Environment and Natural Resources Trust Fund

2025 Request for Proposal

General Information

Proposal ID: 2025-219

Proposal Title: Improving -- Forest Health via Post-Duff-Burning Soil Analysis

Project Manager Information

Name: Lee Frelich

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: Study forest-bed duff-fire effects on soil, earthworms, nutrient cycles, tree regeneration seedbed characteristics, root systems, invasive shrub spread (buckthorn, honeysuckle), and hydrophobicity, to improve fire management for resilient ecosystems.

ENRTF Funds Requested: $700,000

Proposed Project Completion: June 30, 2027

LCCMR Funding Category: Methods to Protect or Restore 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.

While forest fires are often seen as destructive, they are vital for ecosystem renewal, nutrient cycling, controlling invasive species, and creating diverse habitats. A critical aspect of fire management is duff-burning, i.e., burning of accumulated organic material such as leaves and twigs on the forest floor. However, changing climate, erratic weather seasons, and alteration of the duff thickness by invasive earthworms, are leading to more unpredictable fire patterns. Therefore, a better understanding of duff fire behavior and its effects under these new conditions is crucial. Given that, the problem is the lack of a lab-scale well-controlled-facility to study the various effects of duff burning practices on soils in cost-effective ways. This project aims to comprehensively study, in the lab, the effects of weather and earthworm invasion on duff fire behavior, as well as the impacts of duff burning on soil, including nutrient cycles, post-fire characteristics of seedbeds for tree regeneration, root systems, spread of invasive shrubs (e.g., buckthorn, honeysuckle), and forest floor hydrophobicity. By providing insights into the complex interactions between fire and soil dynamics, this study will enhance fire management approaches, refine prescription burning strategies, and advance our capacity to forecast forest ecosystem reactions to fire occurrences.

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.

We aim to establish a laboratory-scale duff-burning facility to replicate forest floor fires, employing advanced measurement techniques to measure duff-burning processes and their impacts on soil. By recreating duff layers characteristic of coniferous (pine) and deciduous (oak, maple) forests, and simulating fall and spring fires, we will investigate how variations in duff thickness and soil structures influenced by earthworm invasion, affect burning patterns. Utilizing cutting-edge optical and sensing tools will allow monitoring of soil temperatures, moisture levels, and duff combustion characteristics during a burn. We will characterize select soil properties before and after burning. Following lab-scale trials, we will analyze duff burning effects in the field.

Our novel lab-scale duff-burning facility will enable us to answer critical questions about duff-burning as a management practice: Can we create optimal conditions for pine and oak forest regeneration or suppress weedy shrubs? Does duff-burning increase or decrease soil heterogeneity that provides diverse niches for seedlings? How does duff burning affect post-fire nutrient supplies (N, P, Ca) and carbon sequestration? Can we mitigate post-fire soil hydrophobicity to reduce runoff and erosion? Ultimately, our project will empower fire managers to anticipate soil responses to fires, facilitating more precise burn prescriptions and enhancing forest management practices.

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?

Between 2018 and 2022, Minnesota experienced nearly 6000 reported fires, costing over $23 million in 2023 for preparedness, prevention, and suppression by the DNR. Although human activity triggers most wildfires, environmental factors also contribute to their propagation, creating devastating incidents like Pagami Creek, Ham Lake, and GreenValley Fires. As forest fires become more frequent and intense, exacerbated by dry and erratic winters, our project aims to enhance understanding through a specialized lab-scale duff-burning facility. This is crucial for refining prescription burning techniques, improving fire management practices on invasive shrubs, soil nutrient dynamics, soil sustainability - vital for Minnesota's forest preservation.

Activities and Milestones

Activity 1: Development, instrumentation, and commissioning of outdoor lab-scale duff burning facility

Activity Budget: $220,000

Activity Description:

In this activity, we will construct, instrument, commission, and test an outdoor laboratory-scale duff-burning facility measuring approximately 4 feet in length, 3 feet in width, and 3 feet in height. The construction and troubleshooting of this facility will be supported by SAFL Co-PIs. To simulate wind conditions, a large axial fan with a diameter of 3.5 feet will be integrated into the setup. The facility will be enclosed with high-temperature-resistant glass, allowing for observation of the duff and soil layers from the side and facilitating temperature profile measurements. Additionally, a radiant heater positioned on the enclosure's roof will generate diverse temperature conditions. To replicate rainfall and control humidity, a water sprinkler system will be installed on the facility's roof.

