

**Environment and Natural Resources Trust Fund**

# 2022 Request for Proposal

## **General Information**

**Proposal ID:** 2022-199

**Proposal Title:** Quantify on-farm methane emissions with low-cost sensor networks

## **Project Manager Information**

**Name:** Jiayu Li

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

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## **Project Basic Information**

**Project Summary:** We will characterize and deploy a suite of low-cost methane sensors for quantifying on-farm methane emissions.

**Funds Requested:** $425,000

**Proposed Project Completion:** June 30 2025

**LCCMR Funding Category:** Air Quality, Climate Change, and Renewable Energy (E)

## **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.**

Methane (CH4) is a primary greenhouse gas (GHG), whose impact on global climate is more than 25 times stronger than carbon dioxide (CO2) on a 100-year basis. Thus, methane emissions have been closely monitored to slow climate change. On-farm methane emissions are a significant source in Minnesota, which is poorly quantified. On-farm methane emissions are mainly from enteric emissions and manure management. Methane emissions from large dairies are under heightened scrutiny in Minnesota, as these cows’ emissions are a significant methane source in the region. Accurately quantifying on-farm methane emissions in Minnesota can significantly improve climate projections.   
 On-farm methane emissions can be estimated using bottom-up and top-down methods. Bottom-up methods usually measure methane emissions per cow and scale it up with the total number of cows. While top-down methods use methane concentrations measured from a tall tower, flight, or satellite to estimate methane emissions inversely. Large uncertainties exist for these methods as a series of assumptions are involved. On-site direct measurements are ideal for quantifying on-farm methane emissions to validate bottom-up and top-down estimations. Recent advances in low-cost methane sensors can enable direct measurements at multiple locations.

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

This project addresses Priority E: Air Quality, Climate Change, and Renewable Energy. We will quantify on-farm methane emissions with direct measurements from low-cost methane sensors. Preliminary results are promising as several sensors responded linearly to methane in lab tests. The funding from LCCMR will allow us to continue the study: developing calibration algorithms, building sensor networks, and quantifying on-farm methane emissions. Sensors will be calibrated with advanced algorithms to provide accurate and robust results. Then, we will build a sensor network containing 20-30 end devices to realize direct measurements with high spatiotemporal resolution. Such a sensor network will be deployed in 3-5 dairy cow farms of different scales to map on-farm methane concentrations. Finally, we will use these direct-measurement data to quantify on-farm methane emissions, which can be compared with existing methane emission inventories.

**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?**

Methane emissions from large dairies are under heightened scrutiny in Minnesota. It is a big challenge to quantify and reuse on-farm bio-methane. Farm owners are struggling with the maintenance requirements and financial return. A large reason for this dilemma is that on-farm emissions are poorly quantified, which cannot support consecutive environmental or financial analyses. We will quantify on-farm methane emissions with direct measurements, providing a sound foundation for farm owners and policymakers for farm management plans. The method developed by this proposal can also be used to quantify other methane emission sources, such as natural gas leakage and landfills.

## **Activities and Milestones**

### **Activity 1: Calibrate low-cost methane sensors and build a sensor network**

**Activity Budget:** $225,000

**Activity Description:**In this activity, we will 1) design a sensor suite and 2) build a sensor network. Low-cost methane sensors are currently poorly characterized. Most low-cost methane sensors are metal-oxide (MOX) sensors sensitive to both methane and volatile organic compounds (VOCs). The sensor suite contains multiple sensors to exclude interference, and we will cross-reference responses from all sensors for methane concentrations. The sensor suite consists of 8 different MOX sensors, 2 photoionized detectors (PID) that solely responsive to VOCs, a relative humidity (RH) sensor, and a temperature (T) sensor. Responses from all sensors will be evaluated to develop an advanced algorithm to calculate methane concentrations from 2 to 50 ppm, the typical concentration range on farms. Then, we will build a sensor network containing 20-30 sensor suites as end devices. Besides the sensor suite, end devices will also include anemometers to measure real-time wind speed and wind direction. A telemetry module will be integrated into end devices for data acquisition. The sensor network will be tested in the lab for general calibration and characterization, preparing for further deployment.

