Environment and Natural Resources Trust Fund
2018 Request for Proposals (RFP)

Project Title: **ENRTF ID: 157-E**

Agricultural Weed Control Using Robots

Category: E. Air Quality, Climate Change, and Renewable Energy

Total Project Budget: $ 600,000

Proposed Project Time Period for the Funding Requested: 3 years, July 2018 to June 2021

Summary:

A robot, powered by solar energy, will be developed to control weeds on agricultural lands. We envision significant reductions in fossil-fuel and herbicide use while increasing local energy production.

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Sponsoring Organization: U of MN - Morris

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Morris MN 56267

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Visual shows the conventional method of weed control compared to proposed use of robots powered by solar energy.

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%

PROJECT TITLE: "Agricultural Weed Control Using Robots"

I. PROJECT STATEMENT

Minnesota farmers and land managers are engaged in an annual battle to control weeds. Each year, significant amounts of herbicide, diesel fuel, labor, and money are expended in an effort to stay ahead of weed infestations. Control of weeds is critical in the production of food. Current methods of weed control using herbicides have been very effective, but may have unintentional and harmful consequences to our air, land, water, and wildlife resources. We propose to develop improved methods using robots to control weeds on agricultural lands. Solar energy will be used to power the robots. In this first phase, weed control robots will be tested within pastures. In a future phase, testing will include weeding robots within row crops such as corn and soybeans. In accomplishing these goals, we aspire to:

- Significantly reduce the use of herbicides on agricultural and natural lands across the State of Minnesota,
- Replace fossil fuel and resulting air emissions with clean energy produced locally,
- Protect water resources by preventing surface and ground water contamination with herbicides,
- Reduce the impact of herbicide on wildlife, desired native plant species, and the evolution of herbicide tolerant 'super' weeds,
- Develop new time-saving tools for farmers as well as natural lands managers to control weeds,
- Advance the rapidly growing field of robotics within the State,
- Partner with MN companies to development and manufacture cutting-edge robotic technologies.

The project team will develop and test a robotic mowing system to control weeds and improve forage quality in a dairy pasture. The robot will be electric powered fueled by a portable solar PV charging station that will be installed on a cargo trailer. The robotic pasture mower will be developed in partnership with a Minnesota manufacturing company, The Toro Company, and researchers at U of MN. Safety protocols will be developed and tested. The mowing robot will then be field tested in pastures at the U of MN West Central Research and Outreach Center (WCROC). Finally, the robot will be demonstrated to farmers and land managers at workshops, field days, and events such as Farmfest. Additional funding will be sought in a future second phase and will include field robots for weed control in corn and soybean fields. The second phase inter-row and intra-row weed hunter robots will be more technically advanced requiring additional engineering, navigation and visual identification hardware and software development, and testing.

II. PROJECT ACTIVITIES AND OUTCOMES

ACTIVITY 1: **Budget: $491,591**

Description: Design, Integrate, and Field Test a Robotic Pasture Mower

A robotic mower capable of operating in harsh pasture terrains will be jointly developed by the U of MN and a Minnesota turf equipment manufacturer, The Toro Company (Toro). The mower will designed to incorporate affordable consumer class sensors and control systems which will allow for autonomous operation. Once developed, the system will be field tested under various operating conditions and scenarios in pastures, fields, grounds, and roadway ditches at the WCROC.

Activity 1: Outcome	Completion Date
1. Convert Toro Groundsmaster 3280D Mower from diesel to electric power	*5/1/2019*
2. Develop navigation / logic systems to allow for autonomous operation	*7/2/2019*
3. Develop and test safety and fail-safe logic and protocols	*10/1/2019*
4. Integrate and commission mower with navigation systems and conduct HazOP	*4/1/2020*
5. Field test robot within pastures at the WCROC	*6/1/2021*
6. Display / demonstrate the mowing robot at state-wide events	*6/30/2021*

ACTIVITY 2: **Budget: $108,409**

Description: Design, Develop, and Field Test a Portable Solar-Powered Charging Station

The team will design, assemble, and test a charging station that can be trailered to the field location and allow proof-of-concept for robots to re-charge. The system will be tested within pastures at the WCROC and demonstrated at a state-wide event.