Professor Biswas possesses a wide array of measurement equipment, including high-speed camera systems (color and infrared), thermocouples, blowers, and data acquisition tools. Collaborating closely with Co-PIs Frelich and Yoo, Professor Biswas will ensure that the duff burning facility accurately simulates real forest bed conditions. This innovative test facility holds significant importance as it provides a controlled environment for studying forest bed duff fires, offering invaluable insights into fire dynamics and management strategies.

Activity Milestones:

Description	Approximate Completion Date
Complete design of the duff burning facility	December 31, 2025
Complete build, sensor integration/instrumentation, first fire in the facility	February 28, 2026
Complete a series of safety and calibration tests and commission the facility	April 30, 2026
Activity 1 summary report	May 31, 2026

Activity 2: Comprehensive lab-scale and field-scale experimental campaign investigating duff burning across various duff and soil compositions and wind conditions

Activity Budget: $180,000

Activity Description:

Over a six-month period from May 1 to November 30, a comprehensive series of tests will be conducted using various types of duff materials sourced from coniferous and deciduous forests, with differing thicknesses to mimic different stages of earthworm invasion. Mineral soils, representative of Minnesota's forest soils, will also be simulated. Environmental conditions such as wind, temperature, and rainfall will be manipulated to study their impact on duff burning behavior. The lab-scale experiments will involve monitoring soil temperature and moisture content using thermocouples and humidity sensors, while cameras will capture temperature distributions and combustion zones. The effects of duff burning on earthworm species and post-burn soil nutrient levels will be examined, along with sampling of combustion products to measure emissions. Field visits to areas undergoing prescribed burns will enable the collection of soil samples and earthworm assessments, providing detailed insights into the ecological implications of duff burning on forest ecosystems.

Activity Milestones:

Description	Approximate Completion Date
Complete the first test campaign by varying the duff and soil composition	June 30, 2026
Complete studying the effect of dry leg on duff burning and prescription burn in a	October 31, 2026
In-situ and ex-situ testing of pre- and post-combustion analysis of organic matter	November 30, 2026

Complete analysis of all the lab-scale testing data	December 31, 2026
Activity 2 summary report	December 31, 2026

Activity 3: Post-duff-burning measurements, soil testing, and data analysis

Activity Budget: $230,000

Activity Description:
In this task, we will perform pre- and post-burn soil analysis to characterize the duff-burn-induced soil changes. Our analyses will target bulk density, soil carbon and nitrogen contents, mass concentrations of major oxide elements (e.g., Ca, Mg, K, Si, Fe, and Al and P), hydrophobicity, and water infiltration rates. Soil bulk density is critical data in assessing the total masses of elements of interest. Additionally, determining soil bulk density prior to and post-burning practices helps assess the soil's capacity to store and transport heat and water. Soil carbon and nitrogen content measurements, together with bulk density, will inform the extent to which duff-burning oxidizes organic matter and nitrogen in the soils. With major oxide measurements, we will be able to assess the transfer of inorganic nutrient elements from the duff layer to mineral soils through duff-burning practices. Fores fires might change how soil materials interact with water. For example, burnt organic matter often acquires a new tendency to repel water, resulting in the loss of water infiltration into soils and subsequently increased runoff and soil erosion. We will use Modified Philip-Dunne (MPD) infiltrators to quantify the water infiltrations before and after duff burning experiments.

Activity Milestones:

Description	Approximate Completion Date
Complete water infiltration measurements along with the first test campaign with varying duff and soil	June 30, 2026
Complete the analysis of soil samples collected from the first year	December 31, 2026
Complete the analysis of soil samples collected from the experiments conducted in year 2	March 31, 2027
Activity 3 Summary report	May 31, 2027

Activity 4: Disseminate acquired knowledge with fire managers and forest researchers

Activity Budget: $50,000

Activity Description:
In this activity, post-duff-burning soil analysis and measurements offer valuable insights essential for developing predictive modeling capabilities for fire managers and forest researchers. By examining soil properties, nutrient levels, and hydrophobicity post-burning, researchers can better understand the immediate and long-term effects of prescribed burns on forest ecosystems. This data can be used to refine existing predictive models, allowing fire managers to anticipate and mitigate the potential impacts of future burns more effectively. Additionally, by incorporating information about soil response to duff burning into predictive models, forest researchers can improve their understanding of how different environmental factors influence fire behavior, ultimately enhancing overall forest management strategies.