**Activity Milestones:**

|  |  |
| --- | --- |
| **Description** | **Completion Date** |
| Build methane sensing suite | December 31 2022 |
| Develop advanced algorithms to calculate methane concentrations from sensors | December 31 2022 |
| Build and test a sensor network | June 30 2023 |

### **Activity 2: Quantify on-farm methane emission by deploying a sensor network**

**Activity Budget:** $200,000

**Activity Description:**The specific tasks are 1) mapping on-farm methane concentrations and 2) characterizing the methane emission intensity. The sensor network will be deployed at 3-5 Minnesota dairy farms to monitor methane concentrations, wind direction, wind speed, relative humidity, and temperature. End devices will be strategically deployed within barns, at ventilation ports, at manure storages, and in the surrounding environment. The ambient methane concentrations upwind and downwind of the animal facility will also be monitored. The data collected from the sensor network can be used to quantify source emissions in multiple ways. Using conventional methods, we can calculate enteric emissions from methane concentrations inside and outside the cattle barn. Manure management emissions can also be calculated from downwind gradients around the manure storage. We can also use air dispersion models (e.g., AERMOD) and computational fluid dynamic models (e.g., COMSOL) to simulate the real-time methane emissions. With the sensor network, the accuracy of emission quantification will be improved, and a temporal pattern can be captured. These results can be a good supplement to the current national and regional inventories and can be used to develop a spatially and temporally resolved inventory for methane emissions from farming animals in Mid-west.

**Activity Milestones:**

|  |  |
| --- | --- |
| **Description** | **Completion Date** |
| Deploy the sensor network to map methane concentrations | June 30 2024 |
| Analyze temporal and spatial patterns of on-farm methane concentrations | December 31 2024 |
| Quantify on-farm methane emissions with conventional and new methods | June 30 2025 |

## **Project Partners and Collaborators**

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Organization** | **Role** | **Receiving Funds** |
| Timothy Griffis | University of Minnesota | Timothy Griffis’ research aims to improve the scientific understanding of the biophysical mechanisms that govern the exchange of energy and mass between the Earth’s surface and the lower atmosphere. Dr. Griffis will provide standard instruments for methane sampling. Dr. Griffis and Li will finalize on-farm methane sampling plans. | Yes |
| Dylan Millet | University of Minnesota | Dylan Millet’s group aims to understand the chemical composition of the atmosphere and how it is affected by humans and by the biosphere. They study atmospheric processes at multiple scales. In this project, Dr. Millet and Li will develop new methods to calculate on-farm methane emissions with low-cost sensors. | Yes |
| Monika Vadali | Minnesota Pollution Control Agency | Monika Vadali from the Minnesota Pollution Control Agency (MPCA) leads the Assessing Urban Air Quality project that was previously funded by the LCCMR. Her project deployed 44 low-cost multi-pollutant AQMESH sensors in Twin Cities. In this project, Dr. Vadali and Li will discuss practical issues regarding sensor deployment. | No |

## **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 be funded?**This proposal’s major outcomes will be: 1) an accurate, portable, and low-cost sensor suite designed for methane detection and 2) a methodology for methane emission characterization. These outcomes can also be deployed to characterize other non-agricultural methane emissions, such as natural gas leaks from city pipelines, oil and gas productions, and landfills. The low-cost sensor suite can also support citizen science to raise public awareness of greenhouse gas emissions, which is ideal for outreach programs and mass communication. The content of this proposal will be attractive to funding agencies, such as the DOE, NSF, and NASA.

