Environment and Natural Resources Trust Fund
2019 Request for Proposals (RFP)

Project Title: **ENRTF ID: 087-B**

Sustaining Fresh Water Resources while Producing Healthy Crops

Category: B. Water Resources

Sub-Category:

Total Project Budget: $ 496,988

Proposed Project Time Period for the Funding Requested: June 30, 2022 (3 yrs)

Summary:

Minnesota leads production of sweet corn, peas, and potatoes, which are increasingly groundwater-irrigated. This project identifies hydrologic, agronomic, and economic tradeoffs to inform water management and policy during future droughts.

Name: Tracy Twine

Sponsoring Organization: U of MN

Title: Associate Professor

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St. Paul MN 55108

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Minnesota has 7,177 agricultural wells and this number increases each year. How can we balance sustainable production of sweet corn, peas, and potatoes with fresh water quantity and quality outcomes?

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%
____ If under $200,000, waive presentation?			

PROJECT TITLE: Sustaining fresh water resources while producing healthy crops

I. PROJECT STATEMENT

Minnesota is a top producer of sweet corn, peas, and potatoes—which are all increasingly irrigated with groundwater. High-capacity irrigation wells have doubled since the 2012 drought, mainly in the Central Groundwater Province where jack pine, oak, and aspen forests are being rapidly converted to irrigated cropland. Irrigation removes drought risk but will deplete coldwater trout streams (e.g. the Straight River), lakes, and wetlands and increase groundwater nitrates without adaptive management. **We propose to perform strategic crop experiments, develop state-of-the-art modeling tools, and produce three key products for stakeholders:**

1. New water and nitrogen management benchmarks for sweet corn, pea, and potato crops integrated into extension recommendations and popular irrigation scheduling programs like Wisdom 2.0.

2. Groundwater recharge, yield response, and nitrate leaching maps under different irrigation development scenarios housed online with drop-down menus of simulations (irrigated vs. rainfed, agriculture vs. forest land use, historical/future time periods) for statewide stakeholders to understand how different choices can impact water resources across Minnesota.

3. Economic and environmental tradeoffs between irrigation-induced groundwater export/import, crop losses resulting from drought, groundwater depletion resulting from irrigation, and nitrate leaching.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Water and nitrogen benchmarks for sweet corn, pea, and potato crops BUDGET: $270,660

We currently lack information about how sweet corn, pea, and potato crops manage water, nitrogen, and carbon under stress, which poses roadblocks to understanding their hydrological impacts and tradeoffs. We will conduct greenhouse experiments to measure soil moisture, photosynthesis, evapotranspiration, and chlorophyll content under a variety of irrigation and fertilizer regimes. We will use greenhouse data to build water, nitrogen, and carbon stress functions. To validate stress functions, we will partner with three commercia producers to take similar measurements from the Pineland Sands, Red River Valley, and Minnesota River Valley regions during 2020 and 2021. **We will use the validated crop stress functions to develop meaningful irrigatior and fertilizer benchmarks. These benchmarks will be incorporated into extension recommendations, shared with state trade associations, and embedded in irrigation scheduling programs like Wisdom 2.0.**

Outcome	Completion Date
1. Develop water, nitrogen, and carbon stress functions for sweet corn, pea, and potato	*May 2021*
2. Translate validated stress responses into benchmarks for agricultural producers	*December 2021*

Activity 2: Fresh water and crop yield impacts from irrigation development BUDGET: $105,650

We do not understand the long-term impacts of sweet corn, pea, and potato production on groundwater recharge, nitrate leaching, and evapotranspiration at the state scale. We will use a state-of-the-art plant-soil-atmosphere model, Agro-IBIS, to predict irrigated and rainfed crop yields, groundwater recharge, nitrate leaching, and other hydrological outcomes. The model accounts for fertilization and irrigation; however, currently sweet corn, peas, and potato are being built with data from healthy, unstressed crops. The stress functions produced by **Activity 1** will be incorporated into Agro-IBIS, and with this new stress capability, we will produce estimates of crop yields, groundwater recharge, and nitrate leaching under different irrigation development scenarios. **Results will inform statewide and local water planning, irrigation development projects, drinking water assessments, and surface water managers using an online mapping platform.**

