Environment and Natural Resources Trust Fund

2023 Request for Proposal

General Information

Proposal ID: 2023-156

Proposal Title: Multi-Level Monitoring and Control Toward Smart Pasture Management

Project Manager Information

Name: Ce Yang

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

Office Telephone: (612) 626-6419

Email: ceyang@umn.edu

Project Basic Information

Project Summary: This project will develop new pasture management strategies using multi-level robotic monitoring and precision agricultural techniques to remove weeds in pastures and determine optimal time and location for grazing rotation.

Funds Requested: $1,027,000

Proposed Project Completion: June 30, 2026

LCCMR Funding Category: Foundational Natural Resource Data and Information (A)

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

Narrative

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

Dairy farms in Minnesota maintain and manage large pastures for grazing cows. Well-managed pastures with dense and healthy grass help to provide a nutrition-rich diet to livestock, prevent wind and water erosion and recharge underground water system. Weed control, rotation grazing and herding are critical actions in pasture management. Weeds can spread quickly and take over large areas if left uncontrolled. Our team has previously developed an electric mower (Cowbot) to autonomously mow the entire pasture. When operating on large acreage, mowing the entire field leads to high operating costs and energy requirements. Precision control for targeted weed removal will reduce the energy footprint of using an autonomous mower on the pasture. Another critical component of maintaining pastures is rotational grazing. It helps to maximize production and reduce sediment and nutrient runoff. The timing for rotation of livestock between paddocks is commonly determined based on satellite footage. Greenness of the grass in satellite images is the sole indicator of the readiness of an area for grazing, which is inaccurate and subjective and leads to suboptimal decisions. An energy-efficient multi-level monitoring and control system for optimized pasture management is needed to address the weed control and grazing schedule problems in pastures.

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.

We aim to design and develop a "smart pasture" that comprises an ecosystem of ground and aerial robots and supporting infrastructure for multi-level precision control and remote sensing. A drone based spectral imaging system will be useful to detect weeds in pastures based on their morphological and spectral differences from pasture grasses. Imaging can help in detecting grass biomass in pastures (Zhou et al., 2021), which further helps decide if an area is ready for grazing. Drone flights can be flexibly scheduled to cover different areas at desired times in the pasture, which enables better monitoring of the pasture for both weed control and grazing rotation. Therefore, we propose to use a drone-based spectral imaging system to monitor the pasture. Co-PI Maini has previously developed an electric weed mowing robot (key member of ENTRF-funded Cowbot project) that uses a flail-deck for pasture weed management by autonomously mowing the entire pasture. Detecting weeds on the pasture and targeted weed control would reduce the energy footprint of the electric mower and bring down the cost of adopting electric mowers for dairy farmers. We will use multi-level imaging sensors using ground and aerial robots to detect and localize weeds for precision control.

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 demonstrate a multi-level cooperative robot system for pasture management. The focus is pasture weed and grazing management based on robotic sensing, weed cutting and autonomous navigation using drones and a ground robot. The future use of the system will also include unmanned herding, in which a robot will help guide the cow herd while the drones monitor the herd and set boundaries for the herd movement. These outcomes will help preserve the state's pasture systems and natural resources by providing more efficient management and weed control while freeing dairy producers from tedious labor and time consuming activities.

Activities and Milestones

Activity 1: Aerial robot setup, data collection and modeling for weed detection in pasture and grazing rotation

Activity Budget: $450,708

Activity Description:
A drone based hyperspectral camera system will be used to collect data in WCROC pastures starting in the grazing season of 2023. Drone hyperspectral images provide image pixels with high definition spectral information, which have been used in weed detection in farmlands and alfalfa yield prediction in previous studies. More questions need to be answered regarding its application to pasture monitoring, including classification of grass and weeds and grass biomass estimation for grazing rotation. Manual weed identification will be conducted as ground truth for weed detection, and grass yield records will be kept closely following drone flight schedules. Collected images will be stitched and georectified to generate the field view of pasture paddocks with location information. Strategic Artificial Intelligence (AI)-based modeling and detection algorithms will be trained and validated. Advanced models improve with larger input dataset from diverse scenarios. Therefore, data collected in the years 2024-2026 will be used to greatly increase the reliability of the detection models, which is the key to its adoption for smart pasture management. The drone sensing platform also has potential use in cattle herding by cooperating with the a ground based robot.

