isocyanate and non isocyanate polyurethane pathways will be evaluated to produce polymers suitable for controlled release fertilizer coatings. Polymer synthesis and formulation work will be conducted in the laboratory to identify coating systems with appropriate viscosity, stability, and permeability for fertilizer applications. The resulting polymers will be characterized for viscosity, crosslink density, hydrophobicity, thermal stability, and permeability to understand their ability to regulate nutrient diffusion. Promising polyurethane formulations will be selected and optimized to enable controlled nutrient release aligned with crop uptake. The optimized coating materials will form the basis for fertilizer coating and nutrient release testing in subsequent project activities. This work will establish a sustainable pathway to transform Minnesota agricultural and food processing waste streams into high value biodegradable coating materials that improve fertilizer efficiency while reducing nutrient losses to Minnesota waters.

Activity Milestones:

Description	Approximate Completion Date
Conversion of waste streams, individually and in combination, into polyurethane precursors	March 31, 2028
Polymer characterization and permeability evaluation	May 31, 2028
Selection of optimal polyurethane coating formulations	June 30, 2028

Activity 2: Production of coated fertilizer granules and nutrient release evaluation

Activity Budget: $75,000

Activity Description:
Selected polyurethane formulations developed in Activity 1 will be applied as controlled release coatings on commercially available granulated urea and phosphorus fertilizers purchased for this study. These fertilizers will serve as standardized substrates to evaluate coating performance under controlled laboratory conditions. Coating experiments will be conducted using laboratory scale coating methods to produce coated fertilizer prototypes with defined coating thickness and polymer structure. The influence of coating parameters, including polymer composition, crosslink density, and coating thickness, will be evaluated to regulate nutrient diffusion and achieve controlled nutrient release. The coated fertilizer granules produced in this activity will be used to evaluate nutrient release behavior through dissolution and diffusion experiments conducted under controlled aqueous conditions. Nutrient release kinetics will be measured to determine the rate and duration of nutrient availability. Based on these results, coating parameters and polymer formulations will be refined to optimize release profiles aligned with crop nutrient demand while minimizing early nutrient losses. The coated fertilizer prototypes generated in this activity will provide the materials necessary for subsequent environmental performance testing in soil column and simulated tile drainage systems designed to represent Minnesota agricultural conditions

Activity Milestones:

Description	Approximate Completion Date
Development of laboratory scale fertilizer coating process	February 28, 2029

Production of coated fertilizer prototypes	June 30, 2029
Nutrient release kinetics testing in aqueous systems	June 30, 2029
Optimization of coating thickness and polymer parameters for controlled nutrient diffusion	September 30, 2029
Development of nutrient release profiles representing Minnesota soil temperature and moisture conditions	December 31, 2029

Activity 3: Evaluation of nutrient loss reduction under simulated Minnesota soil conditions

Activity Budget: $60,000

Activity Description:
Environmental performance of coated fertilizers will be evaluated using replicated laboratory scale soil column experiments and simulated tile drainage systems representing Minnesota agricultural conditions. Coated fertilizer prototypes developed in Activity 2 will be compared with conventional fertilizers to quantify differences in nutrient transport and loss. Soil columns packed with representative Minnesota soils will be subjected to controlled irrigation events that simulate rainfall and drainage typical of row crop systems. Leachate will be analyzed for nitrate nitrogen and dissolved phosphorus to measure nutrient losses over time. These experiments will generate data on nutrient release behavior, fertilizer efficiency, and reductions in nitrate leaching and phosphorus runoff, providing evidence of the potential of polyurethane coated fertilizers to reduce nutrient losses and protect Minnesota water resources.

Activity Milestones:

Description	Approximate Completion Date
Quantify nitrate leaching and phosphorus runoff from experimental systems	January 31, 2030
Data analysis and nutrient loss reduction modeling	January 31, 2030
Establish soil column and tile drainage simulation systems representing Minnesota soil condition	June 30, 2030
Conduct soil column experiments with coated and conventional fertilizers	June 30, 2030

Activity 4: Data integration and technology readiness for future field evaluation

Activity Budget: $35,000

Activity Description:
Experimental results will be integrated to develop nutrient release models that describe how polyurethane coatings regulate nutrient diffusion and availability under different soil moisture and temperature conditions. These models will be used to quantify potential reductions in nitrate leaching and phosphorus runoff and to estimate the environmental benefits of controlled release fertilizer systems. The findings will provide a scientific basis for optimizing coating formulations and predicting fertilizer performance under Minnesota agricultural conditions. Results from this project will support future field trials and technology implementation through collaboration with growers, fertilizer industry partners, extension specialists, and water quality initiatives aimed at improving nutrient management and protecting Minnesota's surface waters and groundwater.