Outcome	Completion Date
1. Identify crop and water impacts under several different irrigation scenarios	*September 2021*
2. Create a website with drop-down menus of different simulations for stakeholders	*December 2021*

Activity 3: Groundwater export/import and economic impacts of irrigation **BUDGET: $120,678**

Though Minnesota records how much water we use for agricultural irrigation (~80-120 billion gallons per year), we do not know if these resources are remaining in place or being exported. Evapotranspiration transforms 90% of the water used by plants into atmospheric vapor that can either be exported downwind to another region or remain in place to form precipitation. We will use a regional weather model (WRF) that uses Agro-IBIS modules to quantify connections between groundwater and rainfall impacts. We will conduct rainfed and irrigated simulations over the Upper Midwest to understand how precipitation patterns change during dry, average, and wet years. Agro-IBIS keeps track of groundwater applied as irrigation, which we will use to estimate the quantity of groundwater imported or exported from Minnesota as precipitation. **We will use water estimates to build an economic framework to value groundwater in the context of irrigated agriculture and fresh water ecosystems. We will quantify the tradeoffs between crop losses resulting from drought, potential groundwater depletion resulting from irrigation, nitrate leaching, and groundwater exported/imported as precipitation.**

Outcome	Completion Date
1. Quantify groundwater import/export under different irrigation development scenarios	*February 2022*
2. Identify agricultural, hydrological, and economic benefits, risks, and tradeoffs	*June 2022*

III. PROJECT PARTNERS:

A. Partners receiving ENRTF funding

Name	Title	Affiliation	Role
Dr. Mallika Nocco	**David H. Smith Fellow**	**University of Minnesota**	**Co-PI**
Dr. Tracy Twine	**Associate Professor**	**University of Minnesota**	**PI**
Dr. Chris Kucharik	**Professor**	**University of Wisconsin**	**Co-PI**
Dr. Bonnie Keeler	**Prog. Dir. NatCap Project**	**University of Minnesota**	**Co-PI**
Dr. Kate Brauman	**Lead GWI, IonE**	**University of Minnesota**	**Co-PI**

B. Partners NOT receiving ENRTF funding: *N/A*

IV. LONG-TERM- IMPLEMENTATION AND FUNDING:

The proposed research leverages climate datasets and modeling outcomes from a previously funded LCCMR Project (FY2015 04a). Outcomes will be implemented into statewide water policy and outreach efforts including University of Minnesota Agricultural Extension publications and commonly used irrigation scheduling programs like Wisdom 2.0. We will also share crop stress benchmarks with regional trade associations for each crop (e.g. Area II Potato Growers Council). Mapped outcomes will be accessible on a web platform that will facilitate an understanding of different land use choices (irrigation, crop type) on environmental and economic flows of water, nitrogen, and carbon. This online resource will be publicized through social media and University conduits. We will interpret watershed-specific results and provide recommendations for individual watershed council groups. We will also share outcomes with the groundwater policy community as a whole by regularly attending Minnesota Groundwater Association Meetings.

V. TIME LINE REQUIREMENTS:

The combination of proposed experimental research and new computational modeling products requires a three-year timeline to accomplish our project goals. We will focus on greenhouse/field data collection and model programming and development through December 2020. Following the data collection phase, we will focus on modeling different meteorological scenarios, quantifying groundwater import/export, assessing tradeoffs, economic valuation, and stakeholder feedback through June 2022.