Activity Milestones:

Description	Approximate Completion Date
Complete additional lab-scale and field testing, if necessary	February 28, 2027
Perform additional measurements during field-scale prescription burns, if necessary	April 30, 2027
Prepare a brief summary of learnings for dissemination to fire managers	May 31, 2027
Activity 4 Summary report	May 31, 2027

Activity 5: Reporting, IP and patent filing, results dissemination, and journal paper writing

Activity Budget: $20,000

Activity Description:

This phase of the project will focus on the final data analysis and report writing. In addition to meeting the deliverable requirements of the LCCMR Fund, the project team will prepare manuscripts for submission to peer-reviewed journals and will communicate the results of the project to the DNR fire managers and other stakeholders.

Activity Milestones:

Description	Approximate Completion Date
File IP and patents before any public disclose of research results	September 30, 2026
Finished writing the first draft of the journal/conference article	March 31, 2027
Activity 5 summary report	April 30, 2027
Final project report	June 30, 2027

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Lee Frelich	Department of Forest Resources, University of Minnesota	Prof. Lee Frelich is the Director of the UMN Center for Forest Ecology and a top expert in fire ecology and earthworm invasion. Frelich has been a leading researcher on fire in deciduous (oak, maple) and coniferous (pine) forests for 40 years, and in earthworm invasion ecology for 25 years.	Yes
Kyungsoo Yoo	Department of Soil, Water, and Climate, University of Minnesota	Prof. Kyungsoo Yoo, an eminent soil scientist, will contribute to this project as an expert in soil genesis and soil erosion. Yoo has extensive experience studying the impacts of invasive earthworms on soil structure and biogeochemistry in Minnesota, Alaska, and Fennoscandia.	Yes
Christopher Feist	St. Anthony Falls Laboratory, University of Minnesota	Christopher Feist has been involved in SAFL and energy research on projects ranging from novel wind turbine drivetrains to energy systems to mapping the hearing abilities of bald and golden eagles. Chris will be in charge of overseeing the design and development of the duff burning facility development.	Yes
Ben Erickson	St. Anthony Falls Laboratory, University of Minnesota	Ben Erickson will provide technical support and develop the lab-scale duff burning facility used in this project.	Yes
Erik Noren	St. Anthony Falls Laboratory, University of Minnesota	Ben Erickson will provide technical support and develop the lab-scale duff burning facility used in this project.	Yes
Erik Steen	St. Anthony Falls Laboratory, University of Minnesota	Erik Steen will provide technical support for the development of the duff burning system. Erik is also the safety officer of the research site and will develop safety plans at the test site.	Yes

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?

Our project aims to thoroughly investigate the impact of forest floor duff fires on soil dynamics, nutrient cycles, invasive shrubs, earthworms, and root systems. This knowledge will be shared with Minnesota fire managers and researchers through the DNR. Our study will contribute to the development of an improved Forest Fire Control System to enhance future forest fire management strategies. This will be achieved through our Co-PIs engaging with the DNR to discuss and incorporate the results into the project or by presenting findings at conferences. Additionally, there is potential for patenting the Forest Fire Control System.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
A Biodiversity Checkup for Minnesota's Big Woods	M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 03l	$109,000

Project Manager and Organization Qualifications

Project Manager Name: Lee Frelich

Job Title: Benjamin Mayhugh Assistant Professor

Provide description of the project manager's qualifications to manage the proposed project.
Prof. Sayan Biswas, Benjamin Mayhugh Assistant Professor of Mechanical Engineering, is an expert in clean energy, combustion, fire science, and novel laser-based sensing and diagnostics, will lead this project. PI Biswas has extensive expertise in large-scale fire systems, and currently leads an ARPA-E grant developing strategies for clean burn of 20-50 ft tall flare flames. Besides combustion and fire systems, PI Biswas has extensive experience developing optical sensors for energy applications. His research has received support from the Department of Energy (DOE), Advanced Projects Research Agency-Energy (ARPA-E), Office of Naval Research (ONR), National Science Foundation (NSF), and several clean energy companies. He manages an annual research portfolio of $2.5M. Before joining the University of Minnesota in 2020, Dr. Biswas spent 3+ years at the Sandia National Laboratories and 5+ years at Purdue University, working on combustion and developing advanced light/laser sensing systems. To date, PI Biswas has published 20+ journal articles, 40+ conference articles, 1 single-authored book, 6 book chapters, and holds 1 US patent. PI Biswas leads a highly diverse research group consisting of 6 PhD, 2 MS, and 10+ UG students. The Biswas team comprises 30% women and 20% students from underrepresented and indigenous backgrounds. His lab actively participates in educating the community about our energy future and in K-12 outreach activities, inspiring the next generation of scientists and engineers, and providing an open and equitable learning atmosphere for women, minorities, and indigenous students. Prof. Biswas serves on several technical and advisory committees, volunteering for his professional societies and local Minnesota-based organizations.

