Environment and Natural Resources Trust Fund

2023 Request for Proposal

General Information

Proposal ID: 2023-194

Proposal Title: Making Prescribed-Fire Safer and Wildfires Easier to Predict

Project Manager Information

Name: Lian Shen

Organization: U of MN - St. Anthony Falls Laboratory

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Project Basic Information

Project Summary: To make wildfires easier to predict and prescribed-fires safer to conduct, we will develop a modeling tool that learns from drone-measured in-situ data, providing fast, accurate predictions of fire spread.

Funds Requested: $489,000

Proposed Project Completion: June 30, 2026

LCCMR Funding Category: Methods to Protect, Restore, and Enhance Land, Water, and Habitat (F)

Project Location

What is the best scale for describing where your work will take place?

Statewide

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

During the Project and In the Future

Narrative

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

The Minnesota DNR needs a new tool that can provide fast, accurate predictions of fire spread, making wildfires easier to predict and prescribed-fires safer to conduct. As the climate changes, more frequent wildfires are an increasing environmental, public health, and safety concern in Minnesota. Last summer, our state experienced one of its most active fire seasons, forcing the closure of the Boundary Waters for the first time in nearly half a century. The Greenwood Fire, which blazed 15 miles southwest of Isabella, doubled in size in a few days to 31 square miles and forced the evacuation of 250+ Minnesotans. From tense nights away from home to canceled trips to health implications from smoke and over-taxed firefighting resources, fires are having a larger-than-ever impact on Minnesotans. Yet, the DNR, Indigenous tribes and other organizations recognize the need for prescribed-burning, a practice which prevents catastrophic wildfires by reducing available fuel while promoting ecosystem health and climate change resiliency. To make wildfires easier to predict and prescribed-fires safer to conduct, we will develop a new high-resolution modeling tool that can learn from drone-based in-situ data, thus providing real-time predictions of fire spread in fine-scale measurements, a capability beyond current models.

What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.

With our fast and accurate tool, we will make it easier for the DNR to predict wildfire spread, providing critical assistance on-the-ground as firefighters strategize containment plans and allocate human and aerial resources. This tool will also make prescribed-burns safer to conduct, allowing for more prescribed-burning to reduce the risk of catastrophic wildfires and improve ecosystem health. To develop this model, we will 1) use state-of-the-art computational software to analyze and accurately simulate the dynamic interactions between wind, land topography, and canopy on fire spread; we will 2) use drones equipped with meteorological equipment to collect weather data from fires in real time, incorporating observations into the model for increased accuracy; and we will 3) ultimately create a fast and accurate predictive tool for wildfire spreading rate and prescribed-burns behavior beyond what exists today. Our tool will be fast enough so that it can be operational using a laptop in real time; meanwhile, it will be accurate such that the interactions among fire, canopy, and atmosphere can be captured with physical models. In developing this tool, we will work closely with the DNR and practitioners. We have also planned substantial educational and outreach activities for the dissemination of our product.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

As last summer demonstrated, fires are going to be increasingly part of our future here in Minnesota. By investing in a cutting-edge tool to more accurately predict the spread rate of wildfires and prescribed-burns, the state of Minnesota is preparing to protect Minnesotans and their property from the growing risk of wildfires while both conserving and enhancing Minnesota's prized forests through the increased and safe use of prescribed-burning, a practice which prevents catastrophic wildfires while increasing ecosystem health and resilience to climate change.

Activities and Milestones

Activity 1: High-fidelity computer simulation study of fire-wind-vegetation interaction dynamics

Activity Budget: $146,000

Activity Description:
With the advent of modern computers, computer simulation has become a powerful research tool for the study of wildfires. Just like a flight simulator, one can use computer calculation to obtain a detailed description of fire behavior under various environmental conditions. Analogous to weather forecasting, which is mostly done via computer simulation nowadays, the spread of wildfires and prescribed burns can be predicted.

To accurately simulate wildfires, the dynamical interactions among the fire, ambient and fire-induced air motions, and fuel need to be captured faithfully in the computational algorithms. In this project, we will use state-of-the-art computational software that has the powerful capabilities of simulating the effects of wind, land topography, and canopy on fire spread. We will also study the feedback effects of fire on the air motions, such as the buoyant rise of hot air plumes and the drawing of ambient air towards the fire. The simulation data to be obtained in this research activity will greatly improve our understanding of wildfire behavior, which will help us establish a solid foundation for the development of an accurate and fast-running wildfire prediction tool (Activity 3).