2019 Proposal Budget Spreadsheet

Project Title: Sustaining fresh water resources while producing healthy crops

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

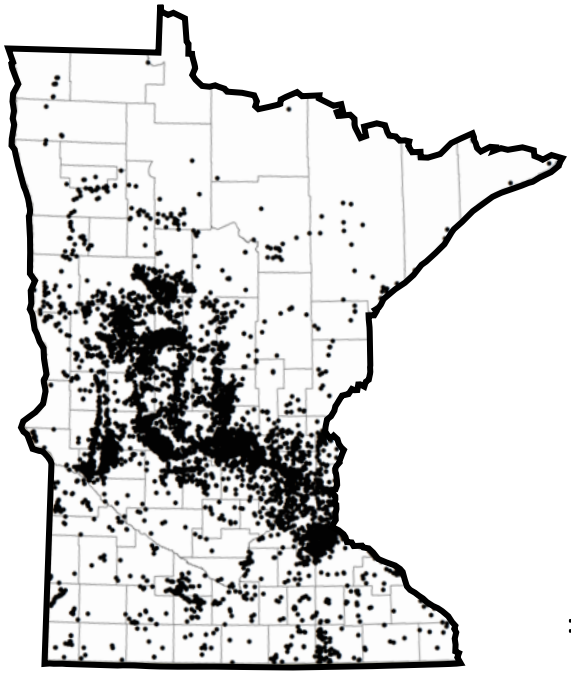
BUDGET ITEM (See "Guidance on Allowable Expenses")	**AMOUNT**
Personnel: *Research Associate (Postdoctoral)* , 1 person, 100% salary and benefits, 3-years. $217,263	
Personnel: *Research Assistant (Doctoral Student)* , 1 person, 100% salary, benefits, and tuition reimbursement, 3-years. $139,685	
Personnel: *Research Associate* , 1 person, 9% salary and benefits, 1-month, Year3**.** $17,984	
Personnel: *Research Associate* , 1 person, 9% salary and benefits, 1-month, Year2**.** $11,395	
Personnel: *Associate Professor* , 1 person, 9% salary and benefits, 1-month, 3-years**.** $45,278	
Total Personnel:	$431,605
Professional/Technical/Service Contracts: *Laboratory analyses* (service). Laboratory analyses of carbon and nitrogen content for leaves, stems, roots, and ears/tubers/peas	$ 3,000
Professional/Technical/Service Contracts: *Data storage* (service) for 10TB estimated storage at Minnesota Supercomputing Institute beyond 20TB provided.	$ 6,816
Equipment/Tools/Supplies: *Spectroradiometer* . Portable machine to estimate canopy cover and chlorophyl content using reflectance at a variety of wavelengths. Will be used in greenhouse and field experiments.	$ 12,000
Equipment/Tools/Supplies: *Greenhouse (rental).* Rental of experimental space in University of MN Greenhouse facility. Includes power, water, fertilizer, climate control, potting supplies, and space. Daily rental for 699 days.	$ 9,023
Equipment/Tools/Supplies: *Soil moisture sensors* . Sensors will be used in both greenhouse and field experiments to measure soil moisture status in stressed and control treatments.	$ 5,000
Acquisition (Fee Title or Permanent Easements):	$ -
Travel: *Field season travel to MN Farms.* In-state travel to three MN farms over the 2021 field season to perform crop stress function validation experiments.	$ 2,000
Additional Budget Items: *Publication costs* . Publication fees for anticipated peer-reviewed journal articles from this work ($8,000). Subaward to UW-Madison to Dr. Chris Kucharik to create required high-resolution model dataset, 1 person, 9% salary and benefits, 1-month, Year 1 ($19,544).	$ 27,544
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 496,988

