Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-264

Proposal Title: Automated Weed Management for Herbicide Water Runoff Reduction

Project Manager Information

Name: Junaed Sattar

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: This project will quantify the effect of herbicide use in precision agriculture on water quality using observations from autonomous underwater and aerial vehicles towards environmental sustainability and cost-effective weed control.

Funds Requested: $829,000

Proposed Project Completion: 2024-06-30

LCCMR Funding Category: Water Resources (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.

Herbicide use is essential to ensure high crop yield in a variety of agricultural applications. If untreated with herbicides, weeds can occur in ever-increasing frequency and occur across geographically dispersed regions. Weed escapes (such as giant ragweed, tall waterhemp, and common lambsquarters in Minnesota) are undesirable because they compete with corn and soybean for light, water, and nutrients; if present in large enough densities, these can reduce crop yield, and potentially can produce seeds that can transmit and spread herbicide resistance. Deciding which herbicide or mix of herbicides to use in a spot spray program to control weed escapes depends on many factors, including knowledge of what weed species are present. To date, there has been little research devoted to the automated identification of weed species that have escaped application of glyphosate or atrazine herbicides. There is a pressing need to identify weed escapes at early growth stages so that appropriate spot-spraying measures involving the most effective chemical product can be used, reducing water quality degradation. The proposed project thus aims to address these two opportunities by developing a system to detect and classify commonly-occurring weeds to assist in reducing herbicide use and alleviate the impact on water quality.

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.

The investigators will use small unmanned aerial vehicle (UAV) platforms equipped with vision sensors to capture imagery of crop fields, which will be enhanced by deep machine learning techniques to assist in the detection and classification of weed varieties. To measure the effect of herbicides on water quality, sensor-equipped aquatic robots will be deployed in headwater ditches and wetlands to conduct long-term sampling and assessment. The methodology includes ground truth assessment of weed species and weed densities, aerial imagery collected with a multispectral camera mounted on a UAV, processing of the aerial imagery using deep learning techniques, and development of algorithms and an automated decision support system to distinguish giant ragweed, common waterhemp, and lambsquarters weed species from one another and indicate the severity of infestation. The captured images will be enhanced using the techniques developed by Dr. Sattar's group; specifically, he will apply super-resolution and enhancement methods, either on-board the UAV or offline, to make the weed detection process even more robust. The amount of herbicide reduction and the quantities that are found in the nearby water deposits will be evaluated through a buoyancy operated robotic platform which, equipped with sensors, will quantify the

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 outcome of this project is the creation and validation of a commercially available process that will significantly reduce the amount of herbicide applied in row crop fields. As weeds become increasingly resistant to glyphosate, other herbicides that are known to disperse much farther, like dicamba and 2,4D, are being adopted. Since herbicide applications occur at least twice per year for every field, the risk of runoffs increases. By quantifying the effect of herbicides on water quality of run-off areas, this project will greatly assist in preserving Minnesota's vital aquatic resources, and also lower use of toxic chemicals.

Activities and Milestones

Activity 1: Weed pressure map creation and classification of weed species from UAV images

Activity Budget: $331,600

Activity Description:

Activity description: This activity would involve using Unmanned Aerial Vehicles to fly over selected crop fields with known infestations of specific species of weed and capture pictures at different altitudes and UAV velocities. Commercially-existing technology is often challenged in such tasks as the velocity and altitude of the UAV has to be well-controlled to capture images of sufficient clarity for weed classification tasks. Dr. Sattar and his team at the UoM specializes in enhancing imagery captured under degraded visual conditions, both in terms of improving visibility and resolution. Combining those techniques with deep-learned object classification methods (e.g., those used by his team for aquatic debris detection), different species of weeds will be detected and localized. This can be potentially conducted both during the UAV flyover and also afterward, processing the captured imagery offline. Working with our industry partner Sentera, the investigators will identify potential locations with known weed infestations to collect data so that the image enhancement, super-resolution, and weed detection systems can be developed. The outcome of this activity will be a system involving UAVs, cameras, and on- and off-board computational resources, to detect, identify, and map species of weed in crop fields in Minnesota and beyond.

Activity Milestones:

Description	Completion Date
Ground truth data collection for giant and common ragweed, tall waterhemp, and common lambsquarters	2021-12-31
High-resolution UAV based multispectral imagery and imagery annotation	2022-04-30
Develop and deploy machine vision algorithms to enhance and super-resolve high-resolution imagery	2022-08-31
Creation of automated machine vision algorithms to distinguish herbicide-resistant weeds	2023-05-31
Conduct field tests in selected fields to validate systems, collect data, and refine methods.	2024-06-30

Activity 2: Develop a water quality assessment mechanism using autonomous underwater robots.