Activity Milestones:

Description	Completion Date
Drone sensing and ground truth data collection from WCROC pastures	October 31, 2023
Image labeling, weed detection and pasture grass yield model training and calibration	April 30, 2024
Verification and improvement of remote sensing models using multiple year's data	October 31, 2025
Drone and ground platform integration for multi-level monitoring of weed in pastures	June 30, 2026

Activity 2: Design and develop an autonomous ground vehicle system to efficiently manage pasture systems through weeding and cattle herding

Activity Budget: $563,218

Activity Description:
To operate in the rough conditions on the pasture we need a platform that is mechanically suitable for the task and can operate a mowing implement. In the initial phase of the project, we will use the Cowbot, built previously (Cowbot-1) to collect data and test individual components. While Cowbot-1 was built by custom modifying a diesel platform due to non-availability of electric mowers in the market, the availability of electric mowers has since improved significantly. We will design Cowbot-2 to be energy efficient and suitable for sensor mounting while still being mechanically robust to operate on rough terrain building on lessons learned with Cowbot-1. We will equip Cowbot-2 with sensors and design computer algorithms to allow it to intelligently traverse on the pastures. We will design artificial intelligence methods to detect weeds on the pasture using onboard sensors and design path planning algorithms that would allow the Cowbot-2 to be energy efficient by mowing only weeds instead of mowing the entire pasture. We will also develop coordination and cooperation strategies between the drone and Cowbot for multi-level monitoring and control. We will also study the cooperation between aerial and ground robots for potential use in cattle herding.

Activity Milestones:

Description	Completion Date
Develop specifications for Cowbot-2 and acquire ground vehicle	December 31, 2023
Software based control of Cowbot-2	November 30, 2024
Weed detection module design and evaluation and path planning methods for mowing	November 30, 2025

Evaluate multi-level weed control strategies	June 30, 2026

Activity 3: Educate consumers, industry representatives, farmers and the general public about smart pasture management

Activity Budget: $13,074

Activity Description:

The results from all activities will be used to demonstrate the potential of a multi-level monitoring and control system toward smart pasture management. The knowledge and information generated will be disseminated to agricultural producers, technology providers, students, government officials, and other stakeholders through social media, University of Minnesota Extension websites, and conferences and workshops such as the Midwest Farm Energy Conference and Dairy Extension field days. Strategic information will be presented to farmers and industry representatives. Through this project we will develop the "Future Smart Pasture - manage pastures with multi-level collaborative robots" guidebook and disseminate it through a dedicated web portal and University Extension. We will publish peer-reviewed articles from project results in national journals. This will provide information to farmers, researchers and the tech companies well beyond the funding period.

Activity Milestones:

Description	Completion Date
Conduct smart pasture workshops and webinars and present results at conferences	July 31, 2025
Demonstrate multi-level monitoring for grazing rotation and weed control at UMN WCROC dairy field days.	August 31, 2025
Submit semi-annual reports and a comprehensive final report	June 30, 2026
Prepare and submit peer-review journal articles	June 30, 2026

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Bradley Heins	University of Minnesota	Co-PI	Yes
Parikshit Maini	University of Minnesota	Co-PI	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 work be funded?

The results and final products of this project will be demonstrated in state and regional conferences to show the potential of cooperative robots in smart pasture management through multi-level monitoring and control. We will publish findings in peer-reviewed journals and extension articles, and disseminate information and knowledge to farmers, educators, government officials and other stakeholders. Technology providers will be informed so that more efforts and greater progress can be made toward broader technology applications to smart pasture management, beyond the period of this funding. We will seek USDA NIFA Inter-Disciplinary Engagement in Animal Systems to support our ongoing efforts.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Agricultural Weed Control Using Autonomous Mowers	M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 08d	$750,000
Agrivoltaics To Improve The Environment And Farm Resiliency	M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 07c	$646,000

Project Manager and Organization Qualifications

Project Manager Name: Ce Yang

Job Title: Assistant Professor

Provide description of the project manager's qualifications to manage the proposed project.

Ce Yang is a MNDrive Robotics, Sensor and Advanced Manufacturing faculty member at the University of Minnesota (UMN). Yang's laboratory works on remote sensing and sensor applications in the area of agricultural and biological engineering. Crop monitoring and protection by various advanced sensing technologies has been the focus in Yang's group for eight years. Yang's research focuses on drone remote sensing for efficient fertilizer management in corn field and disease monitoring in wheat fields with the aim to reduce chemical input and eliminate runoffs in farmlands. Yang also works on regenerative agriculture through novel crop physiology research using remote sensing to store carbon in the soil and address climate change. Yang's agricultural robotics lab in the College of Food, Agriculture and Nature Resource and College of Science and Engineering at UMN will manage the whole procedure from experimental design, data collection to research finding dissemination by conference/forum/field day presentations, lectures and peer-reviewed publications.