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: Title: "Understanding and Building Capacity to Address Changing Water Availability in the Upper Corn Belt" (Proposal Number: 2016-10226, end date April 2020). Funder: USDA AFRI. PI: Mae Davenport, Co-PI Bonnie Keeler, Kate Brauman, Ray Arritt (Iowa State), and J Arbuckle (Iowa State).	$ 494,707	*secured*
Other Non-State $ To Be Applied To Project During Project Period: The Minnesota Supercomputing Facility provides high speed computing and data storage to funded projects. Estimated 1 million units (total project) required at $0.05/unit (=$500,000) plus 20TB storage/year at $700/TB/yr (=$42,000)	$ 542,000	*committed pending funding*
Other State $ To Be Applied to Project During Project Period:	N/A	
In-kind Services To Be Applied To Project During Project Period:	N/A	
Past and Current ENRTF Appropriation: Title: Water sustainability in Minnesota: "Current trends, future threats, and the value of clean water" PI: Bonnie Keeler, Co-PIs Kate Brauman, Tracy Twine	$ 234,000	*Legally Obligated (end June 2019)*
Other Funding History: David H. Smith Conservation Research Fellowship (Cedar Tree Foundation) to Dr. Nocco. Currently funding (end June 2019) development of healthy (unstressed) Agro-IBIS crop models for sweet corn, peas, and potatoes.	$ 150,000	*Secured*

How much groundwater are we exporting/importing and what is its economic value?

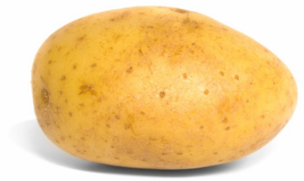
↓Forest + ↑Cropland
=↓Groundwater Quality?



- 7,177 Agricultural Wells in MN

↑Irrigated Cropland
=↓Streams, Lakes, Wetlands?

How can we sustain crop productivity during droughts while maintaining healthy fresh waters?



Sustaining fresh water resources while producing healthy crops
Project Manager Qualifications and Organization Description

Project Manager: Dr. Tracy Twine is an Associate Professor in the Department of Soil, Water, and Climate at the University of Minnesota. She studies how human land use and climate change affect the structure and functioning of natural and managed ecosystems. She uses numerical models to examine how climate variability affects yield and water use of soybean and corn across the US Midwest. She has also been evaluating different scenarios of planting crops and grasses for bioenergy and their effects on energy, water, and carbon budgets. She also examines how urban areas affect their surroundings and just led study to measure the Twin Cities urban heat island through use of a dense network of temperature sensors. For the proposed project, Dr. Twine will use her 20 years of experience developing the Agro-IBIS model, and her knowledge of soil-plant-atmosphere interactions to lead a campaign of measurements and modeling to better understand and prepare for how major MN crops of sandy soils can best manage drought stress.

Resources (Twine Lab and Department): The Twine lab is located on the Saint Paul campus of the University of Minnesota within the College of Food, Agricultural, and Natural Resource Sciences. The Department of Soil, Water and Climate offers substantial administrative, secretarial, computer, and building and equipment maintenance support. Administrative staff assist with recruitment of research staff, graduate students, and postdoctoral scientists, provide personnel support, maintain and administer accounting records for all operational and grant funds including purchasing, travel arrangements and reimbursement, and compliance with University and federal requirements. Administrative, secretarial, and receptionist services and general computer hardware and software support is provided to all faculty and staff.

Resources (Computing): The research project will also make use of the Minnesota Supercomputing Institute (http://www.msi.umn.edu) for numerical modeling and other advanced computational work. Established in 1983, the Minnesota Supercomputing Institute (MSI) is the University of Minnesota's principle center for computational research. MSI provides services to over 560 active groups that sponsor more than 3,300 unique users from 19 different university colleges, maintaining an array of systems dedicated to the computational needs of investigators in the state of Minnesota's higher education institutions and their collaborators.

Organization: The University of Minnesota, founded in the belief that all people are enriched by understanding, is dedicated to the advancement of learning and the search for truth; to the sharing of this knowledge through education for a diverse community; and to the application of this knowledge to benefit the people of the state, the nation, and the world. The University's mission encompasses research and discovery, teaching and learning, and outreach and public service. For more details, please see
http://regents.umn.edu/sites/regents.umn.edu/files/policies/Mission_Statement.pdf