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

Project Title: **ENRTF ID: 042-A**

Building Statewide Daily Soil Temperature Maps

Category: A. Foundational Natural Resource Data and Information

Sub-Category:

Total Project Budget: $ 847,326

Proposed Project Time Period for the Funding Requested: June 30, 2024 (4 yrs)

Summary:

Building statewide daily soil temperature maps has many practical benefits in Minnesota where soil temperature can be different from air temperature because of thick snow cover and organic layer.

Name: Kyungsoo Yoo

Sponsoring Organization: U of MN

Job Title: Professor

Department: Dept. of Soil, Water, and Climate

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St. Paul MN 55108

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Location:

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

This map shows the thicknesses of snow cover and forest organic layer in Minnesota and how they can make soil temperatures substantially differ from air temperatures within the State.

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

Building statewide daily soil temperature maps

I. PROJECT STATEMENT

This project will produce statewide daily soil temperature maps. Important information will be available to users of these maps. For example, which areas of Minnesota are more likely to be flooded during spring snowmelt due to frozen soils? Are mid-summer soil temperatures cooler in conifer forests with thick organic layers than in nearby deciduous forests with thin organic layers? Are mid-winter soil temperatures warmer in Ely than Mankato due to thick snow cover insulation?

These types of information contained in statewide daily soil temperature maps offer short- and long-term utility for managers of natural resources. Soil temperature (and the presence of frost) informs agricultural planning (tillage and planting seed), engineering operations (building and road construction) and flood preparation. Environmentally, water quality and soil nutrient cycles are controlled by chemical reactions that respond to soil temperature. Ecologically, germination and survival of native tree seedlings and competing invasive species are sensitive to soil temperature. Therefore, state-wide daily soil temperature maps are a foundational source of natural resource information.

Maps of statewide daily soil temperatures are particularly important in Minnesota. Minnesota has a unique convergence of three biomes—boreal conifer forest, temperate deciduous forest and grasslands—that vary greatly in factors that affect soil temperatures. Snow cover protects soils against extreme cold and is thicker and longer in duration in the north than the south. Organic layers on the soil surface keep soils cool during hot summer days; they vary from relatively thin in grasslands south and west, to moderately thick in deciduous forests, to very thick in coniferous forests of northeastern MN. On top of these general trends, snow cover and organic layers vary locally from hilltops to swampy lowlands. Consequently, **in Minnesota, soil temperatures are spatially and temporally heterogeneous in ways that cannot be projected from air temperature.**

We will measure soil temperature (at depths from the surface to 1 m) across the latitudes, the three biomes, soil texture types, and topographical variability that characterize Minnesota, and compile already-published or ongoing agricultural soil temperature measurements to form a comprehensive soil temperature data set. Second, we will build a numerical model of soil temperature that is scalable with existing soil survey data (SSURGO). Third, we will distribute the data through online maps and geospatial data formats, identify primary users of our data, and provide them with targeted training for use of our data sets.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1. Obtaining Soil Temperature across Latitudes, Biomes, Topography, and Agricultural Fields. We will acquire currently unavailable soil temperature data across vegetation types and agricultural fields at three latitudes in Minnesota. For agricultural fields, we will also compile and incorporate publicly available data from the State Climatology Office and Minnesota Department of Agriculture. For each measurement, we will also determine snow cover thickness and organic layer thickness. Air temperature and dew point will be also measured to estimate heat transfer between the atmosphere and soils. Soil temperature and snow depth sensors will be designed, manufactured, and programmed within the University of Minnesota. This will keep costs low and give graduate students experience with engineering and programming aspects of the project. **ENRTF budget: $338,930 (40% of total budget).**

Activity 2. Soil Temperature Modeling and Geospatial Representation. We will construct a scalable computer model that describes the daily statewide soil temperature. This will be achieved by using the USDA soil survey data (SSURGO), state land use and land cover, statewide LiDAR elevation data, and atmospheric weather data

as input variables for the model. We will characterize heat properties of soil materials in the laboratory and combine the analyses results with the SSURGO dataset to model statewide soil thermal properties. These efforts will result in a new capacity to expand the limited measurements of soil temperature to the entire state. **ENRTF budget: $254,198 (30% of total budget).**

Activity 3. Demonstrating Utility. From our product, we will create online daily maps showing (1) the areas with frozen soils and (2) the difference between air and soil temperatures. Both will demonstrate the utility of our products in improving the State's natural hazard prevention, engineering, and farming. For scientific and government agencies involved in the management of natural resources, we will test three hypotheses to demonstrate the utility of our products as a fundamental data set. First, **soil frost depth** is largely an inverse function of snow depths. Second, at a given summer air temperature, soil temperature is **lowest in conifer forests** (thick organic layer), **highest in deciduous forests** (thin organic layer), and **intermediate in prairie** (thin organic layer but thick root mat). Third, winter and spring soil temperature may increase in the north with increasing **snow depth** (contrary to air temperature). **ENRTF budget: $211,832 (25% of total budget).**

