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

Project Title: **ENRTF ID:** **086-B**

Optimal Configuration of Windbreaks for Agricultural Water Conservation

Category: B. Water Resources

Total Project Budget: $ 368,614

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

Summary:

This proposal aims to develop a predictive tool that enables optimal configuration of windbreaks, canopy, and wind turbines for reduction of farm-scale water loss due to soil evaporation.

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Problem statement, idea, and the a preliminary drawings for the new test section in SAFL wind tunnel

_____ Funding Priorities _____ Multiple Benefits _____ Outcomes _____ Knowledge Base

_____ Extent of Impact _____ Innovation _____ Scientific/Tech Basis _____ Urgency

_____ Capacity Readiness _____ Leverage _______ TOTAL ______%

PROJECT TITLE: Optimal Configuration of Windbreaks for Agricultural Water Conservation

I. PROJECT STATEMENT

This proposal aims to develop a predictive tool that enables optimal configuration of windbreaks, canopy, and wind turbines for reduction of farm-scale water loss due to soil evaporation.

1. ***Why evaporation reduction in irrigated agriculture is important?***

Water, food, and energy are tightly intertwined—especially in the era of intensive urbanization and population growth. Irrigated agriculture is the biggest consumer of freshwater in the U.S. (~115,000 million gallon per day) compared to water use for indoor and outdoor household purposes (~27,800 million gallon per day). **Therefore, 5% reduction in irrigation water is almost equivalent to 20% saving for domestic use. Soil evaporation is the largest component of the water loss in crop production.**

2. ***Is there a sustainable way for soil evaporation reduction?***

Near surface wind is one of the main drivers of evaporation. Thus, one sustainable way is to suppress the wind energy through optimal configuration of roughness elements (i.e., windbreaks, canopy, and wind turbines).

3. ***What are the knowledge and technical gaps?***

We do not yet have predictive tools that can properly quantify the local effects of roughness elements on farm-scale heterogeneity of soil evaporation. For instance, we still do not know the optimal height and spatial arrangement of natural canopies for effective reduction of farmland evaporation. Another example is the effect of wind turbines. Wind turbines significantly change near surface atmospheric mixing, yet we currently do not have scientific capabilities to predict potential soil salinization in the wake of turbines due to accelerated rates of evaporation and/or determine the shielded regions in which the crop yield may improve. This knowledge gap stems from the difficulties in conducting field experiments under all feasible land-atmospheric conditions.

4. ***How do we fill the technical gaps? What are the objectives of this proposed project?***

This project will achieve its goal by: **(1)** redesigning the SAFL wind tunnel test section to conduct detailed evaporation studies by including a control volume of soil, which is monitored by continuous weight measurements and distributed array of sensors; **(2)** examining combined effects of canopy, windbreak, and wind turbine on evaporation fluxes under different land-atmospheric conditions; **(3)** developing a new simulation tool that enables farm-scale prediction of evaporation over surfaces with complex roughness configurations; **(4)** validating the performance of the simulation tool through field experimentation; and **(5)** developing modern software packages that make the outcomes accessible for farmers, engineering firms, and decision makers.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Redesigning the SAFL wind tunnel test section for evaporation studies — Budget: $65,200

The SAFL wind tunnel is already equipped with a system that controls air and surface temperatures, which allows simulation of the diurnal cycle of atmospheric thermal stability. A new test section will be designed to accommodate a moist soil volume. The soil surface temperature will be forced by radiative heating and wind cooling; its moisture content will be continuously measured by a scale; and its surface heat and water vapor fluxes will be monitored with a three-dimensional array of temperature and humidity probes.

Outcomes and Products:	**Completion Date**
1. A new test section for SAFL wind tunnel *that advances SAFL capabilities to study water evaporation under controlled land-atmosphere conditions and different configurations of surface roughness elements.*	*Aug 2019*
2. A unique wind tunnel dataset *on heterogeneity of moisture fluxes under different wind velocity conditions, solar radiation scenarios, and surface roughness configurations.*	*Oct 2019*
3. A project specific data server *for storage and public sharing of the project data.*	*Nov 2019*

Activity 2: Developing a new tool for prediction of farm-scale evaporation — Budget: $180,200

We will use the wind tunnel data to develop a novel tool to predict microscale (< 1 km^2) spatial heterogeneity of cropland evaporation—under all feasible land-atmosphere conditions, complex configuration of roughness elements, and irrigation scenarios.