Activity Milestones:

Description	Completion Date
High-fidelity simulation of fire-atmosphere interactions	December 31, 2024
High-resolution simulation of wildfires and prescribed burns under in situ Minnesota environmental conditions	March 31, 2025
Analyses of simulation data to obtain a deep understanding of fire spread behavior	September 30, 2025

Activity 2: Drone-based weather and fire data collection and assimilation into the fire prediction model

Activity Budget: $159,000

Activity Description:
The main challenge in simulation of fire propagation at high-resolution is that the predictive model needs real time and near field meteorological data to make accurate predictions. Weather stations are sparse and often far from the location that fire takes place. Satellite observations are also very low-resolution and cannot provide detailed information to be used for fine-scale simulations of fire propagation. We aim to equip the drones we have at the St. Anthony Falls Laboratory with a lightweight meteorological equipment as well as a lightweight visible camera to measure wind speed, air temperature, humidity as well as the extent of fire in real time and relay the observations to a data logger at the ground station that enables transfer of the collected data to the fire prediction model. The data will be integrated into the model to correct its assumptions about meteorological variables and burned areas and eventually its forecasts. Modern machine learning tools (e.g., artificial neural networks) will be used to conduct this data assimilation.

Activity Milestones:

Description	Completion Date
Hardware and software developments for the remote sensing platforms	June 30, 2024
Deploying the platforms in the field	September 30, 2024
Developing the data assimilation technique	June 30, 2025
Dissemination of research findings via at least two open access journal publications	June 30, 2026

Activity 3: Development of a fast-running and accurate predictive tool for wildfire spread rate and prescribed-burns behavior

Activity Budget: $184,000

Activity Description:

The ultimate goal of this project is to develop a fast-running and accurate predictive tool for the spread rate for wildfires and the behavior of prescribed-burns for Minnesota DNR and practitioners. The predictive modeling tool will be built based on the high-fidelity simulations in Activity 1 and the drone-based field data collection in Activity 2. Our predictive tool will be fast enough so that it can be operational using a laptop in real time. Meanwhile, it will be accurate such that the dynamical interactions among the fire, canopy fuel, and atmosphere can be captured with physical models.

In our model development, advanced machine learning techniques will be employed to substantially speed up the calculations. Our model will incorporate local high-resolution canopy structure and in situ meteorological conditions. We will account for the mutual interaction among multiple fire lines and the effects of different ignition patterns, which are important for the planning and carrying out of prescribed burns. In our wildfire spread model development, we will work closely with Minnesota DNR experts and practitioners. We have also planned substantial educational and outreach activities for the dissemination of our research products.

Activity Milestones:

Description	Completion Date
Development of an advanced predictive tool for the spread of wildfires and behavior of prescribed-burns	March 31, 2025
Validation and improvement of the predictive tool through comparison with Minnesota wildfire and prescribed-burn cases	December 31, 2025
Workshops and seminars for dissemination of research products	June 30, 2026

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Travis Verdegan	Predictive Services Coordinator at the Minnesota DNR, member of the Statewide Prescribed Burn Committee	Provide insight regarding DNR needs and gaps in existing predictive technologies	No
Becky Marty	Regional Ecologist for the Minnesota DNR, leader in developing Itasca State Park's progressive prescribed-burning program (1995-2003)	Provide insights about prescribed-burns and the needs of practitioners, as well as serving as a connecting link to fire personnel in the DNR	No
Lane Johnson	Research Forester at UMN's Cloquet Forestry Center, fire ecologist involved in fire restoration work in northern Minnesota	Provide insights about prescribed-burns and the needs of practitioners, as well as serving as a resource for outreach and education efforts	No

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this work be funded?

The goal of this project is to develop a fast-running and accurate predictive tool for the spread rate for wildfires and the behavior of prescribed-burns for Minnesota DNR and practitioners. We will work closely with fire experts such as Travis Verdegan, DNR Predictive Services Coordinator, as well as with the Minnesota Interagency Fire Center and Statewide Prescribed Burn Committee. We will also consult expert prescribed-fire practitioners Lane Johnson, UMN Fire Ecologist, and Becky Marty, DNR Ecologist.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Extraction of Solar Thermal Energy in Minnesota	M.L. 2017, Chp. 96, Sec. 2, Subd. 07a	$250,000

Assess and Develop Strategies to Remove Microscopic Plastic-Particle Pollution from Minnesota Water Bodies	M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 04b	$300,000
Remote Sensing And Super-Resolution Imaging Of Microplastics	M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 08j	$309,000