Activity Budget: $497,400

Activity Description:

This activity would involve using Autonomous Underwater Vehicles (AUVs) to assess the water quality in headwater ditches near herbicide application zones. Specifically, the aim will be to quantify the volume of chemicals resulting from herbicide applications, their dispersal, and long-term implications. Research from Mulla et al. (2002) shows that herbicide runoff can be reduced by over 30% by targeting applications to areas with weeds. Uniform herbicide management results in development of herbicide resistance, weed escapes, loss of crop yield, and water pollution. As these chemicals are not concentrated in a single area, but often disperse broadly, a single immovable sensor would not be ideal to provide broad coverage for assessment. Dr. Sattar and his group will support this activity by designing, building, and deploying AUVs in headwater ditches near the study fields with appropriate sensors to sample and assess water quality over fixed time periods. The AUVs will be constructed at the IRVLab directed by PM Sattar, and prototyped and validated at the facilities of the University of Minnesota Twin Cities. After consultations with the industrial partner and collaborators Drs. Mulla and Johnson, these AUVs will be deployed in the headwater ditches to collect samples and quantify herbicide runoff effects.

Activity Milestones:

Description	Completion Date

Design, construction, and prototyping of autonomous underwater vehicles for water quality assessment	2022-03-31
Water quality sensor systems interfacing with AUV, design validation	2022-07-31
Initial water quality sampling to assess sensors and identify future evaluation zones	2022-08-31
Pilot field deployment of AUV in selected runoff zones for time-limited assessment.	2022-09-30
Long-term deployment of AUV and sensors in selected runoff zones for extended water quality assessment	2024-06-30

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Dimitris Zermas	Sentera	Principal Research Scientist at Sentera.Precision Agriculture Engineering expertise; evaluation of the use of aerial imagery obtained from small quadcopter UAV swarm in the application of weed management; will also provide engineering staff support, data annotation, UAV equipment, and sensor supplies, and field trial assistance. evaluate potential technology commercialization.	Yes
Gregg A. Johnson	University of Minnesota	Associate professor of Agronomy and Plant Genetics at the Southern Research and Outreach Center of the University of Minnesota. Expert in integrated weed management, field selection for data collection (Waseca), weed species identification, provide AUV field trial assistance.	Yes
David J. Mulla	University of Minnesota Twin Cities	Project collaborator, specializing in soil and water science, particularly in measuring water quality benefits of variable rate herbicide management.	Yes

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?

The findings from the proposed work will provide a quantitative measure of water quality in runoff areas after herbicide use, assisting in creating meaningful regulations and policies benefiting both agricultural and environmental purposes. Additionally, this will assist farmers two-folds: maximizing crop yield with well-defined use of herbicides and increase cost savings by reducing the amount used. Collaboration with a Minnesota industrial partner like Sentera will also facilitate technology commercialization and deployment, putting findings in the hands of the end-users quickly. PM Sattar and collaborators will seek funding from various sources (e.g., USDA beyond the duration of the project.

Project Manager and Organization Qualifications

Project Manager Name: Junaed Sattar

Job Title: Assistant Professor, Department of Computer Science, University of Minnesota Twin Cities

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

Junaed Sattar is an Assistant Professor, Department of Computer Science, University of Minnesota Twin Cities, and also the founding director of the Minnesota Interactive Robotics and Vision Laboratory, part of the Minnesota Robotics Institute. Dr. Sattar manages a team of 11 graduate and 10 undergraduate students, conducting research in Field and Underwater Robotics. His creates novel systems and methods to enable robust autonomous behavior for outdoor robots, particularly those that operate underwater, without the need for constant human input, while being aware of, human safety and well-being. His group has been working with vision-guided robotic systems, both for underwater and terrestrial applications. To mitigate the effects of poor visibility conditions, his group has done groundbreaking work in visual scene enhancement, super-resolution, and enhancing lane visibility for driver's assistance under degraded conditions (such is in snowstorms). Moreover, he and his group have extensive experience designing, building, and operating robotic platforms for outdoor use, and these systems have seen significant applications in the lakes and rivers of Minnesota, and also in the Caribbean sea for coral inspection tasks and systems validation. These are important and relevant experiences and skills required for the successful completion of the proposed project for a number of reasons. Firstly, the proposed research will involve the processing of imagery of crop fields taken by aerial vehicles from various altitudes, and at potentially high speeds. These images are likely to be somewhat degraded. Also, a UAV cannot fly too close to the crop at lower altitudes for safety, thus the images captures are likely to contain weed and other undesirable

elements at lower resolutions, which would require enhancement. Dr. Sattar's expertise in addressing these issues in robot vision systems and his experience in deploying robust vision algorithms in pragmatic systems make him uniquely suitable to lead this project.

