



Environment and Natural Resources Trust Fund

2022 Request for Proposal

General Information

Proposal ID: 2022-257

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: \$816,000

Proposed Project Completion: June 30 2025

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 optimize crop yield potential in many agricultural applications. Although herbicides provide good control of most common weeds, there are many situations where weeds escape the initial pre-emergence herbicide control. Consequently, farmers will uniformly re-apply herbicide across the entire field after the crops emerge, resulting in over-application and potential for herbicide runoff that can compromise water quality in surrounding water bodies. The continuous monitoring and precise application of herbicide applications is not well studied when applied in conjunction with alternative agricultural practises such as the inclusion of cover crops. The potential environmental and financial benefits from the combination of both agricultural practises can be transformative for Minnesota in minimizing the impairment of watersheds and producing additional savings for the farmers. The proposed project aims to address this opportunity by developing an automated system to detect commonly-occurring weeds, apply herbicide where necessary, and assess the effect of herbicide usage on the watersheds between fields with cover crops and fields with traditional corn-soybean rotation practises.

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, camera-quipped unmanned aerial vehicles (UAVs) to capture imagery of crop fields, enhancing them using deep machine learning techniques to assist in the detection and classification of weed. To measure the effect of herbicides on water quality, sensor-equipped aquatic robots will be deployed in open runoff zones (e.g., headwater ditches) 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 UAVs, processing of the aerial imagery and algorithm development. An automated decision support system will distinguish crops from weeds and further classify the weeds into grass, amaranth, giant ragweed, and other broadleaf weed species and indicate the severity of infestation. Dr. Sattar's group will enhance captured images using techniques they developed; specifically, super-resolution and enhancement methods will be used, either on-board UAVs or offline, to create a robust weed detection process. An aquatic robot will collect water samples and measure the amount of herbicide reduction and the quantities found in nearby headwater ditches. Differences between the conventional practices (corn-soybean rotation) and the use of a cover crop such as alfalfa will be quantified and analyzed to assess potential benefits.

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?

This project will create and validate 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 be more mobile, but less persistent, like dicamba and 2,4D, are being adopted. Since herbicide applications occur at least twice per year for every field, the risk of runoff increases. By quantifying the effect of herbicides on the water quality of nearby headwater ditches, this project will greatly assist in preserving Minnesota's vital aquatic resources, and lower the use of toxic chemicals.

Activities and Milestones

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

Activity Budget: \$325,100

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 have to be well-controlled to capture images of sufficient clarity for weed classification tasks. Dr. Sattar and his team at the UofM 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 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 the different weed species of interest | September 30 2022 |
| High-resolution UAV based multispectral imagery and imagery annotation | February 28 2023 |
| Develop and deploy machine vision algorithms to enhance and super-resolve high-resolution imagery | July 31 2023 |
| Creation of automated machine vision algorithms to distinguish herbicide-resistant weeds | February 28 2024 |
| Conduct field tests in selected fields to validate systems, collect data, and refine methods. | May 31 2025 |

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

Activity Budget: \$490,900

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 | March 31 2023 |

| | |
|--|----------------|
| Prototyping of AUVs in controlled environments and design refinement | May 31 2023 |
| Water quality sensor systems interfacing with AUV, design validation | June 30 2023 |
| Pilot field deployment of AUV in selected runoff zones for time-limited assessment. | August 31 2024 |
| Long-term deployment of AUV and sensors in selected runoff zones for extended water quality assessment | April 30 2025 |

Project Partners and Collaborators

| Name | Organization | Role | Receiving Funds |
|------------------|-------------------------------------|--|-----------------|
| 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 |
| 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 |
| 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 |

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 project findings will provide a quantitative measure of water quality in runoff areas after herbicide and cover crop 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 increased 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. He 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 as 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 | | \$57,188 |
| Collaborator: David Mulla | | Soil and water science specialist, particularly in measuring water quality benefits of variable rate herbicide management. | | | 36.5% | 12.51 | | \$34,779 |
| 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 | | \$19,975 |
| 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 | | \$147,035 |
| 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 | | \$147,035 |
| Field Scientist | | Field selection and preparation for AUV and UAV tests, weed location scouting | | | 31.8% | 50.01 | | \$56,798 |
| CSE Undergrad | | Computer Science and Engineering Undergrad summer support for AUV design, fabrication, testing | | | 0% | 4.5 | | \$7,920 |
| ROC Undergrad | | Undergrad student assitant for field selection for data collection tasks (Waseca), weed species identification, provide AUV field trial assistance. | | | 0% | 4.5 | | \$6,600 |
| | | | | | | | Sub Total | \$477,330 |
| 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 assesement in headwater ditches and other runoff zones. | | | | | \$40,564 |
| | 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 | \$60,627 |
| 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 | \$816,000 |

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: [628477af-772.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. It also shows th...

Optional Attachments

Support Letter or Other

| Title | File |
|--|----------------------------------|
| University of Minnesota Support Letter | dcdad62e-2da.pdf |
| Sentera Support Letter | 17818f51-cbc.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?

Yes, Sponsored Projects Administration



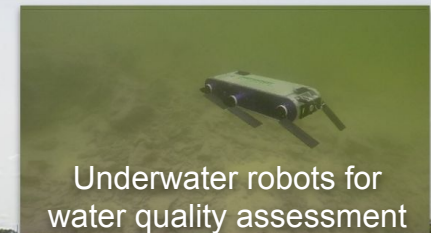
Automated weed management for herbicide water runoff reduction



Aerial drones for weed detection



Variable rate herbicide application



Underwater robots for water quality assessment

Herbicide runoff



Cover Crop

VS

Corn/Soy