Outcomes and Products:	**Completion Date**
1. An open source software tool *that will provide easy access to the evaporation predictive tool by the research community, and engineering firms.*	*Aug 2020*
2. Engineering guidelines and manuals *for optimal configuration of canopy, windbreaks and wind turbines for reduction of soil evaporation.*	*Oct 2020*
3. A web-based GIS tool *for public demonstration of the effects of canopy, windbreaks, and wind turbines on long-term water conservation and crop production.*	*July 2021*

Activity 3: Field validation **Budget: $123,200**

The team will build and deploy a movable self-standing flux tower to monitor farm-scale evaporation heterogeneity under the influence of a wind turbine and natural canopy (orchards, corn canopy) using the EOLOS wind research station and the Agricultural Eddy Covariance site at the university's UMore Park.

Outcomes and Products:	**Completion Date**
1. A movable and height adjustable Meteo-Flux tower *will be built and made available to the SAFL and U of M community. The tower will be equipped with an open-path gas analyzer, sonic anemometer, temperature, and soil moisture probes.*	*Oct 2019*
2. A unique field-scale dataset from the flux tower and the available LIDAR velocity profiler *that will decode the field-scale relationship between evaporation and crop yield heterogeneity. This dataset will be used for field validation of the developed evaporation predictive tool. The dataset will be publically available through the project data server.*	*Apr 2021*

III. PROJECT STRATEGY

A. Project Team/Partners

Ardeshir Ebtehaj: Assistant Professor at SAFL and Department of Civil Environmental and Geo-Engineering, UMN—expert in hydrologic sciences, remote sensing, and land-atmosphere interactions.

Michele Guala: Assistant Professor, SAFL and Department of Civil Environmental and Geo-Engineering, UMN—expert in experimental fluid mechanics, wall turbulence and wind energy.

Timothy Griffis: Professor, Department of Soil, Water, and Climate, College of Food, Agricultural and Natural Resource Sciences, UMN—expert in biometeorology and near surface atmospheric processes.

John Baker: Adjunct Professor, Department of Soil, Water, and Climate, College of Food, Agricultural and Natural Resource Sciences, UMN—expert in soil sciences and agronomy.

B. Project Impact and Long-Term Strategy

- The new wind tunnel test section and the movable flux tower will put SAFL in a unique position to conduct new signature research for improving national food, water, and energy security.
- The expected outcomes will help technological developments and sustainable policymaking toward improved efficiency of crop production and preservation of Minnesota freshwater resources. **We anticipate that the outcomes and provided engineering guidelines will lead to sustainable agricultural practices with more than 5 to 10% farm-scale reduction in soil evaporation.**
- The results will enable improved irrigation and soil conservation (e.g., mulching) strategies that account for potential effects of wind turbines on long-term soil fertility and sustainability of crop production.
- To foster applications of the developed tools, the **long-term strategy** is to demonstrate the impacts of optimal configuration of canopy and windbreaks on farm-scale reduction of soil evaporation through a simple Web-GIS and visualization tool. We will also document the outcomes as engineering guidelines, in collaboration with the Minnesota Departments of Agriculture and Commerce to foster related policymaking and engagement of provide sectors for related water conservation technological developments.

C. Timeline Requirements

The project will require 3 years efforts of a PhD student for developing the evaporation predictive tool and 2 years of a postdoctoral research associate for conducting the field experiments under the supervision of the project's PIs.

2018 Detailed Project Budget

Project Title: Optimal Configuration of Windbreaks for Agricultural Water Conservation

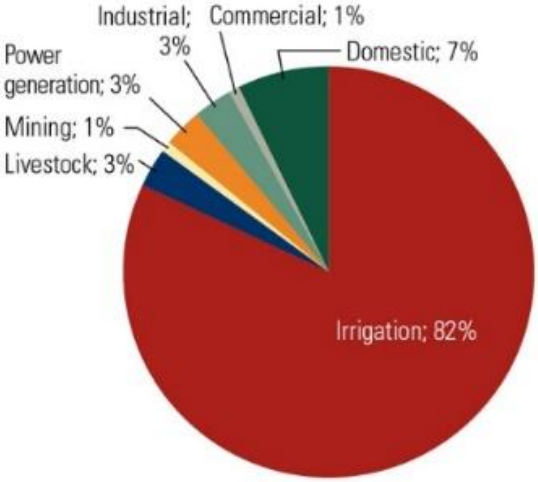
IV. TOTAL ENRTF REQUEST BUDGET: $368,614 for 3 years