Activity Milestones:

Description	Approximate Completion Date
Development of nutrient release models	June 30, 2030
Preparation of technical reports and stakeholder outreach	June 30, 2030
Identification of partners for field scale evaluation	June 30, 2030

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Jayendra Amamcharla	University of Minnesota	Co-Principal Inverstigator, working on the physical property charavterization of different formulations of polyurethane coated fertilizer	Yes

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.
Project results will be disseminated through peer-reviewed publications, conference presentations, stakeholder workshops, and outreach to Minnesota industry and agricultural partners. All dissemination materials will acknowledge support from the Environment and Natural Resources Trust Fund (ENRTF) in accordance with the ENRTF Acknowledgment Guidelines.

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?
Project results will be implemented by sharing performance data with Minnesota growers, extension specialists, watershed districts, and fertilizer industry partners to guide future field evaluation and adoption. This project will generate laboratory scale validation, nutrient release models, and quantified nutrient loss reduction metrics needed to support pilot scale testing. The findings will provide a strong scientific foundation for expanded field trials and technology development. Future work will build on this project through strong collaborations with industry partners, growers, and water quality initiatives to accelerate field implementation and commercialization.

Project Manager and Organization Qualifications

Project Manager Name: Prasanth Kumar Sasidharan Pillai

Job Title: Assistant Professor

Provide description of the project manager's qualifications to manage the proposed project.
Dr. Prasanth K. S. Pillai has established a strong research portfolio in the design and development of bio-based and upcycled polymer systems, including polyurethane materials derived from industrial and agricultural byproducts. His work integrates lipid chemistry, biomass valorization, and polymer engineering to convert underutilized waste streams into high-performance materials with environmental applications. A major focus of his research has been the synthesis and modification of polyurethane networks using renewable feedstocks and industrial side streams as polyol sources. Dr. Pillai has contributed to the development of polyurethane and polyurethane-inspired systems derived from functionalized lipids, modified plant oils, and biomass-based intermediates. These systems have been engineered with tunable crosslink density, mechanical strength, barrier properties, and controlled permeability, key parameters for coating and encapsulation technologies. His work also includes non-isocyanate polyurethane approaches and sustainable polymer chemistries designed to reduce environmental impact while maintaining performance. Several of these innovations have resulted in United States granted patents, demonstrating both novelty and practical applicability.

Across five U.S. granted patents (for polyurethanes), Dr. Pillai has demonstrated expertise in converting industrial byproducts into functional polymeric materials suitable for coatings, packaging, and controlled release applications. His patented technologies reflect strengths in chemical modification strategies, structure–property optimization, and

translational scale-up. He has successfully bridged laboratory-scale polymer synthesis with application-driven performance testing, including permeability control and durability assessment. This combination of patented polyurethane innovation, industrial byproduct valorization, and materials engineering uniquely positions Dr. Pillai to develop waste-derived polyurethane fertilizer coatings aimed at reducing nitrogen and phosphorus losses. His prior intellectual property achievements underscore both technical capability and readiness to deliver scalable, environmentally impactful solutions aligned with Minnesota's land and water protection goals.

Organization: U of MN - College of Food, Agricultural and Natural Resource Sciences

Organization Description:
The College of Food, Agricultural and Natural Resource Sciences (CFANS) at the University of Minnesota is a leading research and education institution dedicated to advancing sustainable food systems, agricultural productivity, and environmental stewardship across Minnesota. CFANS integrates expertise in soil science, water quality, agronomy, food systems, environmental chemistry, and bioproducts engineering to address challenges at the intersection of agriculture and natural resource protection.