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

Organization Description:

The department of Bioproducts and Biosystems Engineering in the College of Food, Agricultural and Natural Resource Sciences (CFANS) at UMN tackle core issues in agricultural engineering, biological engineering, environmental

engineering. The department has very dynamic interdisciplinary research activities and many researchers have received grant supports from the LCCMR program. WCROC from CFANS will participate as the research and demonstrate site for field experiments and showcasing the opportunities for smart pasture management, as well as generate new opportunities for the 5,000+ Minnesota dairy producers to utilize multi-level sensing/control techniques to achieve best management, reduce labor use and environmental footprint. The WCROC also hosts a Midwest Farm Energy Conference every 2 years in Morris, Minnesota where strategic information is presented to farmers and industry representatives. The University of Minnesota provides a range of facilities and sufficient laboratory space to perform each of the activities described in this proposal. UMN Sponsored Projects Administration (SPA) will be the entity authorized by the Board of Regents to manage the project agreements with LCCMR program.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Project Manager		To manage and report the overall project progress			33.5%	0.12		$25,490
WCROC Project Coordinator		project coordination, field testing, ground robot modifications			33.5%	0.3		$25,312
WCROC Technician		Modify ground vehicle to custom needs, maintenance and minor repairs			33.5%	0.3		$25,312
1 Postdoc		Path planning for Cowbot and fundamental research in cooperation between aerial and ground robots, project coordination with key personnel			20.9%	3		$196,249
Graduate Research Assistant		Drone remote sensing application including data collection, processing and analysis, conference presentations and publications			23.6%	1.5		$161,231
Graduate Research Assistant		Research and algorithm development in weed detection using the Cowbot: data collection, processing, analysis and integration			23.6%	1.5		$161,231
Undergraduate Student		Smart Pasture Technology for MN Farms			0%	0.45		$12,000
WCROC Researcher 3		Technician for data collection, system testing, data collection and management			28.7%	1.05		$138,998
WCROC Researcher 5		Engineering Technician to help with system design and placement and management			28.7%	0.6		$32,176
WCROC Farm Animal Attendent		Farm management to assist with labor of project, i.e. fencing, moving cattle			7.5%	0.24		$7,524
							Sub Total	**$785,523**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Equipment	Drive-by-wire capable eletric mower from Toro or similar with a mowing implement (includes	This mower serves as the base model for the development of Cowbot-2 for					$110,000

		modifications to make the electric mower drive-by-wire). This is for Task 2	path planning, navigation and weeding					
	Equipment	Update a drone system for drone hyperspectral imaging in Task 1	The drone system for Task 1 will be updated in 2024 as the current drone platform was discontinued and technical support for current drone platform will be ended by 2024					$15,000
	Equipment	Onboard sensors for gound robot	single board computer + RTK GPS + cameras + IMU + lidar + data communication equipment					$36,000
	Tools and Supplies	WCROC fence, tool and lab supplies	Fiberglass fence posts, insulators, poly wire and additional fence energizers. All objectives will require supplies that include: plot markers, sample bags, protective clothing. Seeds for cropping system objectives will also be ordered.					$15,000
	Tools and Supplies	Drone and camera maintenance	Drone imaging equipment needs to be maintained and repaired with batteries and parts					$4,500
	Tools and Supplies	Cowbot accessaries and supplies	Onboard power supplies + high data rate cables + mounting equipment + tools + field carry and storage					$7,500
	Equipment	Three high performance computers with graphic cards	Hyperspectral image and Cowbot data processing requires high performance computers with graphic cards for processing image cubes collected from the drone system and modeling as well as Cowbot navigation and path planning modeling and simulation.	X				$12,000
							Sub Total	**$200,000**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								

	Miles/ Meals/ Lodging	Eight overnight trips ($750) per year to WCROC from UMN campus for three years.	Drone image collection, Cowbot system development and test in the pasture					$18,000
	Conference Registration Miles/ Meals/ Lodging	Visit and demo at Minnesota Farm Fest - space rental, lodging and travel, transportation of equipment, display signs	Outreach activities					$6,000
	Conference Registration Miles/ Meals/ Lodging	Participation in Midwest Farm Energy Conference	In-state outreach activities					$1,500
							Sub Total	**$25,500**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Publication fees for 4 papers in total for year 2 and 3.	Publication fees for peer-reviewed journals papers and IEEE conference proceedings					$7,200
							Sub Total	**$7,200**
Other Expenses								
		WCROC Dairy Internal Service Fees	(Uncommon) Support for forage and crop testing. This is for WCROC dairy for services that include planting forages and crops as well as some seeds for the WCROC Dairy pastures. This is internal to the U of MN WCROC.					$8,777
							Sub Total	**$8,777**
							Grand Total	**$1,027,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Equipment, Tools, and Supplies		Three high performance computers with graphic cards	Two computers are needed for data processing and analysis of large-scale hyperspectral image sets collected with the drone and multi-modal sensor data collected on the Cowbot. The third computer is needed to develop and test path planning and navigation algorithms for the Cowbot. These three computers will be used by the postdoc and two graduate research assistants to efficiently conduct the tasks in this project.

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: 5efa2ef6-e43.pdf

Alternate Text for Visual Component

The file demonstrates the smart cattle pasture management scenario with workflow and shows the key items from the cooperative robot system....

Optional Attachments

Support Letter or Other

Title	File
parikshit_UNR_support_letter	507deea9-6ab.pdf
Institutional Approval of Submission	78b395a3-3da.pdf
Letter of support from Dr. Volkan Isler	90dfb9a4-86c.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?

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

LCCMR Project - Multi-Level Monitoring and Control Toward Smart Pasture Management