BUDGET ITEM	AMOUNT
Personnel:	$ 323,114
Ardeshir Ebtehaj, PI (75% salary, 25% benefits): 16.65% FTE, 1.5 months in 3 years. Ardeshir will provide expertise in theoretical developments for the new microscale evaporation predictive tool. Ardeshir expertize at the intersection of hydrologic and computational sciences will be used to develop modern optimal estimation models that enable redistribution of the net solar radiation into heat and evaporation fluxes depending on complex configuration of surface roughness elements. ($19,911)	
Michele Guala, Co-PI (75% salary, 25% benefits): 16.65% FTE, 1.5 months in 3 years. Michele will provide scientific knowledge in experimental modeling of the surface roughness effects on evaporation fluxes with particular emphasis on instrumentation and experimental setup of the wind tunnel and flux tower. ($21,813)	
Timothy Griffis, Co-PI (75% salary, 25% benefits): 16.65% FTE, 1.5 months in 3 years. Tim will provide scientific expertise in model development and field validation with particular emphasis on the effects of crops transpiration in the model, experimental setup of the flux tower and data collection in the field. ($28,085)	
Staff Engineer and IT support (78% salary, 22% fringe): 20% FTE, 1.8 months. S/He will provide support for redesign of the wind tunnel, equipment purchases, installation, and data collection both in the tunnel and flux tower in the field. ($30,971)	
Two graduate students (59% salary, 41% fringe): Brandon Sloan who is recipient of the Departmental Fellowship of the Department of Civil, Environmental and Geo-Engineering, UMN (3 years, $138,498) and another PhD student (2 years, $92,332) will be funded during the three years of the project. Brandon will be working with Ebtehaj and Guala in SAFL and will be responsible for wind tunnel experimentation and evaporation model development. The second student will be working with Griffis and Baker for field validation and experimentations. ($222,335)	
Equipment/Tools/Supplies:	$ -
Supplies: Steel parts and Plexiglas sheets for construction of the soil box ($1,000), steel parts for support and lifting of the soil box ($1,000), different soil types ($500), wires and electrical supplies ($500), materials for construction of windbreaks, synthetic canopy and miniaturized turbines ($1,000).	$ 4,000
Equipment: 20-25 soil temperature and moisture sensor ($5,000), a scale for monitoring of soil box and water balance ($4,000), two air moisture sensors ($1000), heaters for radiative heating ($2500), two pyranometers for monitoring of surface net radiation ($1500), electrical and computer hardware for automatic data collection/storage ($5,000), infrared camera for monitoring soil surface temperature and moisture ($1,000), a flux station with H2O Open-Path Gas Analyzer and 3-D Sonic Anemometer ($20,000)	$ 40,000
Travel: *Be specific. Generally, only in-state travel essential to completing project activities can be included.*	
During second and third year of the project the team need to travel to the UMore Park for site selection, installation, and deployment of the flux tower and collection of the field measurements. The expense largely covers the transportation costs.	$ 1,500
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	**$ 368,614**

V. OTHER FUNDS

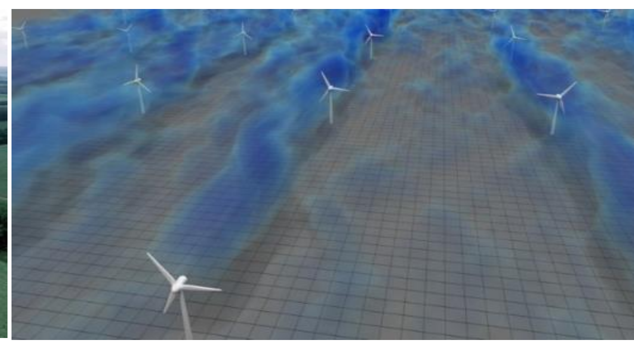
SOURCE OF FUNDS	AMOUNT	Status
In-kind Services To Be Applied To Project During Project Period: Unrecovered UMN overhead (54% MTDC)	$ 136,764	Secured

Reduction of evaporation water loss is the key for sustainable agricultural water conservation.