Project Manager and Organization Qualifications

Project Manager Name: Lian Shen

Job Title: Kenneth T. Whitby Professor

Provide description of the project manager's qualifications to manage the proposed project.
This project will be led by Dr. Lian Shen as the project manager. Dr. Shen holds the Kenneth T. Whitby Professorship in the Department of Mechanical Engineering at University of Minnesota. He earned his Doctor of Science degree from Massachusetts Institute of Technology in 2001. After three years of postdoctoral training at MIT, he joined the faculty of Johns Hopkins University in 2004. In 2012, he was recruited by the University of Minnesota to join its faculty. Dr. Shen teaches fluid mechanics and thermal sciences courses. He is a world expert on the study of environmental fluid flows and turbulence in the atmosphere and water environments. He is serving on the editorial boards of five international journals. Dr. Shen has carried out a large number of research projects funded by federal and state agencies, including two previous projects of the Minnesota Environment and Natural Resources Trust Fund.

Co-investigator Dr. Ebtehaj is an Associate Professor with the department of Civil, Environmental, and Geo- Engineering at UMN. He has published around 40 peer-reviewed papers on environmental remote sensing and weather forecasts. Dr. Ebtehaj is an associate editor of the Journal of Hydrometeorology. He is the recipient of a NASA's new investigator award in 2018 for his contribution in remote sensing sciences and weather forecasts.

This project will be assisted by Clare Boerigter, who is the Communications Manager at the St. Anthony Falls Laboratory. She fought wildfires as a wildland firefighter for the U.S. Forest Service in 2012, 2013 and 2015. She holds a Master of Fine Arts in Writing and specializes in writing and outreach around wildfire and prescribed-burns. Previously, she worked for the Minnesota Forest Resources Council, the University of Minnesota's Cloquet Forestry Center, and the Forest Service's Northern Research Station. She is well connected within the Minnesota fire community.

Organization: U of MN - St. Anthony Falls Laboratory

Organization Description:
This project will be performed in the St. Anthony Falls Laboratory (SAFL, http://www.safl.umn.edu) at the University of Minnesota. SAFL is an interdisciplinary fluid mechanics research and educational institution. It has 22 faculty members and 37 research and administrative staff members. SAFL is a world-renowned research laboratory specializing in environmental and geophysical fluid mechanics studies. SAFL researchers have performed many innovative environmental studies for the state of Minnesota. Some of the projects were or are funded by the Minnesota Environment and Natural Resources Trust Fund. The proposed research leverages the unique and advanced capability of simulating and measuring environmental flows at SAFL, which has 16,000 square feet of space dedicated to research.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Project Manager - Lian Shen		Oversees the whole project; responsible for the research planning and reporting; leads the research on fire simulations			25%	0.12		$35,192
Co-investigator - Ardeshir Ebtehaj		Leads the research on drone-based weather and fire data collection and assimilation into the fire prediction model			25%	0.18		$33,671
Staff - Clare Boerigter		Communications Manager with a fire background to oversee educational and outreach component and facilitate relationships between researchers and fire personnel			22%	0.36		$31,917
Graduate Student Research Assistants		Perform computer simulations of fire spread and interaction with the environment; develop wildfire and prescribed-burn predictive modeling tools			38%	6		$341,228
Undergraduate Student Assistants		Assist data analysis and model validation			0%	0.6		$19,287
							Sub Total	**$461,295**
Contracts and Services								
							Sub Total	-
Equipment, Tools, and Supplies								
	Equipment	Data storage	To save the data of simulations					$1,000
	Tools and Supplies	Software licences	To conduct the simulation research and analyses					$1,705
	Equipment	Accessories for existing drones in the lab	To enhance the drone measurement capabilities					$2,500
							Sub Total	**$5,205**
Capital Expenditures								

							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	Field experiment	Miles and meals to conduct field experiments					$6,000
	Conference Registration Miles/ Meals/ Lodging	Workshop and seminars	Cost of conferences, workshop, and seminars					$13,500
							Sub Total	**$19,500**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Printing	Outreach materials	Print outreach materails					$1,500
	Publication	Publication of research results	Cost of publishing research in professional journals					$1,500
							Sub Total	**$3,000**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$489,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	Unrecovered F&A	Support of SAFL facilities where research will be conducted.	Secured	$209,107
			Non State Sub Total	**$209,107**
			Funds Total	**$209,107**

Attachments

Required Attachments

Visual Component

File: d6f97991-7fe.pdf

Alternate Text for Visual Component

To make wildfires easier to predict and prescribed-fires safer to conduct, we will develop a modeling tool that can learn from drone-measured in-situ data, providing accurate predictions of fire spread. Illustrated are demonstrations of high-fidelity wildfire simulation and prescribed-burn simulation, and drone deployment during the Boundary Waters wildfire....