Activity 2: Outcome	Completion Date
1. Design a portable hybrid solar PV and electric storage system for charging	*2/1/2019*
2. Integrate solar PV, electric storage, and a charging station on a trailer	*6/1/2019*
3. Field test the portable solar PV charging station and on-board solar at the WCROC	*6/1/2021*
4. Demonstrate the portable solar PV charging station at state-wide events	*6/30/2021*

III. PROJECT STRATEGY

A. Project Team/Partners: Michael Reese (WCROC Renewable Energy Director) will serve as the project manager and will be responsible for all deliverables. Eric Buchanan (Renewable Energy Scientist) will assist as project coordinator focusing on development of the portable solar smart charging station, implements for the early weeding row crop robot, pasture and field testing, and demonstrations. Volkan Isler (Associate Professor - U of MN Computer Science and Engineering) will focus efforts on solar aware navigation, vision processing for crop / row detection, cover planning, and will provide expertise on autonomous navigation and localization. Jonathan Chaplin (Professor - U of MN Bioproducts and Biosystems Engineering) will liaise with manufacturer(s) on design, focus on robot safety protocols including wildlife avoidance, and complete an economic evaluation of robotic weed control. Dana Lonn (retired) and Edric Funk (current), Managing Director of Research and Jack Gust, Senior Research Engineer, The Toro Company, will receive a subcontract for $104,000 ($37,000 labor and $67,000 components and supplies) to: 1) convert a Toro diesel mower to electric power including adding an electric motor and battery storage, 2) aquire and integrate a flail mower, and 3) assist in integrating controls for autonmous operation and in commissioning and testing of the mower system.

B. Project Impact and Long-term Strategy

Successful development of economic solar-powered robotic systems for weed control in pastures and fields will have significant positive impacts to Minnesota's air, land, water, and wildlife resources. The long term strategy is to develop marketable robotic weed control systems that can be manufactured by Minnesota companies and utilized by Minnesota farmers and land managers; and expand the utilization of solar PV within the State. A Minnesota original equipment manufacturer (OEM) is participating on the project team and will provide invaluable experience in developing products for the commercial market. The project team anticipates submitting a future funding request for a second phase of this project which will involve the use of robots to control weeds in row crops.

C. Timeline Requirements - The project is proposed for three full years beginning July 1, 2018 and ending June 30, 2021. Ideally, two years of field testing will be completed to account for seasonal and annual variation.