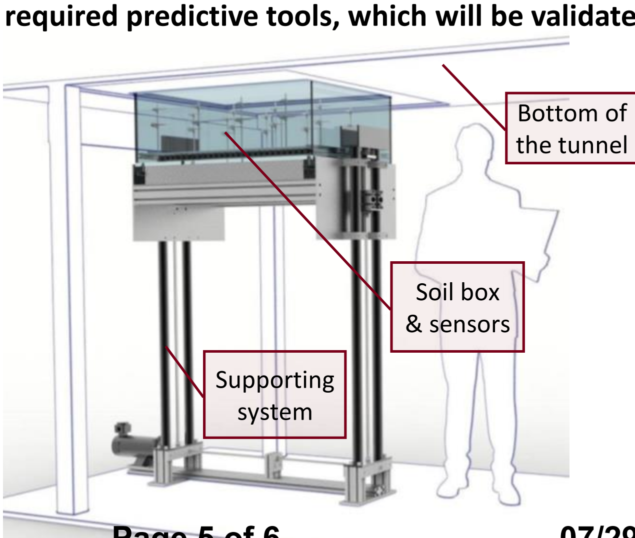
Fact: Agricultural is the largest consumer of freshwater in the U.S. A small conservation (5%) of irrigation water results in a notable water saving (20%) for other sectors. **Soil evaporation is a major component of water loss in irrigated agricultural.**

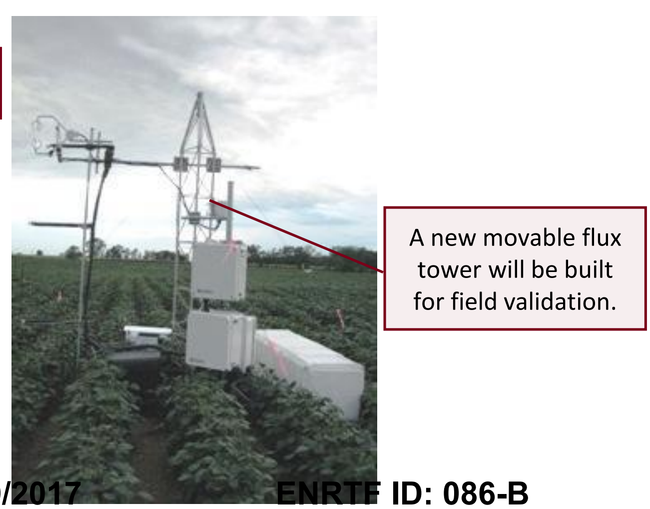
Idea: Optimal configuration of surface roughness elements (i.e., canopy, windbreaks, and wind turbines) can significantly reduce near surface wind velocity and **thus soil evaporation by more than 5 to 10%.**



Knowledge Gap: ***We do not yet have predictive tools that can properly quantify and optimize the effects of surface roughness elements on farm-scale heterogeneity of soil evaporation.***

Solution & Deliverables: We will build a new test section in SAFL wind tunnel by including a soil box and moisture probes (left) to conduct soil evaporation experiments for developing the required predictive tools, which will be validated in the field (right).





Project Manager Qualifications & Organization Description

Project Manager Qualifications

Ardeshir Ebtehaj is an Assistant Professor in the Department of Civil, Environmental, and Geo- Engineering (CEGE) at the University of Minnesota and has a joint appointment with the Saint Anthony Falls Laboratory. Ardeshir received his PhD in Civil and Water Resources Engineering and his MS degree in Mathematics, both from the University of Minnesota in 2013. Prior to joining the department, he worked for two years as a postdoctoral researcher at the Georgia Institute of Technology and he served for one year as an Assistant Professor in Utah State University. He was a NASA Earth and Space Science Fellow during the last year of his PhD training and he was a recipient of both Interdisciplinary and Doctoral Dissertation Fellowships of the University of Minnesota. He is currently an associate editor of the *Journal of Hydrometeorology*, is a member of precipitation technical committee of the American Geophysical Union (AGU), and is a past recipient of an AGU best student paper award.

Organization description

The University of Minnesota, Twin Cities is a public research university in Minneapolis and Saint Paul, Minnesota. The University of Minnesota mission is threefold:

- **Research Discovery** – to generate knowledge, understanding and creativity by conducting high-quality research.
- **Teaching and Learning**—to share knowledge and prepare graduate, professional, and undergraduate students to take leadership roles in the state, the nation, and the world.
- **Outreach and Public Service** – to exchange knowledge between university and society by applying scholarly expertise to community problems.