Organization: U of MN - College of Science and Engineering

Organization Description:
The University of Minnesota, Twin Cities is a public land-grant research university in the Twin Cities of Minneapolis and Saint Paul, Minnesota, and one of the most comprehensive research universities in the nation. The University leadership acknowledges that the University of Minnesota Twin Cities is built within the traditional homelands of the Dakota people. It is the flagship institution of the University of Minnesota System and is organized into 19 colleges, schools, and other major academic units. The University advances Minnesota state and US society through new ideas, technologies, treatments, and cures, and continues to create and transfer technology to companies for the development of new products and services that benefit the public good and foster economic growth. The University's College of Science and Engineering received $141.9 million in research funding in FY2015. The University of Minnesota College of Science and Engineering (CSE) ranks #4 in the country for the best bachelor's degree in engineering. In other rankings, CSE majors traditionally rank among the top 20.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Sayan Biswas		PI			27.06%	0.24		$33,708
Lee Frelich		Co-PI			27.06%	0.24		$15,810
Kyungsoo Yoo		Co-PI			27.06%	0.24		$38,184
ME Research Assistants		Research Assistants			43.64%	2		$240,580
LAAS Research Assistant		Research Assistant			45.74%	1		$110,492
Ben Erickson		Senior Personnel			25.09%	0.03		$6,977
Erik Noren		Senior Personnel			25.09%	0.06		$15,576
Chris Feist		Co-PI			27.06%	0.02		$1,600
Erik Steen		Senior Personnel			26.24%	0.02		$16,076
Undergraduate Students		Undergraduate Students			0%	0.01		$1,045
							Sub Total	**$480,048**
Contracts and Services								
							Sub Total	-
Equipment, Tools, and Supplies								
	Tools and Supplies	The requested budget for materials and supplies encompasses various consumables essential for the project's operations. These expenses are estimated based on previous supply purchases and include energetic polymer binders and plasticizers totaling $10,000 per year, oxidizer and forest duff amounting to $5,000 per year, and curing agent, reagent, stabilizer, and catalyst totaling $3,000 per year. Additionally, cleaning chemicals are budgeted at $500 per year, with controls and wiring allocated $1,000 per year, and mechanical parts and fasteners set at $500 per year. These supplies encompass items such as soils, duff,	The requested budget for materials and supplies is essential for supporting the duff burning facility experiments. Energetic polymer binders and plasticizers enable stable duff fuel formulation, facilitating controlled combustion experiments. Oxidizer and forest duff provide realistic fire scenarios for studying ignition and propagation dynamics. Additionally, curing agents, stabilizers, and cleaning chemicals ensure material stability and					$53,119

		oxidizers, duff fuels, chemicals, as well as miscellaneous consumables required for conducting experiments and maintaining equipment.	equipment maintenance, contributing to reliable experimental outcomes. Controls, wiring, and mechanical parts are vital for setup operation and safety. Overall, these supplies are critical for conducting comprehensive experiments and gaining insights into forest fire dynamics.					
							Sub Total	**$53,119**
Capital Expenditures								
		Camera system, Data Acquisition (DAQ) system, Soil temperature measurement thermocouples, Radiant heater Protective enclosures for electronic components ,Software for data analysis and visualization, Calibration equipment for thermocouples, Mounting hardware and brackets for installation, Safety equipment (e.g., fire extinguishers, protective gear)	The budget allocated for the instrumentation of the duff burning facility encompasses various essential components necessary for comprehensive data collection and analysis. This includes acquiring a camera system to capture visual data during the burning process, a Data Acquisition (DAQ) system to record and monitor critical parameters in real-time, soil temperature measurement thermocouples for precise temperature monitoring of the soil surface and subsurface layers, and a radiant heater to facilitate controlled burning experiments. Each of these instruments plays a crucial role in enabling researchers to observe, analyze, and understand the dynamics of duff burning behavior, providing valuable insights into fire management strategies and forest ecosystem dynamics.	X				$35,833
							Sub Total	**$35,833**
Acquisitions and Stewardship								
							Sub Total	**-**

