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

Project Title: **ENRTF ID: 091-B**

Better Fertilizer Management to Prevent Further Water Contamination

Category: A. Foundational Natural Resource Data and Information

Total Project Budget: $ 392,000

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

Summary:

To prevent more nitrate pollution from agricultural operations, we will develop an online fertilizing recommendation tool that integrates airborne remote sensing with advanced crop models.

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Sponsoring Organization: U of MN

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Images of previous years remote sensing trial and workflow for the proposed project are shown.

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

PROJECT TITLE: Integration of remote sensing with crop modeling for preventing further water contamination from agricultural pollution

I. PROJECT STATEMENT

Nitrate contamination in groundwater is now a public health concern that affects the entire communities in Minnesota. And we need to regulate the root - nonpoint source pollution from agriculture, especially from our corn fields. To reduce leaching of nitrate from the corn field to our environment, one strategy is to apply variable rate technology to meet the crop's N requirement after crop emergence. There have been efforts to address this problem using remote sensing, but producers are reluctant to implement this strategy because of the limited outcome. Another strategy to determine appropriate in-season N rates is to use a crop systems modeling approach. Models, however, are limited by periodic calibration based on observed measurements, which can be difficult to obtain. Recent research that has compared the effectiveness of remote sensing to that of model-based approaches in corn suggests that a combination of the two may allow producers to leverage the strengths of each to provide the strongest N recommendation.

Our overall goal is to utilize the advantages of both remote sensing and crop systems modeling to determine the optimum rate and timing of in-season N fertilizer in corn. The specific goals of my research are three folds:

(i) More accurate airborne remote sensing approaches to determine relative corn N stress;
(ii) Model simulation of soil and crop N dynamics throughout the course of the crop season;
(iii) Online map tool for variable rate N recommendation that benefits both the farmers and our environment.

To achieve the above-mentioned goals, (i) machine learning (i.e., classification of "big data") algorithms on multispectral and hyperspectral imagery will be used to investigate more accurate approaches to determine relative corn N stress. (ii) Environmental Policy Integrated Climate (EPIC) cropping system model will be used to simulate the corn life cycle. (iii) And we will develop and evaluate an online informatics system that determines the optimum rates and timing of in-season N fertilizer in corn. We expect that this online fertilizer-mapping tool will start to serve the public in the crop season of 2021. Multiple years' data will be used to build a reliable closed-loop of data collection, model correction and system adjustment.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Airborne image collection and analysis **Budget: $179,000**

An unmanned aerial vehicle (UAV) platform will be used to capture hyperspectral imagery and color images over corn N rate trials in Saint Paul, Waseca, Grand Rapids, Lamberton etc., at two early growth stages (V5 and V10). Machine learning algorithms will be applied to process the images. Treatment and ground truthing data will also be collected in the trips to validate the remote sensing data.

Outcome	Completion Date
1. Airborne hyperspectral images collected into the database	6/30/2021
2. Spectral band selection (to reduce equipment cost)	10/1/2019
3. Image processing using machine learning algorithms	12/31/2019

Activity 2: Crop system modeling using EPIC crop system modeling **Budget: $124,000**

It is necessary to repetitively test the crop system model. We use the EPIC model since it emphasizes water hydrology and environmental policy. Remote sensing results will be used as input parameters for the model. To calibrate the EPIC model, the following measurements will be collected as parameters as well: soil PH and organic matter, residual soil nitrate-N, in-season tissue samples for total N, end of season plant biomass and N uptake, and grain yield. Other spatial datasets such as soil electroconductivity measurements, LiDAR elevation data, soil survey data, and weather data will also be collected.

Outcome	Completion Date
1. Ground truthing data collected into the database	6/30/2021
2. Calibrated model based on ground truthing data	10/1/2019
3. Integration of remote sensing data into the EPIC model	4/1/2020

Activity 3: Online mapping tool for in-season N recommendation **Budget: $89,000**

An online mapping tool based on both airborne image input and the EPIC model will be developed for in-season N recommendation. Users will visit the webpage and upload their airborne images (color + infrared + multispectral bands) from corn field with GPS coordinates, and obtain the N recommendation maps.

