Environment and Natural Resources Trust Fund

M.L. 2025 Approved Work Plan

General Information

ID Number: 2025-219

Staff Lead: Lisa Bigaouette

Date this document submitted to LCCMR: June 19, 2025

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

Project Budget: $646,000

Project Manager Information

Name: Lee Frelich

Organization: U of MN - College of Food, Agricultural and Natural Resource Sciences

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Project Reporting

Date Work Plan Approved by LCCMR: June 24, 2025

Reporting Schedule: March 1 / September 1 of each year.

Project Completion: June 30, 2028

Final Report Due Date: August 14, 2028

Legal Information

Legal Citation: M.L. 2025, First Special Session, Chp. 1, Art. 2, Sec. 2, Subd. 08k

Appropriation Language: $646,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to thoroughly investigate the impact of forest floor duff fires on soil dynamics, nutrient cycles, invasive shrubs, earthworms, and root systems to improve fire management for Minnesota's forest preservation. This appropriation may also be used to develop an outdoor lab-scale duff-burning device.

Appropriation End Date: June 30, 2028

Narrative

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.

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 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 mobile duff burning-monitoring 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 mobile duff burning-monitoring 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, K, 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

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 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.

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

Activities and Milestones

Activity 1: Development, instrumentation, and commissioning of a mobile duff burning-monitoring facility

Activity Budget: $210,000

Activity Description:
In this activity, we will construct, instrument, commission, and test an outdoor mobile duff burning-monitoring 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 carried out by the Saint Anthony Falls Lab (SAFL) Co-PIs. To be mobile, this facility will be equipped with gasoline-powered generators and water reservoirs.
The Co-PIs at SAFL possess a wide array of engineering skills. Collaborating closely with Project Manager Frelich and Co-PI Yoo, Co-PIs at SAFL will ensure that the duff burning facility accurately simulates real forest bed conditions, that the experimental fires can be characterized as to flame length and heat output, and that impacts on the soil can be characterized as to flame length and heat output, and that impacts on the soil can be measured, e.g. via thermocouples and other data acquisition systems. 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	March 31, 2026
Complete a series of safety and calibration tests and commission the facility	May 31, 2026
Activity 1 summary report	June 30, 2026

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

Activity Budget: $160,000

Activity Description:
Over a six-month period from May 1 to October 31 in 2026 and 2027, 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 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	October 31, 2026
Complete studying the effect of dry lag time on duff burning and prescription burn in	October 31, 2027

In-situ and ex-situ testing of pre- and post-combustion analysis of organic matter	October 31, 2027
Complete analysis of all the lab-scale testing data	December 31, 2027
Activity 2 summary report	March 31, 2028

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

Activity Budget: $220,000

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, and P), hydrophobicity, and water infiltration rates. 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. Forest 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 the analysis of soil samples collected from the first year	March 31, 2027
Complete water infiltration measurements along with the first test campaign with varying duff and soil	October 31, 2027
Complete the analysis of soil samples collected from the experiments conducted in year 2	March 31, 2028
Activity 3 Summary report	May 31, 2028

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

Activity Budget: $40,000

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 and field testing, if necessary	October 31, 2027
Perform additional measurements during field prescription burns, if necessary	October 31, 2027
Prepare a brief summary of learnings for dissemination to fire managers	December 31, 2027
Activity 4 Summary report	May 31, 2028

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

Activity Budget: $16,000

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 at conferences and other meetings.

Activity Milestones:

Description	Approximate Completion Date
File IP and patents if necessary before any public disclose of research results	September 30, 2027
Finished writing the first draft of journal/conference articles	March 31, 2028
Activity 5 summary report	May 31, 2028
Final project report	June 30, 2028

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
Matthew Lueker	Saint Anthony Falls Laboratory	Matthew Lueker will provide technical support for construction of the experimental duff burning apparatus	Yes

Dissemination

Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.
Plans for dissemination, presentation, documentation, and sharing

Our approach to dissemination and sharing is guided by the following goals:

- Engaging beneficiaries: We will actively involve and inform stakeholders such as forest and fire managers, soil surveyors, and land managers throughout the research process. This will be achieved through regular updates, relevant workshops, and collaborative meetings (virtual/in-person) to ensure that those who could benefit most from our findings are aware of the ongoing research and its potential implications.

- Sharing results for resource management: Research findings will be disseminated through a combination of scientific publications, technical reports, and presentations at relevant conferences and workshops. Additionally, we will provide tailored briefings and summaries to resource management entities in Minnesota to help them apply the results to

improve land and resource management practices.

- Ensuring longevity of collections and products: All physical collections, data, and other products generated from this research will be carefully documented and preserved. We will collaborate with local institutions and repositories to ensure that these materials are accessible for future research and reference. This will include archiving datasets in publicly accessible databases and ensuring the long-term availability of any physical samples or collections.

- Promoting behavioral change: Our outreach efforts will include educational materials, policy briefs, and community engagement initiatives aimed at promoting behaviors that better protect, conserve, and enhance Minnesota's environment and natural resources. We will work with local organizations, schools, and community groups to raise awareness and encourage the adoption of best practices informed by our research.