Travel In Minnesota								
	Other	a) Travelling to different MN prescribed burn sites, forest to collect different duff species, and travel to different forest in general to understand their environmental conditions, biweekly/monthly for 6 months, b) One trip per year for PI, Co-PIs and graduate students to a relevant conference	Testing campaign, resource management, duff collection, knowledge dissemination and attract potential customers/end-users					$25,000
							Sub Total	**$25,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Publication cost in open source journals	Open source journal let everyone access the research results at free of cost					$2,000
							Sub Total	**$2,000**
Other Expenses								
		Scientific Services	We will utilize three services to synthesize and characterize the soil post-ash burning: (i) The Characterization Facility, offering TEM, SEM, and EDX analysis. (ii) The Minnesota Nano Center for CNT and BNNT fabrication. (iii) A soil testing facility. Estimates are based on previous user fees. For instance, considering 30 soil tests at 12 square feet each and across 3 depth intervals, totaling 1,080 samples, we aim to target approximately 250 samples by reducing resolutions. Pre-burning characterization will require about 60 samples. The cost for analyzing Total C+Total N is estimated at $155 per sample, totaling $48,050 for 310 samples. Additionally, we plan					$80,000

			to manufacture 5 Modified Philip-Dunne (MPD) infiltrators at a cost of $2,500 in Year 1. Furthermore, we budget $2,000 annually for field and lab supplies. To transport soil to the experimental facility, we plan to rent a construction truck with a driver for Year 1 and Year 2, allocating $2,500 per year. This allocation considers the logistics of handling approximately 10 tons of soil material resulting from 30 experiments, each involving a 12 square feet area at 30 cm depth.					
		Maintenance	During Year 1 and 2, SAFL will assist in constructing the duff burning facility, while PI Biswas will oversee the installation of measurement instruments. The $12,000 allocated annually solely covers the construction costs (materials, etc.), troubleshooting, and maintenance expenses for Year 1 and Year 2. SAFL researchers' and technologists' time is accounted for separately in the personnel tab.					$24,000
							Sub Total	**$104,000**
							Grand Total	**$700,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Capital Expenditures		Camera system, Data Acquisition (DAQ) system, Soil temperature measurement thermocouples, Radiant heater Protective enclosures for electronic components ,Software for data analysis and visualization, Calibration equipment for thermocouples, Mounting hardware and brackets for installation, Safety equipment (e.g., fire extinguishers, protective gear)	The estimated costs for Year 1 and Year 2 are based on the PI's prior experience and consultations with university machinists and technicians for fixture and hardware construction. In Year 1, expenses include instrumentation for the duff burning facility ($15,000), imaging and sampling systems ($5,000), and fixture and fabrication equipment ($2,000). In Year 2, costs entail environmental chamber fabrication for thermal cycle testing ($13,000) and fixture design for structural testing ($833). **Additional Explanation :** The duff burning facility, a unique resource, will serve as a valuable facility for studying forest duff fire behavior in Minnesota forests not only for the duration of the project but also for years to come. Its establishment is anticipated to foster future collaborations between UMN and other fire managers.

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	unrecovered F&A calculated at 55% MTDC	Support of ME facilities where research will be conducted.	Secured	$306,743
			Non State Sub Total	**$306,743**
			Funds Total	**$306,743**

Total Project Cost: $1,006,743

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 667ce8f2-24b.pdf

Alternate Text for Visual Component

The visual representation illustrates the effects of duff burning on the forest ecosystem, including our proposed facility for duff burning, tools for measuring duff fires, methods for soil testing, and the potential impact of our study....

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
article 3	1b188edd-150.pdf
article 2	4d2fa92b-e12.pdf
article 1	9751fe63-350.pdf
Importance of duff burning	cb6ed2f1-b4a.pdf
UMN SPA Letter of Support	5637befb-94d.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Do you understand that travel expenses are only approved if they follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?

Yes, I understand the UMN Policy on travel applies.

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

Yes

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

Yes

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

No

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

No

Does your project include the pre-design, design, construction, or renovation of a building, trail, campground, or other fixed capital asset costing $10,000 or more or large-scale stream or wetland restoration?

No

Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services (as defined in Minnesota Statutes section 299C.61 Subd.7 as "the provision of care, treatment, education, training, instruction, or recreation to children")?

No

Provide the name(s) and organization(s) of additional individuals assisting in the completion of this proposal:

Alex Sullivan, U of MN

Do you understand that a named service contract does not constitute a funder-designated subrecipient or approval of a sole-source contract? In other words, a service contract entity is only approved if it has been selected according to the contracting rules identified in state law and policy for organizations that receive ENRTF funds through direct appropriations, or in the DNR's reimbursement manual for non-state organizations. These rules may include competitive bidding and prevailing wage requirements

N/A