CFANS maintains advanced laboratory facilities, field research stations, and environmental monitoring capabilities that support rigorous evaluation of nutrient dynamics, soil health, and watershed impacts. Faculty collaborate closely with farmers, watershed districts, state agencies, and industry partners to develop and implement science-based solutions that reduce nitrogen and phosphorus losses, improve nutrient management, and protect surface and groundwater resources.

Through interdisciplinary research and strong stakeholder engagement, CFANS delivers measurable, data-driven outcomes that align with the Legislative-Citizen Commission on Minnesota Resources (LCCMR) mission to protect and enhance Minnesota's land, water, and natural resources.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Assistant professor		Lead the project and completion of deliverables			26.7%	0.15		$27,085
Professor and Co-Principal Investigator		Lead the physical properties or fertilizer coating			26.7%	0.12		$31,292
Graduate student		Carry out the polyurethane development and coating work for the prevention of nutrient leach out to the field			12.9%	3		$172,799
							Sub Total	**$231,176**
Contracts and Services								
Lab & Medical Services	Internal services or fees (uncommon)	Lab services include analytical and characterization support to evaluate material structure and performance using SEM, XRD, thermal analysis, permeability tests, and advanced techniques such as LC-MS and NMR.				-		$8,000
							Sub Total	**$8,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	These supplies are required to synthesize bio based polyurethane precursors from agricultural waste streams, formulate and apply polyurethane coatings on fertilizers, and conduct analytical and physicochemical characterization of the developed materials. The supplies will support polymer synthesis reactions, fertilizer coating development, and evaluation of coating performance, including nutrient release behavior, material stability, and structural properties necessary to achieve controlled release fertilizer formulations.	The requested $29,771 supply budget will support laboratory and experimental activities required to develop and evaluate waste-derived polyurethane coatings for controlled-release fertilizers aimed at reducing nitrogen and phosphorus losses from agricultural soils in Minnesota. Supplies will include chemical reagents for polymer synthesis, bio-derived polyols obtained from agricultural and dairy waste streams, crosslinking agents, catalysts, solvents, fertilizer substrates,					$20,824

			analytical standards for nitrate and phosphate analysis, filtration materials, and general laboratory consumables necessary for polymer development, fertilizer coating, and nutrient release evaluation. In Year 1, supplies will support the synthesis, formulation, and characterization of waste-derived polyurethane coating materials. This phase will require polymer synthesis reagents, curing agents, solvents, and coating additives, as well as materials needed to apply coatings to fertilizer substrates such as urea and phosphorus fertilizers. Additional supplies will support the evaluation of physical and functional properties of coating materials, including rheological behavior, thermal stability, and coating efficiency, to identify optimal formulations for polyurethane-coated fertilizers. In Years 2 and 3, supplies will support soil incubation and column leaching experiments designed to evaluate nutrient release behavior and environmental performance under controlled conditions representative of Minnesota agricultural systems. Materials will include soil column components, Minnesota agricultural soils, fertilizers, filtration supplies, water sampling containers, and reagents for nitrate and phosphorus quantification. Additional materials will support sample preparation, nutrient analysis, and monitoring of fertilizer nutrient release dynamics. Across all years, funds will also cover routine laboratory consumables, including glassware, culture vessels, vials, filtration membranes, pipettes, tubing, personal protective equipment, and					

			analytical reagents required for polymer characterization, fertilizer coating evaluation, and nutrient analysis. These supplies are essential to ensure reliable experimental measurements and reproducible data for evaluating the performance of waste-derived fertilizer coatings designed to reduce nutrient runoff and protect Minnesota's surface and groundwater resources.					
							Sub Total	**$20,824**
Capital Equipment								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
							Sub Total	**-**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$260,000**

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: $260,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: ec148fa4-66f.pdf

Alternate Text for Visual Component

This is the visual of the making of polyurethane coated fertilizer to prevent nutrient runoff...

Supplemental Attachments

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

Title	File
Letter from Organization	0b4df85e-88e.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?

N/A

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

Yes

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

Yes

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

No

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:

Dr. Prasanth K. S. Pillai – University of Minnesota (Principal Investigator and proposal lead)

Dr. Jayendra Amamcharla – University of Minnesota (Co-Principal Investigator)

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