**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**

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| **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**