Outcome	Completion Date
1. Setup EPIC bunch runs for high resolution maps	12/30/2018
2. Online tool for in-season N recommendation	3/30/2021
3. Open to users for crop season 2021	9/30/2021

III. PROJECT STRATEGY

A. Project Team/Partners

PI Ce Yang's AgRobot team will be carrying out the proposed activities. Currently, one postdoctoral research fellow, two Ph.D. students, and one visiting scholar are in this group. Both Ph.D. students have drone operation experiences. My second year Ph.D. student Tyler Nigon will work on the airborne image collection and analysis across the three crop seasons. My postdoc Dr. Chuanqi Xie will work on the modeling and online recommendation tool. My time will be evenly distributed to the advising of the graduate student and the postdoc researcher.

B. Project Impact and Long-Term Strategy

The project is expected to impact Minnesota corn growers to avoid excessive fertilizer application, which will cause more environmental problems and tighter government rules in the future. By the end of this project, we want the growers to be aware of this tool to achieve the same or higher yield with less fertilizer use. We will advocate our online recommendation tool in multiple regional meetings.

In the long run, we can hold workshops to educate more growers in drone operation, image collection and the use of our online tool. The government's efforts in preventing water pollution and regulating fertilizer application will also be heard by the MN growers.

C. Timeline Requirements

Since this project is very much depended on crop seasons, and we need multiple years' data to calibrate our model, we will collect the images and data in every crop season. The online tool is expected to open to users in the spring of the third year (2021), however it is possible to be open to the growers willing to test our recommendation system offline in the 2020 crop season.

2018 Detailed Project Budget

Project Title: Saving Out Misquito-Eaters: Management of White-nose Syndrome in Minnesota Bats

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

BUDGET ITEM	AMOUNT
Personnel:	
Ce Yang, Assistant Professor, 3 months summer salary, PI, 75% salary/25% fringe benefits	$ 28,000
Postdoctoral Researcher, 36 months @ 100%, 82% salary/18% fringe	$ 190,000
One graduate student, fieldwork , design work, and analysis, 3 years @50%; 60% salary/40% fringe	$ 144,000
Professional/Technical/Service Contracts:	$ -
Equipment/Tools/Supplies:	$ -
Field equipment unmanned aerial vehicle with imager	$ 5,000
Analysis computers, storage hardware, and ancillary equipment	$ 5,000
Repair and maintenance for recorders and field equipment	$ 2,000
Acquisition (Fee Title or Permanent Easements):	$ -
Travel:	$ -
Multiple field trips to experimental sites and farms in Waseca, Rochester, Becker and Blain for three years	$ 18,000
Additional Budget Items:	$ -
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 392,000

V. OTHER FUNDS *(This entire section must be filled out. Do not delete rows. Indicate "N/A" if row is not applicable.)*

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period:	N/A	*Indicate: Secured or Pending*
Other State $ To Be Applied To Project During Project Period:	N/A	*Indicate: Secured or Pending*
In-kind Services To Be Applied To Project During Project Period: Unrecovered Indirect Costs	$ 202,000	*Secured*
Past and Current ENRTF Appropriation:	N/A	Indicate: Unspent? Legally Obligated?
Other Funding History:	N/A	