## **Project Manager and Organization Qualifications**

**Project Manager Name:** Jiayu Li

**Job Title:** Assistant Professor

**Provide description of the project manager’s qualifications to manage the proposed project.**Dr. Jiayu Li, Assistant Professor for Department of Bioproducts and Biosystems Engineering, University of Minnesota, is the project manager of the proposed project. Jiayu’s research focuses on low-cost air quality sensors and bioaerosols. She has characterized multiple air quality sensors, including particulate matter sensors and multiple gaseous sensors. Her previous work used air quality sensors to map urban air quality with high spatiotemporal resolution. The ongoing project in her lab is characterizing methane sensors for further deployment.

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

**Organization Description:**The College of Food, Agricultural and Natural Resource Sciences (CFANS) is one of seventeen colleges and professional schools at the University of Minnesota. CFANS comprises six divisions, twelve academic units, 10 research and outreach centers throughout Minnesota. CFANS is devoted to create a world that will feed our growing population while sustaining the natural resources upon which we depend. CFANS’ vision is to advance Minnesota as a global leader in food, agriculture, and natural resources through extraordinary education, science-based solutions, and dynamic public engagement that nourishes people and enhances the environment in which we live. Funding for CFANS' cutting-edge research comes from partners of all sizes and specialties. In the 2020 fiscal year, 413 sponsored project awards from 195 distinct funders were received by CFANS.

## **Budget Summary**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Category / Name** | **Subcategory or Type** | **Description** | **Purpose** | **Gen. Ineli gible** | **% Bene fits** | **# FTE** | **Class ified Staff?** | **$ Amount** |
| **Personnel** |  |  |  |  |  |  |  |  |
| PI |  | Project lead, supervision, research, analysis - 4 weeks summer salary |  |  | 36.5% | 0.24 |  | $37,002 |
| 2 Co-PI's |  | Research, supervision, analysis - 2 weeks summer salary each |  |  | 36.5% | 0.24 |  | $55,184 |
| 2 graduate students |  | research, analysis |  |  | 45% | 3 |  | $226,426 |
| 2 undergraduate students |  | research |  |  | 0% | 1.14 |  | $20,652 |
|  |  |  |  |  |  |  | **Sub Total** | **$339,264** |
| **Contracts and Services** |  |  |  |  |  |  |  |  |
| University of Minnesota | Internal services or fees (uncommon) | lab services - weather station and sensor calibration |  |  |  | - |  | $15,000 |
|  |  |  |  |  |  |  | **Sub Total** | **$15,000** |
| **Equipment, Tools, and Supplies** |  |  |  |  |  |  |  |  |
|  | Equipment | Licor 780 methane instrument | analysis |  |  |  |  | $50,000 |
|  | Tools and Supplies | lab supplies | sensors, calibration gas, and other electrical components |  |  |  |  | $14,736 |
|  |  |  |  |  |  |  | **Sub Total** | **$64,736** |
| **Capital Expenditures** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Acquisitions and Stewardship** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Travel In Minnesota** |  |  |  |  |  |  |  |  |
|  | Miles/ Meals/ Lodging | approximately 10,714 miles | visiting sensor locations, sampling |  |  |  |  | $6,000 |
|  |  |  |  |  |  |  | **Sub Total** | **$6,000** |
| **Travel Outside Minnesota** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Printing and Publication** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Other Expenses** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
|  |  |  |  |  |  |  | **Grand Total** | **$425,000** |

### **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** | **-** |

## **Attachments**

### **Required Attachments**

#### ***Visual Component***

File: [83a724cb-514.docx](https://lccmrprojectmgmt.leg.mn/media/map/83a724cb-514.docx)

#### ***Alternate Text for Visual Component***

1) Using low-cost sensors to quantify on-farm methane emissions  
2) The low-cost sensor suite in development for methane detection...

### **Optional Attachments**

#### ***Support Letter or Other***

|  |  |
| --- | --- |
| **Title** | **File** |
| Institutional Approval to submit | [61c47a4e-022.pdf](https://lccmrprojectmgmt.leg.mn/media/attachments/61c47a4e-022.pdf) |

## **Administrative Use**

**Does your project include restoration or acquisition of land rights?**   
 No

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