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 (CH_4) is a primary greenhouse gas (GHG), whose impact on global climate is more than 25 times stronger than carbon dioxide (CO_2) 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. Ineligible	% Benefits	# FTE	Classified 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

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

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?

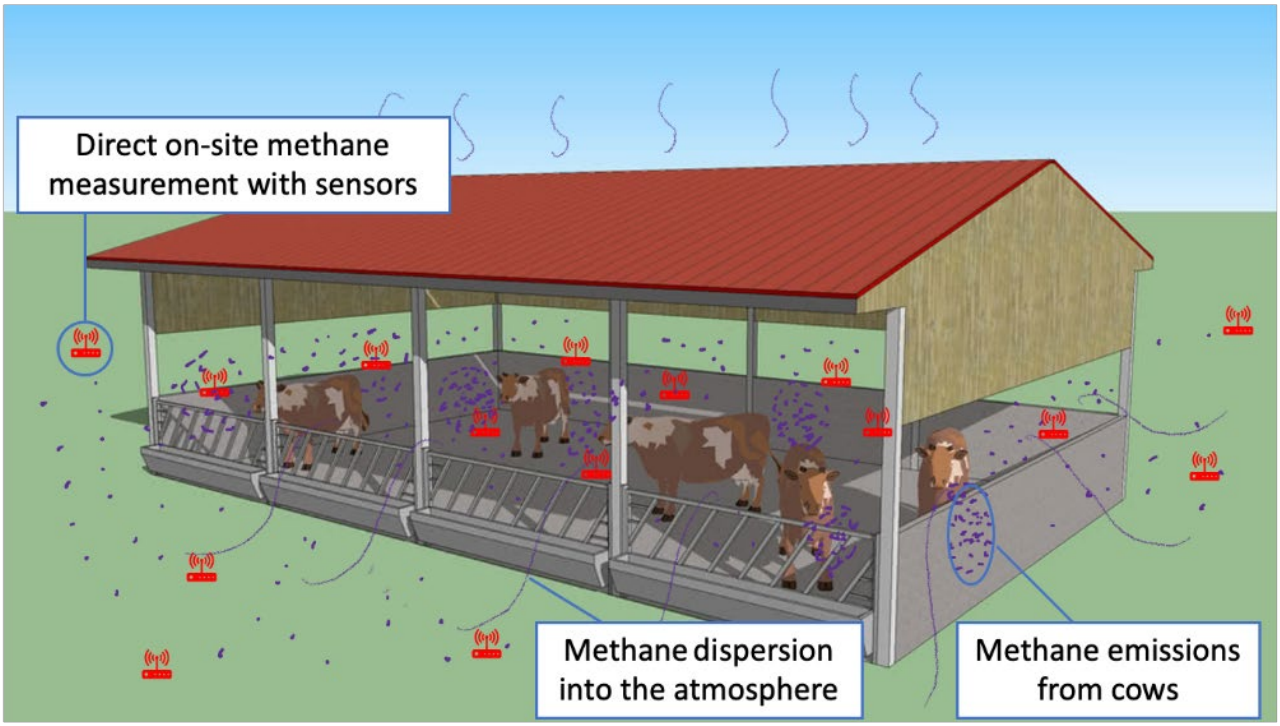
Yes

Does the organization have a fiscal agent for this project?

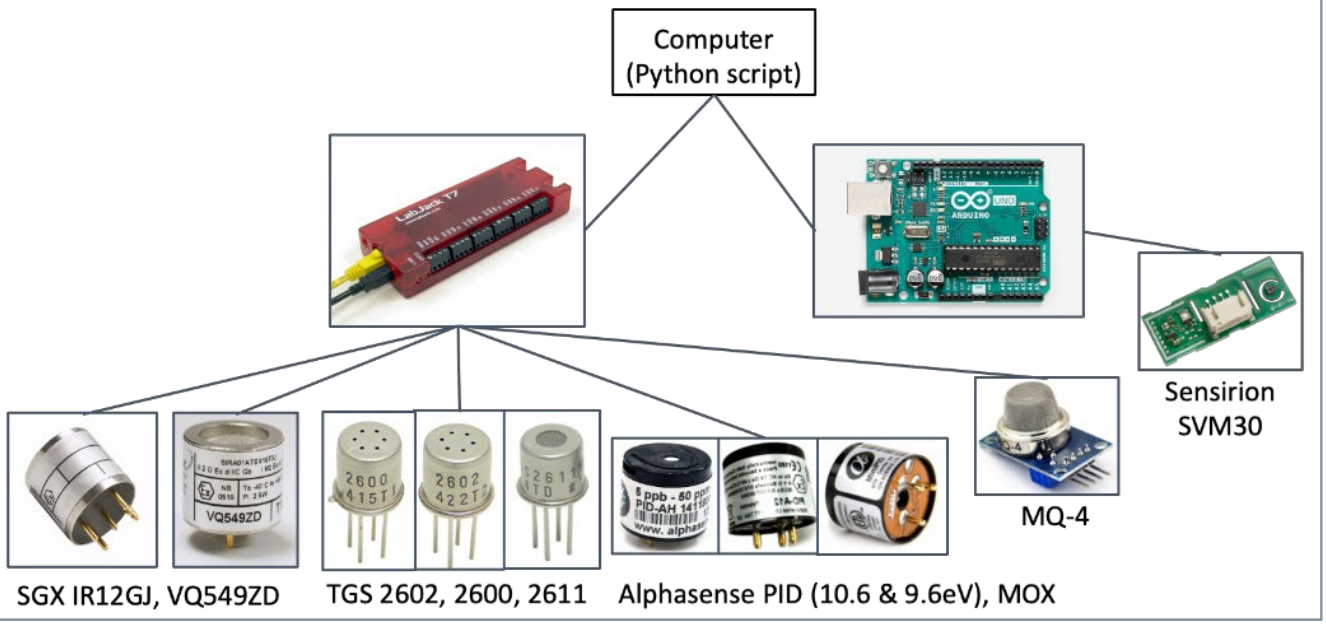
No

Visual Component

(1) Using low-cost sensors to quantify on-farm methane emissions



(2) The low-cost sensor suite in development for methane detection



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