2018 Detailed Project Budget

Project Title: Agricultural Weed Control Using Robots

IV. TOTAL ENRTF REQUEST BUDGET *3* **years**

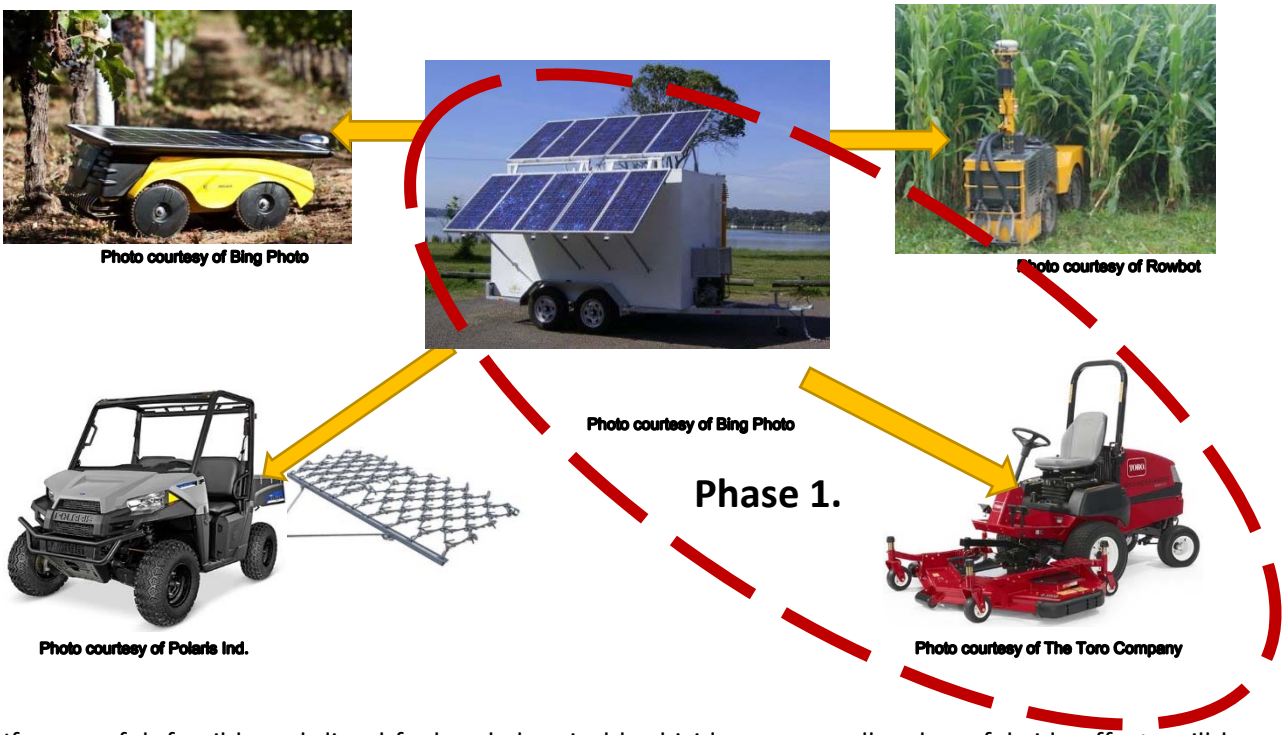
BUDGET ITEM	AMOUNT
Personnel:	
Project Coordinator - Eric Buchanan, $22,105 (FTEs =10% Year 1-3) 33.7 % fringe rate, 2.5% COLA -U of MN WCROC	$ 22,105
Researcher 3 - Technician to be hired for field testing, and data collection (100% FTE - 1 Yr) 27.4 % fringe rate, 2.5% COLA - U of MN WCROC	$ 71,782
Undergrad Student Interns- Evaluation of weed control robots in field studies (One summer intern, fourteen 40 hr weeks each @$12/h) 0% Fringe Rate -U of MN WCROC	$ 6,720
Post Doctorate Research Associate- (100 % FTE for 1 Yr) 22.4% Fringe Rate, 3% COLA - U of MN	$ 73,440
Key Personnel (9 mo appt) - Volkan Isler, PhD, $29,736 - Yr 1-3 -50% of one summer mo.(2 weeks) (33.7% fringe rate, 3% COLA) - U of MN Computer Science and Engineering	$ 29,736
Key Personnel (9 mo appt) - Stergios Roumeliotis- Yr 1-3 -25% of one summer mo.(1 week) (33.7% fringe rate, 3% COLA) U of MN Computer Science and Engineering	$ 16,947
Post Doctorate Research Associate- (42 % FTE-Yrs 1-3) 22.4% Fringe Rate, 3% COLA - U of MN CS&E	81,830
Graduate Student Research Assistant to train under Dr. Volkan Isler - Yrs 1-3 (9 mo. 50% FTE, hourly rate $23.83 plus tutition at $18.29 / AY hr, 17.6% fringe)	$ 115,629
Professional/Technical/Service Contracts:	
Subcontract with The Toro Company, Bloomington, MN for labor ($37,000), components, and supplies to convert a diesel powered mower to electric power and to assist and provide a location to integrate and commission the autonomous hardware and software being developed at the U of MN.	$ 104,000
Contract with an electrician TBD to complete wiring of the portable solar-powered charging station. University of Minnesota professional service policy will be followed in securing services of an electrician to perform this work.	$ 6,500
Equipment/Tools/Supplies: *In this column, list out general descriptions of item(s) or item type(s) and their purpose - one row per item/item type.*	
Lab supplies for Dr. Isler including a laptop computer with NVidia GPU, GPS systems, multiple cameras, component enclosures, and supplies for wiring, soldering, etc.	$ 5,000
Supplies for Reese including energy meters / sensors, and supplies for wiring and securing systems on the portable charging station.	$ 1,000
Cargo trailer for portable solar-powered charging station and robot transport	$ 6,397
Solar PV system including solar panels, bracketing, inverter(s), battery pack, balance-of-plant, & charging station	$ 20,400
Velodyne E-Puck LiDAR and components	$ 10,000
Travel: .	
Eight trips by CSE and BBE Faculty from Saint Paul to Morris, MN (330 miles @ $.56 / mi)	$ 1,478
Lodging and meals for CSE and BBE Faculty in Morris (3 people / 6 nights @ $80 / room and $40 ea for meals)	$ 5,760
WCROC Staff travel from Morris to Twin Cities (330 miles and 2 trips @ .56, 2 nights @ $120 / room and $40 ea for meals)	$ 1,379
Travel, lodging, and meals for one in-state outreach event FarmFest (2 people, 2 trips, 400 mi @$.56/mi, $110 / room, and $40 ea for meals)	$ 748
Additional Budget Items:	
Computer Services Fee - Standard fee charged by U of MN Department of Computer Science and Engineering for use of computers by staff for programming and analysis.	$ 16,749
Farmfest Exhibitor Fee, Tickets, Signage, and Display	$ 2,400
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	**$ 600,000**

