Environment and Natural Resources Trust Fund
2020 Request for Proposals (RFP)

Project Title: **ENRTF ID: 020-A**

Adjusting Crop Water Demand to Protect Minnesota Groundwater

Category: A. Foundational Natural Resource Data and Information

Sub-Category:

Total Project Budget: $ 239,211

Proposed Project Time Period for the Funding Requested: June 30, 2023 (3 yrs)

Summary:

Irrigation increases crop yield but depletes groundwater. We will make computer-generated maps to find places where farmers can use less 'thirsty' crop varieties to save water without sacrificing crop yield.

Name: Xue Feng

Sponsoring Organization: U of MN

Job Title: Dr.

Department: Civil, Environmental, Geo-Engineering

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Web Address:

Location:

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Irrigation increases crop yield but depletes groundwater. We will make computer-generated maps to find places where farmers can use less 'thirsty' crop varieties to save water without sacrificing crop yield.

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

PROJECT TITLE: Adjusting Crop Water Demand to Protect Minnesota Groundwater

I. PROJECT STATEMENT

Agriculture is the most important export industry in Minnesota: half of the state's land area is used for farming, and crop exports total $9.7 billion per year. But these crops need a lot of water. The state does not directly measure agricultural water usage, but we do know that ~1,200 new crop irrigation wells were installed in Minnesota from 2008–2012. Farmers pump more water out of these wells in dry years than in normal years. For example, in a dry year like 2013, more than twice as many farmers applied to pump >10,000 gal. of water per day. Irrigation volumes are especially high in central Minnesota because of its sandy, well-drained soils.

In many places, farmers could use less water while maintaining crop yield—this would conserve groundwater. Many farmers are already taking steps to increase irrigation efficiency (e.g., planting cover crops and using smart irrigation technologies). However, they often have to rely on incomplete market knowledge and trial and error to make one very important decision—which cultivar to plant in the coming year. Each year, there are dozens of cultivars available for a given crop, and some need much more water than others. For example, some corn cultivars require 40% more water to produce the same yield under the same environment.

We will make computer-generated maps to find places where farmers can save water without sacrificing crop yield. To do so, we will estimate the yield and water usage of 5 cultivars for each of 3 widely planted Minnesota crops (corn, soybeans, and wheat), taking into account different climate and soil conditions. Then, we will make maps to identify the most water-efficient cultivar in each area of the state. These maps will help farmers choose the best cultivar for their area, and will help water resource managers incentivize farmers to use these cultivars to reduce groundwater demand from irrigation.

How are we going to do this? Crop water usage and yield depend on four factors: the physiology of the cultivars themselves, soil water supply, climate, and irrigation strategy. We will integrate these factors using:

(1) **New knowledge about how each cultivar will respond** to different climate and soil conditions
(2) **A cutting-edge crop and hydrological model combined with state-wide datasets** to determine cultivar-specific water usage and yield

Our results will be communicated to stakeholders—including commodity groups, extension agents, and DNR and MDA personnel—through online platforms, meetings, extension bulletins on relevant portals, and other means.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: ***Assemble datasets on soils, crops, irrigation volumes, and climates*** **Budget: $ 75,386**

We will compile extensive datasets on soils, weather, crop yield, and irrigation volumes (from flood, sprinkler, and micro-irrigation) from the USDA, DNR, MDA, and statewide weather station networks. We will also compile—from existing literature and our own recent work—physiological data on Minnesota-adapted crop cultivars (corn, soybeans, and wheat). This information will be critical to the modeling efforts (Activity 2 and 3), by providing (i) a baseline for testing the ability of the model to reproduce observed crop yields, and (ii) input parameters for describing cultivar type-specific water use patterns under a wide range of environments.

Outcomes	Completion Date
1. Assemble and process multiple datasets on soil, climate, irrigation by county, and crop physiology (for corn, soybean, and wheat).	05/2021

Activity 2: ***Develop models to predict cultivar water needs and potential yield*** **Budget: $ 81,248**

We will first develop crop water use models capturing the diversity of Minnesota-adapted crop cultivars. These models will integrate water use patterns for these cultivars, and how they will respond to a wide range of climates, soils, and irrigation practices. Importantly, these models will be developed specifically for each cultivar type, using a physiological typology that we have already developed. For example, we know that crop water use increases with atmospheric demand (e.g., when it's hot and dry), soil water supply (from rainfall), and irrigation, but how much it increases will depend strongly on the traits particular to each cultivar, which can be used to define a spectrum of water use "types" (for example, from water-conserving to water-greedy). We will test the model results against actual crop yield data (from Activity 1) and refine the models' abilities to accurately predict crop outcomes under a wide range of climate and irrigation scenarios.