Activity 4. Facilitating the active use of our products. We will identify and contact potential users of our products (for example, road and building engineers, flood preparation groups such as watershed agencies and insurance companies, climatologists, foresters, ecologists, water quality managers, and soil scientists). We will conduct targeted advertisement of our research products through seminars at relevant agencies and inviting stake holders to our meetings. For the targeted users, we will provide training on data-use. To provide this user interface, we will maintain strong online presence from the initiation of the project. **ENRTF budget: $42,366 (5% of total budget).**

ENRTF BUDGET: $847,326 (4yr project)

Outcome	Completion Date
1. Installing soil temperature sensors	*Fall 2022*
2. Developing and parameterizing soil temperature models and geospatial representation	*Fall 2023*
3. Demonstrating utility and facilitating active use of our products	*Summer 2024*

III. PROJECT PARTNERS AND COLLABORATORS:

- Kyungsoo Yoo, Professor, UMN Dept. of Soil, Water, and Climate. (ENRTF supported)
- Xue Feng, Assistant Professor, UMN, Dept. of Civil, Environmental, and Geo-Engineering. (ENRTF supported)
- Lee Frelich, Director of the Center for Forest Ecology at UMN. (ENRTF supported)
- Joel Nelson, GIS Specialist, UMN, Dept. of Soil, Water, and Climate. (ENRTF supported)
- Andy Wickert, Assistant Professor, UMN Earth Science Dept. (Contractor for sensor design and production)

IV. LONG-TERM IMPLEMENTATION AND FUNDING: This project will build extensive soil temperature sensor networks and numerical models. This infrastructure is highly valuable but rare. We will seek to (1) expand the infrastructure to include urban and suburban areas in future projects, (2) secure federal research grants on the interactions between soil temperature and forest dynamics, water quality, soil carbon cycle, agricultural soil management, and engineering projects, and (3) consult the State climatology office, DNR, and other agencies for the long-term web-hosting of the state-wide daily soil temperature maps beyond the lifetime of this project.

V. SEE ADDITIONAL PROPOSAL COMPONENTS:

A. Proposal Budget Spreadsheet: Attached
B. Visual Component or Map: Attached
F. Project Manager Qualifications and Organization Description: Attached

Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet
Legal Citation:

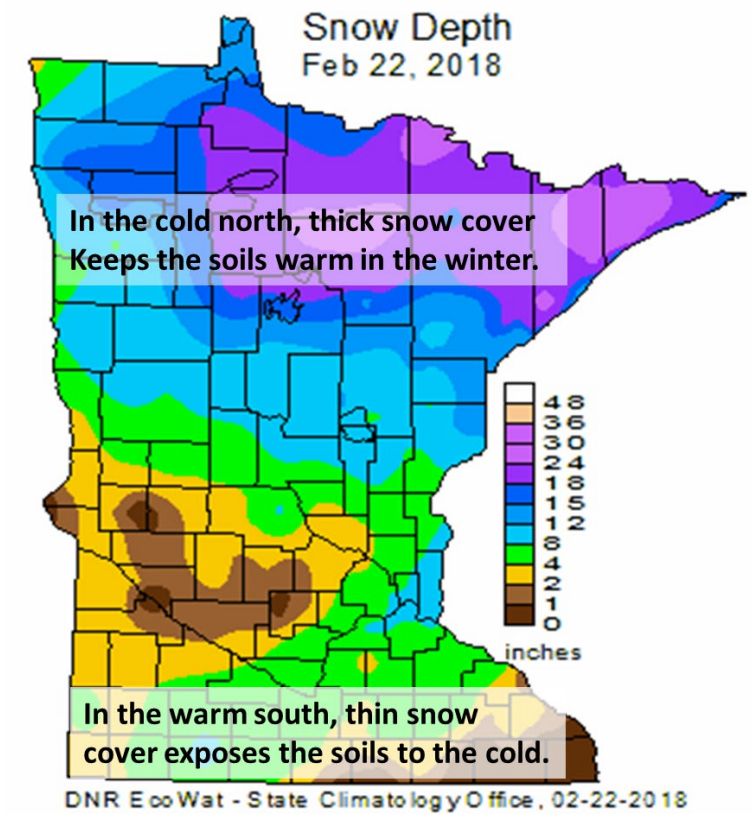
Project Manager: **Kyungsoo Yoo**
Project Title: **Building state wide daily soil temperature maps**
Organization: **Univ. of Minnesota, Twin Cities**
Project Budget: **$847,326**
Project Length and Completion Date: **4 yrs. July2020-June2024**
Today's Date: **4/4/2019**