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period:	$ -	*NA*
Other State $ To Be Applied To Project During Project Period:	$ -	*NA*
In-kind Services To Be Applied To Project During Project Period: *The University of Minnesota is forgoing its indirect cost recovery and use as in-kind match.*	$ -	*NA*
Funding History: The West Central Research and Outreach Center is participating in three current, three ENRTF projects with secured funding, and one pending proposal. However, this proposal is a unique and unrelated project.	$ -	NA
Remaining $ From Current ENRTF Appropriation: *See funding history- not applicable.*	$ -	*NA*

Conventional weed control processes typically use large, diesel-powered sprayers and chemical herbicides are broadcast across crop fields and pastures. Control of weeds is very effective, however, there are unintended and potentially harmful consequences.

Our concept is to evaluate the control of weeds in pastures and row crops using robots powered by the sun. Our project team will utilize off-the-shelf as well as pre-commercial technologies which will be modified to operate autonomously in the mowing of pastures and weeding of fields.



If successful, fossil-based diesel fuel and chemical herbicide use as well as harmful side-effects will be significantly reduced. Local production of clean energy will be increased. Farmers will have new time-saving tools for effective weed control and Minnesota companies will benefit by leading the manufacture of new solar-powered robotic technologies.

Environmental and Natural Resources Trust Fund
2018 Project Manager Qualifications and Organization Description
Project Title: Agricultural Weed Control Using Robots

Michael Reese, Principle Investigator / Project Manager
Since 2001, Mr. Reese has been the Renewable Energy Director at the University of Minnesota West Central Research and Outreach Center – Morris. He has overseen the development of the renewable energy program at Morris and has participated as Project Manager on over $15 million of research and demonstration projects including large and small-scale wind energy, biomass gasification, renewable hydrogen and ammonia, and solar electric and thermal energy systems. Specifically, Mr. Reese has overseen the development of the University's 1.65 MW utility scale wind turbine and is the Principle Investigator for the $3.75 million Wind to Hydrogen to Ammonia system. His biomass energy experience includes serving as WCROC Project Manager on a $1.89 million DOE – USDA biomass research and development project in which a Biomass Gasification Tool Box was developed for deployment of community scale biomass systems. Mr. Reese has also served as the Principle Investigator for solar thermal and solar PV research initiatives. He has been an invited speaker for numerous national and regional conferences on the topic of renewable energy. In addition to renewable energy, he continues to maintain a strong focus in agriculture and rural economic development. Mr. Reese serves / has served on several boards including the West Central Initiative Foundation (6 years – final year as Chairman) and the White Bear Lake Insurance Company (25 years – last 7 as President). In addition to Mr. Reese, the project team includes multidisciplinary faculty and industry researchers with significant experience in robotic automation and navigation, computer science, agricultural and mechanical engineering, renewable energy systems, and prototype development.

The primary organization is the University of Minnesota with researchers from the West Central Research and Outreach Center (WCROC), Department of Computer Science, and Department of Bioproducts and Bioengineering departments. The Toro Company, headquartered in Bloomington, MN will provide a critical role in integrating and prototype development of the robots. Technology development for the software logic, navigation systems, and safety protocol programing will largely be performed at the Minneapolis and Saint Paul campuses. The WCROC, located near Morris, will participate in the custom fabrication of weeding implements and will serve as the primary field testing location. The WCROC is a century-old 1,100-acre agricultural experiment station that focuses on applied research. The WCROC has several relevant program areas including renewable energy and conventional and organic crop production. The WCROC was selected as the 2011 Outstanding Conservationist for Stevens County by the Stevens Soil and Water Conservation District Board. The WCROC is ideally positioned to address critical agricultural issues. The staff have considerable experience in developing and effectively implementing applied research, outreach, and extension programs at the farm-level and within agricultural service professions. WCROC has nationally unique facilities and programs that compare conventional and organic / alternative crop and livestock production systems. The dairy program has the only side-by-side comparison of organic and conventional systems in the nation and the swine program is one of a handful to co-locate conventional and alternative production systems. In addition to agricultural production systems, the WCROC has a robust renewable energy program with community and farm-scale production systems. The renewable energy program features solar PV, solar thermal, biomass energy, geothermal, wind energy, and renewable hydrogen and ammonia production systems. These systems are commercially available but have yet to see wide-scale adoption on farms. A primary goal for the renewable energy program is to significantly decrease fossil-fuel consumption in the agriculture sector. Demonstration, outreach, and impact will be state-wide.