Outcomes	Completion Date
1. Develop and validate models for predicting crop water use and yield	12/2022

Activity 3: ***Use the models to make actionable maps of the most water-efficient cultivars*** **Budget: $ 82,577**

We will produce state-wide maps of crop water use and yield using the verified model from Activity 2, based on existing cultivar types, soils, and irrigation practices within each county (using data from Activity 1). Then, we will produce an additional set of maps that explore "what-if" scenarios in which crop water requirements and yield will be changed according to the deployment of different cultivar types and the application of different irrigation volumes, all under long-term projections of weather patterns across Minnesota. By comparing these two sets of maps, we will be able to analyze the tradeoffs between short-term yield gains and long-term environmental impact, and identify two features of interest: (i) the "optimal" cultivar type for each county that will result in the maximum yield with a given amount of irrigation water, and (ii) locations where there are large, unfulfilled potentials to reduce irrigation demand by deploying less water-intensive cultivars.

Outcomes	Completion Date
1. Produce crop water usage and yield maps based on current and alternate scenarios	04/2023
2. Identify ideal locations for irrigation reduction and optimal cultivars for each county	06/2023

III. PROJECT PARTNERS (receiving ENRTF funding unless otherwise noted)

- Dr. Xue Feng, Assistant Professor, UMN Dept. of Civil, Environmental, and Geo-Engineering
- Dr. Walid Sadok, Assistant Professor, UMN Dept. of Agronomy and Plant Genetics
- We will collaborate with USDA, DNR, and MDA (**not receiving ENRTF funds**) to acquire and interpret data

IV. LONG-TERM- IMPLEMENTATION AND FUNDING

This is a new project that will provide foundational information for evaluating long-term crop water use across the state. Our maps will enable water resource managers to **(1) anticipate demands on groundwater aquifers from crop irrigation** (and appropriate permits accordingly), and **(2) better target water conservation efforts by identifying areas with large, unfulfilled potential for irrigation reduction**. Farmers can use the maps to choose the most water-conserving cultivar to maximize the profitability of their farms *and* the long-term sustainability of groundwater in their region. The maps will be shared publicly online and through meetings and presentations.

V. TIME LINE REQUIREMENTS

Three years of support (July 2020 – June 2023) are requested to collect, process, and analyze data (Activity 1), to construct computer models (Activity 2), to produce crop water use and yield maps based on current and alternate scenarios (Activity 3), and to ensure proper documentation and communication of results (Activity 3).

Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet
Legal Citation:
Project Manager: Xue Feng
Project Title: Adjusting Crop Water Demand to Protect Minnesota Groundwater
Organization: Regents of the University of Minnesota
Project Budget: $239,211
Project Length and Completion Date: 3 years (July 2020 -- June 2023)
Today's Date: 4/15/2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 233,011	$ -	$ 233,011
Dr. Xue Feng, PI, 1.0 month summer salary (11% FTE), 74% salary, 26% benefits. $43,328			
Dr. Walid Sadok, co-PI, 1.0 month summer salary (11% FTE), 74% salary, 26% benefits, $40,315			
Graduate research assistant (Activity 1,2,3), Department of Civil, Environmental, and Geo-Engineering, co-advised by both PIs. (50% FTE), 58% salary, 42% benefits, $149,368			
Professional/Technical/Service Contracts			
	$ -	$ -	$ -
Equipment/Tools/Supplies			
Requesting permission to for dedicated workstation to simulate future weather patterns and crop responses. This station will interface with UMN Supercomputing Institute machines (latter use: no charge).	$ 3,000	$ -	$ 3,000
Capital Expenditures Over $5,000			
	$ -	$ -	$ -
Fee Title Acquisition			
	$ -	$ -	$ -
Easement Acquisition			
	$ -	$ -	$ -
Professional Services for Acquisition			
	$ -	$ -	$ -
Printing			
Publication fees to disseminate project results.	$ 2,000	$ -	$ 2,000
Travel expenses in Minnesota			
Three trips allocated for a PI and a graduate research assistant to travel within Minnesota to meet with DNR staff and stakeholders to disseminate project results. Based on university compensation policy, we estimate mileage ($0.58/mile), lodging ($40/night/person), and meals ($40/day/person) will come out to $300/person/trip, with a total of $1,200.	$ 1,200	$ -	$ 1,200
Other			
	$ -	$ -	$ -
COLUMN TOTAL	$ 239,211	$ -	$ 239,211