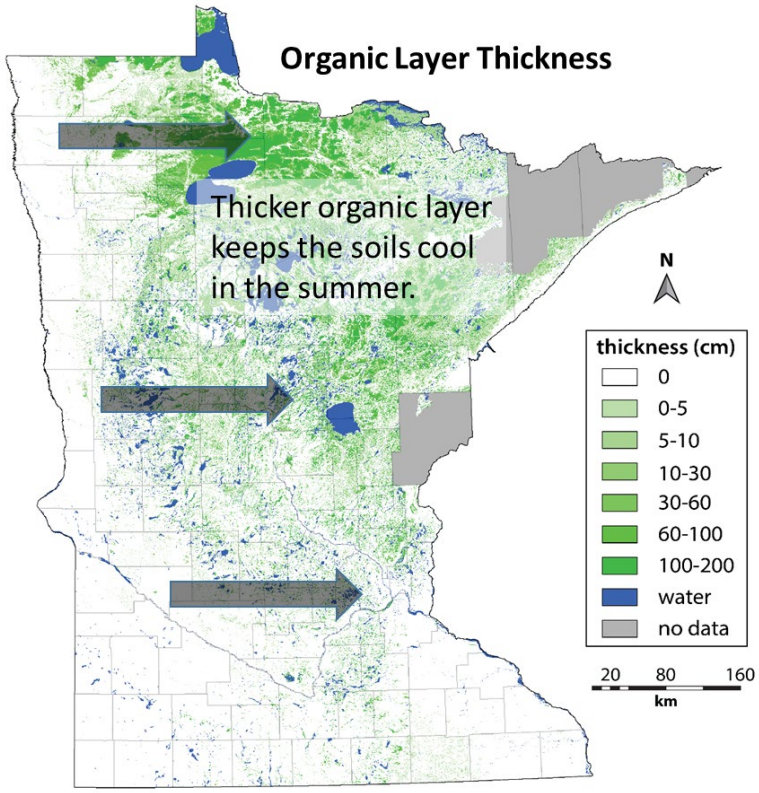
ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ -	$ -	$ -
Total salary and fringe for 4 PIS. This cost breaks down to individual Pis as below. (1) Professor/Project Manager Kyungsoo Yoo, $36,970 , 4.3 % FTE each year for 4 years. Yoo will coordinate the progress of the project and mentoring of students. (2) Asst. Profr/CoP Xue Fengl, $29,349, 4.3 % FTE each year for 4 years. Feng will be responsible for soil climate modeling and creating the model's interface with SSURGO data. (3) CoPI Lee Frelich, $22,000, 4.3 % FTE each year for 4 years. Frelich will be responsible for assessing the soil climate impacts on vegetation changes and structure. (4) GIS specialist, Joel Nelson $88,699, 25 % FTE each year for 4 years. Nelson will be responsible for extracting soil data from SSURGO, guiding field selection using SSURGO and other geospatial data (eg., LiDAR), educating doctoral students on GIS aspects of the project, presenting the outputs in geospatial formats and maps.	$ 177,018		
Two doctoral students, $396,908 (56% salary, 44% tuition and fringe) 100% FTE each year for 4 years. One graduate student will be housed in the Dept. of Soil, Water, and Climate, and the other student will be housed in the Dept. of Civil, Environmental, and Geo- Engineering at the Univ. of Minnesota. These graduate students will conduct their dissertation research on soil temperature. One will focus on field soil temperatures and the other on modeling.	$ 396,908		
Two undergraduate students will be hired as field and laboratory assistants during the summer every year. Pay rate is $12 per hour. Each student will work 20 hrs per week for 15 weeks per summer.	$ 28,800		
Equipment/Tools/Supplies			
soil temperature sensors. 96 temperature probes. Each probe is a stake and measures soil temperature as a continuous function of soil depth to the depth of 100 cm. These sensors will be manufactured in Wickert's lab. $500/temperature stake X 96 = $48,000	$ 48,000		
Snow depth sensors designed with the same principle of ultra Ultrasonic rangefinder. $300 per piece at 96 locations = 28,800	$ 28,800		
Fully sealed robust Air temperature and Relative Humidity sensors at 24 locations (a subset of 96 locations for soil temperature measurements). We have used a cheap sensor for this, but it breaks with dew. $200/each X 24 locations = $4,800	$ 4,800		
Soil moisture sensors. Decagon/METER. $150 eachX 96 locations X 2 depths = 28,800	$ 28,800		
Solar radiation shields for air temperature and relative humidity sensors. 75$ per piece at 24 locations =	$ 1,800		
Telemetered data loggers: $600 per base($460 for base, $100 housing , and $40 cables and wires) at 96 locations =	$ 57,600		
Particle Boron (Cell telemetry module to use with Resnik data logger) $60 per piece X 96 telemetered base = $5760	$ 5,760		
Cell telemetry (data subscription) $3 per month per data logger X 12 months X 3 years X 96 data logger = 10368	$ 10,368		
Computing needs. We understand that computer is an ineligible expense, in normal circumstances. However, we need a well-equipped powerful PC devoted to GIS and modeling demands in this project.	$ 3,500	$ -	
TLS-100 PORTABLE THERMAL CONDUCTIVITY METER (quoted). This equipment will be used to measure thermal conductivity of soil and organic materials collected from the field trips.	$ 3,800		
Laboratory supplies for characterizin specific heat capacity measurements of soil and organic materials. Specific heat capacity and thermal conductivity are used together to calculate heat diffusivity.	$ 3,000		
Field supplies (Fencepost and structure for field logger and sensor installations at 96 locations and 4X utility probe to introduce temperature sticks). We expect the cost of ~$100 per location for fencing and post and $100 per utility probe.	$ 10,000		
Travel expenses in Minnesota - in accordance with the UMN Travel Policy: We have total 8 field trips during the project period. Four trips in the first two years are to install sensors at 96 locations. Each installation trip will last 6 days (5 nights) and involves 6 participants (2 graduate students, 2 undergraduate students, and 2 PIs). The budget included car rental ($77 per day), lodging ($100 per two persons per night), and per diem ($50 per person per day). Another four trips are scheduled for maintenance and repairss. Each maintenance trip is 3 days (2 nights) and involve 4 participants. Same rates are used for rental car, lodging, and diem. There will be also 4 trips budgeted for a GIS speacialist in the last two years (2 days, 1 night, per each) who will travel to related goverment, non-govermental, or corporate organizations to demonstrate our research products tailored for their needs. Car rental for GIS specialist is compact car rate of $50/day, hotel and per diem are same rate as stated above.	$ 21,172		
Other			
We will manufacture soil temperature, snow depth, relative humidity sensors in collaboration with Dr. Wickert in the Earth Science Department at the Univ. of Minnesota. These sensors cost less than commertical equipments and are more versatile with our field needs. This also creates an opportunity to have graduate students in environmental science interact with engineers. Wickert's lab has a capacity to direct graduate students to wire and program low cost sensors. This technical support is $70/hr. We budget total 40 hrs of training.	$ 2,800	$ -	
Lab analyses: soil organic carbon and soil texture analyses ($30 per sample X 96 soils X 5 depths)	$ 14,400		
COLUMN TOTAL	$ 847,326	$ -	$ -

SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State:		$ -	$ -	$ -
State:		$ -	$ -	$ -
In kind: UMN will waiver its indirect cost for organized research (54 % of direct cost.).		$ 358,964	$ -	$ 358,964
Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS	**Amount legally obligated but not yet spent**	**Budget**	**Spent**	**Balance**
		$ -	$ -	$ -

We will build Statewide Daily Soil Temperature Maps.

In Minnesota, soil temperature can be different from air temperature because of snow cover (winter and early spring) and organic layer (summer).





A daily soil temperature map will help (1) farmers to schedule tilling, planting, and harvesting activities, (2) engineers to plan road construction projects, and (3) water resource managers to better predict spring flooding, (4) natural resource managers to better understand environmental and ecological processes.

PROJECT MANAGER QUALIFICATION

Kyungsoo Yoo
University of Minnesota
Dept. of Soil, Water, and Climate

EDUCATION
U.C. Berkeley. Ph.D. Ecosystem Sciences. 2003. / Yonsei Univ. S. Korea, MS. Physics. 1996 / Yonsei Univ. BS. Physics. 1994

POSITIONS
Professor at Univ. of Minnesota: 2018. Aug-Present. / Associate Professor at Univ. of Minnesota: 2013. Aug-2018. July / Assistant Professor at Univ. of Minnesota and Univ. of Delaware: 2006 Jan.-2013 / Postdoctoral Fellow at U.C. Berkeley: 2004-2005

EXPERTISE: Biogeochemistry of invasive earthworms / Soil carbon cycle / Soil erosion.

CREDENTIALS
- Served as PI and coPI for four National Science Foundation Supported Projects and one USDA NIFA Grant.
- Awarded the National Science Foundation's CAREER award (the agency's most prestigious grant to young scientists). 2012
- Published 41 peer-reviewed papers in leading journals and 6 book chapters since 2003.
- Editorial board member for the journal *Geoderma* (a leading journal in soil science), 2017-
- Served on many review panels including National Science Foundation (5 times) and USDA (2 times).

ORGANIZATION DESCRIPTION

The flagship University of Minnesota Twin Cities is the state's land-grant university and one of the most prestigious public research universities in the nation. The University community consists of 31,535 undergraduate students (Fall 2017), 16,033 graduate and professional students, 3911 faculties, and 13,986 staffs. The University's mission, carried out on multiple campuses and throughout the state, is 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 nondegree 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.