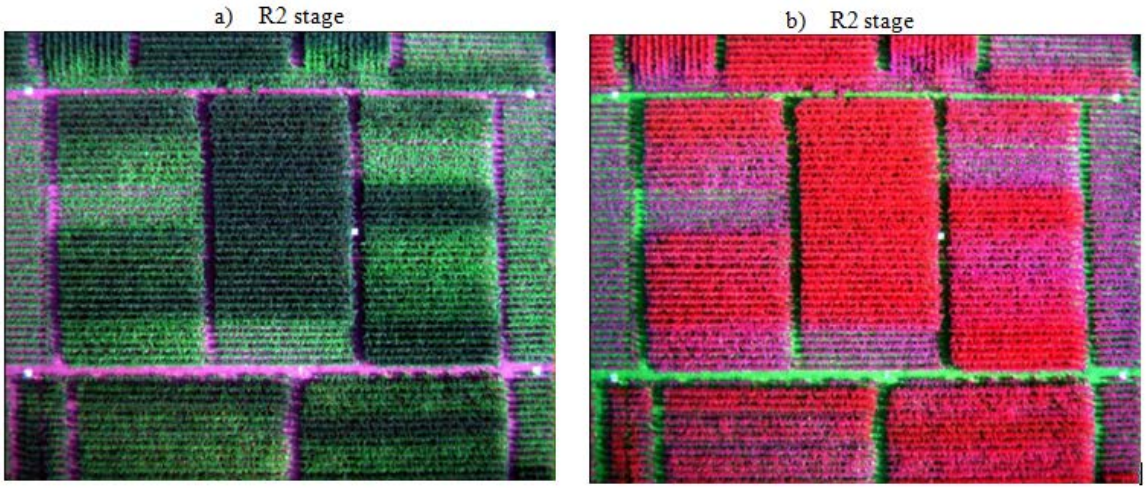

Fig. 1 Color image (a) and infrared image (b) over the same corn field in 2015

Fig. 2 Drone system flied over a corn field in early crop season in 2016

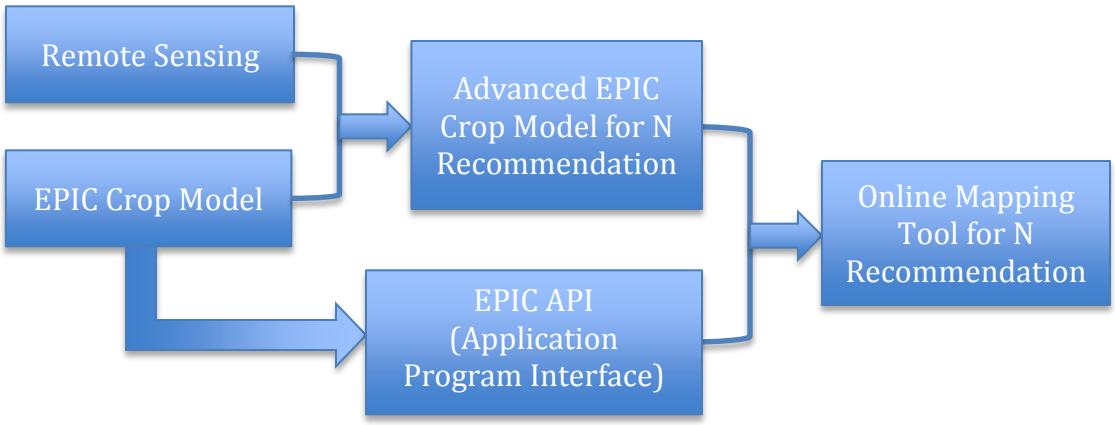

Fig. 3 Work flow of the proposed project

Project Manager Qualifications & Organization Description

The proposed project will be managed by Dr. Ce Yang. Ce Yang is an assistant professor in the Department of Bioproducts and Biosystems Engineering at University of Minnesota. Her background in agricultural engineering and computer science enables her a complete management of the project. She is able to advise her postdoc and graduate students who will work on this project because of her rich experiences using unmanned aerial vehicles, color, multispectral/hyperspectral cameras, ground robots, image analysis software such as Matlab and ENVI, machine learning algorithms for processing hyperspectral images.

University of Minnesota is a well-known land-grant university that offers great opportunities and fosters the future researchers and leaders in many areas. The university's missions are threefold:

- **Research and Discovery** - To generate and preserve knowledge, understanding, and creativity by conducting high-quality research, scholarship, and artistic activity that benefit students, scholars, and communities across the state, the nation, and the world.
- **Teaching and Learning** - To share that knowledge, understanding, and creativity by providing a broad range of educational programs in a strong and diverse community of learners and teachers, and prepare graduate, professional, and undergraduate students, as well as non- degree seeking students interested in continuing education and lifelong learning, for active roles in a multiracial and multicultural world.
- **Outreach and Public Service** - To extend, apply, and exchange knowledge between the University and society by applying scholarly expertise to community problems, by helping organizations and individuals respond to their changing environments, and by making the knowledge and resources created and preserved at the University accessible to the citizens of the state, the nation, and the world.