- Communicating with Minnesotans: We are committed to sharing our work with the broader Minnesota public in an accessible and engaging manner. This will involve creating informational content such as articles, videos, and presentations designed for non-technical audiences, which will be distributed through various media channels, including social media, public talks, and partnerships with local news outlets. Additionally, we will participate in community events and exhibitions to showcase the progress and impact of our research, highlighting the role of the Environment and Natural Resources Trust Fund in making this work possible.

The official ENTRF attribution language and logo will be included in all presentations, print and electronic publications, signage, or other communications based on this project, and the attribution language will also be included in the Acknowledgements section of any peer-reviewed journal articles that result from this project.

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.

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

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Lee Frelich		Co-PI			27.06%	0.2		$15,810
Kyungsoo Yoo		Co-PI			27.06%	0.1		$19,092
LAAS Research Assistant 1		Research Assistant			45.74%	1.5		$196,769
Ben Erickson		Senior Personnel			36%	0.03		$7,017
Erik Noren		Senior Personnel			36.09%	0.06		$15,565
Chris Feist		Co-PI			36%	0.02		$4,000
Erik Steen		Senior Personnel			36.24%	0.02		$26,966
Undergraduate Students		Undergraduate Student lab and field assistants			0%	0.6		$20,000
LAAS Research Assistant 2		Graduate research assistant			45.74%	1		$133,108
Matthew Lueker		Senior Personnel			36%	0.04		$10,800
							Sub Total	**$449,127**
Contracts and Services								
Soil testing laboratory, University of Minnesota	Internal services or fees (uncommon)	Estimated 320 soil samples to characterize changes in soil chemistry before and after experimental duff burning. Total C and N would cost about $155 per sample and other tests such as exchangeable cations and pH would cost $70 per sample. The total allocation for soil sample analyses is $72,000				0		$72,000
							Sub Total	**$72,000**
Equipment, Tools, and Supplies								
	Equipment	Camera system and Data Acquisition (DAQ) system, note that these two items are assembled from components that cost less than $5,000, so that they are not considered capital expenditures. Additional items: Soil temperature measurement	The budget allocated for the instrumentation of the duff burning facility encompasses various essential components necessary for comprehensive data collection and					$35,571

		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), and water tanks and gasoline generators to operate the mobile duff burning device in field locations.	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.					
	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, oxidizers, duff fuels, chemicals, as well as miscellaneous consumables required for conducting experiments and maintaining equipment.	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 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.					$24,802
	Equipment	Additionally, we plan to manufacture 5 Modified Philip-Dunne (MPD) infiltrators at a cost of $2,500 in Year 1.	The MPD measures hydraulic conductivity, in other words how					$2,500

			easily water can move into/through the soil					
	Tools and Supplies	We budget $2,000 annually for field and lab supplies.	Items such as soil corers for collecting soil samples, containers for storing and transporting samples, sieves for sorting soil, measurement devices and chemical reagents needed for soil analyses done in the lab by graduate students.					$6,000
	Tools and Supplies	Materials for construction and maintenance of the portable duff burning facility	During Year 1 and 2, Saint Anthony Falls lab personnel will construct the duff burning facility as well as carry out trouble shooting and maintenance (which is covered under personnel). However, they will use a variety of materials such as steel and glass, etc. to build and maintain the facility which is budgeted here.					$24,000
							Sub Total	**$92,873**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Other	Travelling to different MN prescribed burn sites, forests to collect different duff species, and travel to different forest in general to understand their environmental conditions. 4 trips to four field sites (tbd) in MN for PI Frelich and Co-PI Yoo, and 8 trips for each of 2 graduate students and an undergraduate field assistant.	Testing campaign, resource management, duff collection					$12,000
	Conference Registration Miles/ Meals/ Lodging	2 trips each for PI Frelich and Co-PI Yoo, and 1 trip for each of 2 graduate students to appropriate conferences	Dissemination of results to scientists and forest managers					$10,000

							Sub Total	**$22,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Publication costs for 2 publications in open source journals	Open source journal let everyone access the research results at free of cost					$5,000
							Sub Total	**$5,000**
Other Expenses								
		Truck rental	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.					$5,000
							Sub Total	**$5,000**
							Grand Total	**$646,000**

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 calculated at 55% MTDC	Support of ME facilities where research will be conducted.	Secured	$257,300
			Non State Sub Total	**$257,300**
			Funds Total	**$257,300**

Total Project Cost: $903,300

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
UMN SPA Letter of Support	5637befb-94d.pdf
Importance of duff burning	cb6ed2f1-b4a.pdf
article 1	9751fe63-350.pdf
article 2	4d2fa92b-e12.pdf
article 3	1b188edd-150.pdf
LCCMR 2025-219 Peer Review Research Addendum revised for new PI and timeline v5_Final	7c39feb9-fb9.docx

Difference between Proposal and Work Plan

Describe changes from Proposal to Work Plan Stage

Changed the budget to $646k (from original $700k)

- The project scope is unchanged
- Changed PI and Co-PI efforts
- Reduced travel and supplies

Added dissemination plan

Additional Acknowledgements and Conditions:

The following are acknowledgements and conditions beyond those already included in the above workplan:

Do you understand and acknowledge the ENRTF repayment requirements if the use of capital equipment changes?

N/A

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 project:

Alex Sullivan, U of MN; Dan Hegland, 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