Organization: U of MN - College of Science and Engineering

Organization Description:
The Minnesota Robotics Institute (MnRI) is made up of researchers who are pushing the frontiers of robotic locomotion and perception in the land, air, and water across a vast array of domains including Precision Agriculture, Environmental Monitoring, Underwater Communication & Collaboration, Swarm Robotics, Social Robots, and Robot Perception. The Interactive Robotics Laboratory (http://irvlab.cs.umn.edu), as part of the MnRI, conducts research in underwater robotics motivated by the needs of environmental assessment, conservation biology, water quality assessment, and coral reef mapping and monitoring. The IRVLab specializes in cutting-edge perceptual computing for robotics applications in degraded visual conditions, and rugged robotic device construction, among others. Robotic field trials are a core part of the IRVLab's mission to invent robotics-driven solutions to a number of real-world problems. Students are exposed to the latest innovations in autonomous outdoor systems, and often are creating such innovations themselves. becoming well-equipped to face the challenges in the 21st-century economy in Minnesota and beyond.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Project Manager: Junaed Sattar		Overall project management, student supervision and guidance, robot hardware development			36.5%	33.33		$57,146
Collaborator: David Mulla		Soil and water science specialist, particularly in measuring water quality benefits of variable rate herbicide management.			36.5%	12.51		$33,001
Collaborator: Gregg Johnson		Agronomy and Plant Genetics expert, integrated weed management, field selection for data collection (Waseca), weed species identification, provide AUV field trial assistance.			36.5%	12.51		$19,145
CS&E Graduate Research Assistant #1		Research and development in vision systems enhancement for weed detection and classifications and in underwater sensor design			75.5%	150		$155,588
CS&E Graduate Research Assistant #2		Research and development in vision systems enhancement for weed detection and classifications and in underwater sensor design			75.5%	150		$155,588
Field Scientist		Field selection and preparation for AUV and UAV tests, weed location scouting			31.8%	50.01		$56,193
CSE Undergrad		Computer Science and Engineering Undergrad summer support for AUV design, fabrication, testing			0%	4.5		$6,819
ROC Undergrad		Undergrad student asssitant for field selection for data collection tasks (Waseca), weed species identification, provide AUV field trial assistance.			0%	4.5		$6,819
							Sub Total	**$490,299**
Contracts and Services								
Sentera	Sub award	Staff (Development Support Engineer and Technician): $125,000 Data Annotation: $15,000 Equipment (UAV, camera): $20,783				-		$160,783

							Sub Total	**$160,783**
Equipment, Tools, and Supplies								
	Equipment	AUV (underwater robots + sensors) hardware	Robotic sensors for water quality assessement in headwater ditches and other runoff zones.					$40,595
	Equipment	AUV and algorithm development GPU	Needed for the development and testing of the weed detection and scene enhancement algorithms at the PM Sattar's lab.					$20,063
							Sub Total	**$60,658**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	$20,000 X 3 years	Field testing and design refinement for the underwater robotic sensors. Also, data collection and reployment testing for aerial vehicles.					$61,818
							Sub Total	**$61,818**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**

Other Expenses								
		CS&E Network and Computer Services	Networking and computer charges are expenses charged to sponsored and non-sponsored accounts to support the portion of networking and computer infrastructure used by sponsored and non-sponsored research projects. In a formula found to be Circular A21 compliant by the Office of Treasury Accounting and Int/Ext Sales and SPA, research specific computing is separated from general-purpose computing. The networking and computer support charge is based on FTEs and special projects that can be attributed to research-only projects. PI (Sattar): (100% of 1 month) 173 hrs * $0.932/hr = $162 GRA #1: (50% of 12 months) 1,040 hrs * $2.796/hr = $2,908 GRA #2: (50% of 12 months) 1,040 hrs * $2.796/hr = $2,908 UGRA: (100% of 3 months) 520 * $2.796/hr = $1,454					$22,970
		Field Testing One-time	Field testing (rental, herbicide application)					$30,000
		Plot Fees	Plot fees for Southern Research and Outreach Center in Waseca.					$2,472
							Sub Total	**$55,442**
							Grand Total	**$829,000**

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: ffc5f173-4df.pdf

Alternate Text for Visual Component

The graphic has the project title and the University of Minnesota logo on the top overlaid with an outline map of Minnesota. It depicts a headwater ditch surrounded by crop fields and illustrates how herbicide runoff into the ditches can occur from applicators. It further shows an aerial robot flying over the field to autonomously identify different weed species, and an underwater robot in the headwater ditch working to assess the effect of herbicide runoff on water quality.

Optional Attachments

Support Letter or Other

Title	File
Sentera Support Letter	4df3de76-ce4.pdf
University of Minnesota Support Letter	f3f33bb9-82b.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have patent, royalties, or revenue potential?

Yes,

- Patent, Copyright, or Royalty Potential

Does your project include research?

Yes

Does the organization have a fiscal agent for this project?

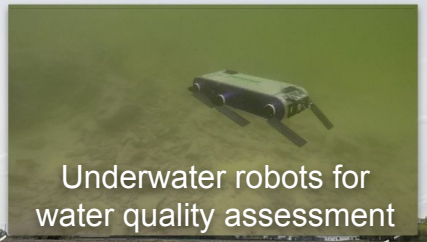
Yes, Sponsored Projects Administration

Automated weed management for herbicide water runoff reduction

Aerial drones for weed detection

Variable rate herbicide application

Herbicide runoff



Underwater robots for water quality assessment