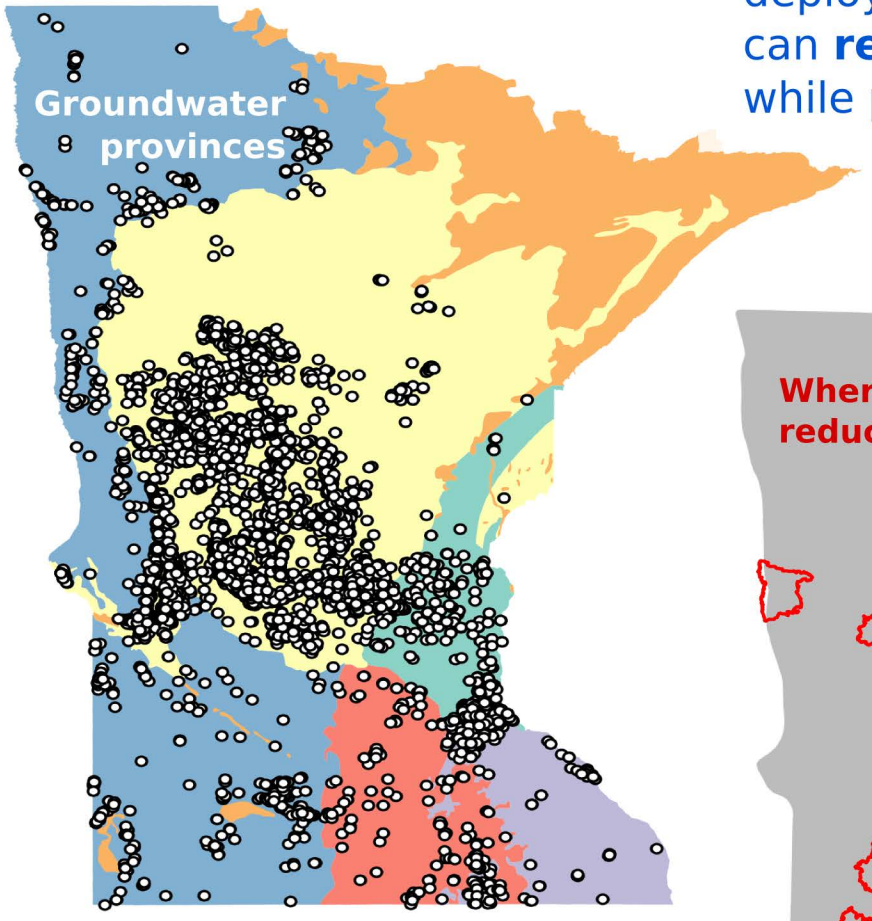
SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State:		$ -	$ -	$ -
State:		$ -	$ -	$ -
In kind: Unrecovered overhead at 54% MTDC		$ 102,485	$ -	$ 102,485

Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS	Amount legally obligated but not yet spent	Budget	Spent	Balance
		$ -	$ -	$ -

Adjusting Crop Water Demand to Protect Minnesota Groundwater

Irrigation increases crop yield but depletes groundwater.

We want to identify areas where deploying less 'thirsty' crop varieties can **reduce irrigation demand** while **producing the same yield**.



Active irrigation wells (>10,000 gal. per day)

Groundwater levels have decreased in parts of the Central, Western, and Metro groundwater provinces.

(Data from DNR)

This information could be especially useful in **Groundwater Areas of Concern.**
(Freshwater Society special report, April 2013)

Farmers can choose from many crop varieties.

Some crop varieties use less water to produce the same yield.

QUALIFICATIONS OF PROJECT MANAGER, DR. XUE FENG

Appointments

2017 – present Assistant Professor, University of Minnesota, Twin Cities
Department of Civil, Environmental, and Geo-Engineering
Faculty at Saint Anthony Falls Laboratory
Graduate faculty in Water Resources Sciences program

Education and Professional Preparation

University of California, Berkeley	Postdoc	Ecohydrology	2015 – 2017
Duke University	Ph.D.	Civil & Environmental Engineering	2015
Stanford University	B.S. / Minor	Mechanical Engineering / Biology	2010

Prior Related Experiences

Feng joined the faculty of Civil, Environmental, and Geo-Engineering at the University of Minnesota in 2017. Her research focuses on the hydrological feedback between soils, plants, and the atmosphere through a mix of field-based and computational methods. She past work with NOAA has investigated the climatic, soil-related, and physiological drivers of plant water stress and mortality during the historic California drought of 2012–2015. She currently studies the role of water table variations on plant carbon uptake and soil carbon emissions from peatland ecosystems near Grand Rapids, MN, in collaboration with the DOE and USDA Forest Service.

PROJECT PARTNER

Dr. Walid Sadok is an assistant professor and plant eco-physiologist in the Department of Agronomy and Plant Genetics at the University of Minnesota. He has expertise in plant water relations, crop productivity and sustainability with a research approach combining empirical methods and modeling. He currently leads a multi-disciplinary, translational research program aiming at identifying new functional traits and novel, physiologically-informed plant sensors to enable enhancing crop tolerance to abiotic stresses and resource-use efficiency, particularly water.

ORGANIZATION DESCRIPTION

The **Department of Civil, Environmental, and Geo-Engineering** is part of the College of Science and Engineering at the University of Minnesota. Its mission is "…to transform the world by addressing critical challenges in designing and protecting our infrastructure, environment, water and earth resources" through education, research, and outreach. Its 30 full time faculty members are engaged in a wide range of socially relevant research topics, including on the protection and remediation of soil and water resources.

The **Saint Anthony Falls Laboratory** (SAFL) is a leading research and education facility of the University of Minnesota, located on Hennepin Island on the Mississippi River. It partners with local, state, and federal agencies, private firms and businesses, and other educational institutions "to benefit society by developing physics-based, cost-effective, and sustainable engineering solutions to major environmental, water, ecosystem, health, and energy-related problems" through advances in fundamental knowledge. Faculties at SAFL integrate lab- and field-based experiments with advanced computational tools to obtain innovative, science-based solutions to real-world problems in fluid-flow and water resources.