Optional Attachments

Support Letter or Other

Title	File
UMN endorsement letter	82ed7b33-38f.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have potential for royalties, copyrights, patents, or sale of products and assets?

No

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

N/A

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

N/A

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

Making Prescribed-Fire Safer and Wildfires Easier to Predict

Needs and Research Questions

1- Wildfire is a growing problem in a changing climate.

2- To control natural and prescribed fire we need modern high-resolution predictive tools that learn from real-time remote sensing data from drones.

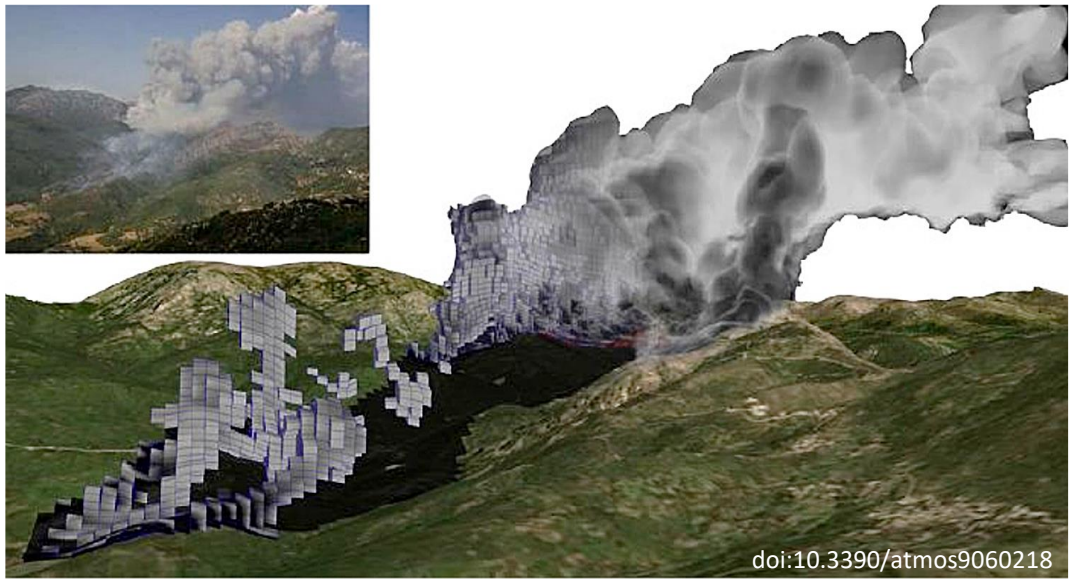
3- Can we predict fire behavior at meter-scale resolution?

Proposed Activities

1- High-fidelity computer simulation study of fire-wind-vegetation interaction dynamics

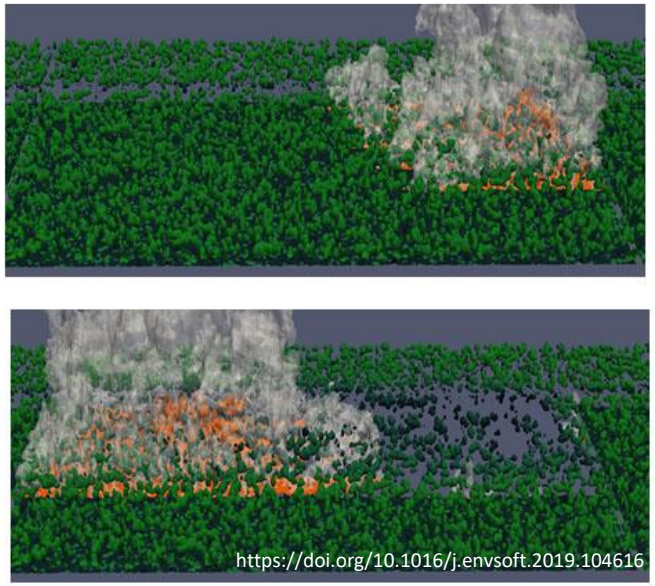
2- Drone-based weather data collection and assimilation into the fire prediction model

3- Development of a fast-running and accurate predictive tool for wildfire spread and predicted-burns behaviors



High-fidelity simulation of wildfire and comparison with photography (upper-left)

Boundary Waters wildfire and deployment of drones for data collection



Demonstration of prescribed fire simulation