Environment and Natural Resources Trust Fund

2026 Request for Proposal

General Information

Proposal ID: 2026-058

Proposal Title: Strategic Metal Mining/Remediation Using Minnesota-Hardy Plants

Project Manager Information

Name: Adrian Hegeman

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

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Project Basic Information

Project Summary: Minnesota-hardy plant species suitable for bio-extraction of strategic metals (nickel, copper, cobalt, and RREs) and removal of toxic elements (cadmium and arsenic) will be identified for phytomining and phytoremediation.

ENRTF Funds Requested: $1,493,000

Proposed Project Completion: June 30, 2029

LCCMR Funding Category: Land (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?

In the Future

Narrative

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

Minnesota holds significant undeveloped copper-nickel deposits, particularly within the Duluth Complex, and is a key area for US strategic metal supply, including copper, nickel, cobalt, and platinum group metals. These resources overlap with popular outdoor recreational and fragile environmental areas along the north shore of Lake Superior and the Boundary Waters Canoe Area (BWCA) which has made mineral extraction through traditional mining approaches highly unpopular despite potential economic benefits. Alternatively, plants that extract metals into their tissues can be harvested for 'phytomining' as an environmentally less disruptive extraction strategy that does not employ large scale ore excavation or chemical treatments that have the potential (real or imagined) for contamination of surface water or other negative impacts. Commercial nickel phytomining is operational in parts of France and the Balkans (see metalplant.com) with soils similar to those in NE Minnesota. While many metal hyperaccumulating plant species suitable for phytomining have been identified worldwide, scarcely any are suitable for use in the metal-rich boreal forest ecosystems in the NE part of our state, Wisconsin, Michigan and parts of Canada. Other opportunities for use of metal accumulating plant species exist in other parts of Minnesota that also need exploration.

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 will address the lack of Minnesota-hardy metal accumulating plant resources by performing a comprehensive survey of metal accumulation in Minnesota woody and herbaceous plants. Previously identified hyperaccumulator species that may be adapted for use in Minnesota or native relatives of previously identified metal accumulators will be collected and carefully assessed for their metal accumulation potential. These assessments will also identify plant species that can be used for phytoremediation, which is the removal of toxic metals like lead, mercury, and cadmium, and metalloids like arsenic and selenium from soils via a similar mechanism of hyperaccumulation followed by biomass harvest, processing, and safe disposal. In addition to identifying MN-hardy plants capable of extracting nickel, copper and cobalt from the well-documented metal resources of the Duluth Complex we will survey the phytomining potential for Rare Earth Elements (REEs). REEs are strategically important because of their use in military and other high-tech applications, and we currently rely on China for their production. Minnesota is not recognized for having concentrations of REEs suitable for traditional mining operations but REE phytomining approaches may be well suited for recovery of these low abundance but omnipresent elements from agricultural systems using cover crops such as pennycress.

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?

Plant species identified for phytomining and remediation will have complementary roles with existing MN mining operations for processing of low-grade materials, getting access to minerals near environmentally sensitive regions (like the BWCA), and detoxification of tailings that often contain high levels of arsenic or heavy metals. If implemented in consultation with stakeholders and sensitivity to ecological impact, phytomining can unlock some economic potential of the Duluth Complex mineral resources without imposing the environmental risks associated with conventional mining. Plants identified for phytoremediation will be generally useful for detoxification of soils contaminated with unsafe levels of toxic metals or metalloids.

Activities and Milestones

Activity 1: Establishing state-of-the art ICP-MS metal analysis capabilities in CFANS at the UMN adjacent to plant, agriculture and bioprocessing expertise

Activity Budget: $595,141

Activity Description:
An Inductively Coupled Plasma-Mass Spectrometer (ICP-MS) Instrument will be purchased through the UMN competitive bidding process and installed in the Plant Metabolomics Laboratory shared instrumentation facility in CFANS on the Saint Paul Campus. The instrument will be operated by a postdoctoral associate who will be recruited from recently graduated Analytical Chemistry PhDs and trained to run the instrument efficiently. Given the numbers of samples that we will need to analyze and the cost of submitting samples for external analysis this is clearly the most cost-effective course of action and will dramatically speed up analysis turnaround time. Assuming external ICP-MS rates could be negotiated down to $100 per sample (Penn State for example charges $287.20 per samples for academic labs) we would be able to perform 6,000 analyses over the 3-year course of the grant where as we should be able to process nearly 25,000-30,000 samples for the same cost with the proposed instrumentation (that assumes ~6 month delay to start-up in Y1 and ~40% downtime for cleaning/maintenance both of which are high estimates). Instrumentation will be an asset for further phytomining and remediation research moving forward and will be managed on a cost-per-fee basis.

Activity Milestones:

Description	Approximate Completion Date
Purchase and Installation of ICP-MS	October 31, 2026
Onboarding staff and training on use of instrumentation, SOP development.	November 30, 2026
Optimize sample analysis pipeline (expected ~1,000 samples per month)	March 31, 2027
Project sample analysis completion est. 25,000-30,000 samples.	June 30, 2029
Development of fee structure for continued support of instrument repair and maintenance until fully depreciated	June 30, 2029

Activity 2: Survey of Minnesota-hardy plants for metal and metalloid accumulation

Activity Budget: $371,108

Activity Description:
Minnesota is estimated to have around 2,100 species of plants with ~ 300 of these being rare or endangered and another 300 or so non-vascular plants (mosses etc.). Of the 1,400 or so remaining species, their suitability for phytomining and remediation will vary based on abundance, growth habit and related factors. We intend to examine plants that grow in a range of habitats within coniferous forest, deciduous forest, prairie grassland, and aspen parkland biomes. Initial target species lists will be developed for each biome based on suitability for phytomining and remediation. Tens of individuals of each species (depending on range and abundance) will be identified, GPS tagged and sampled across their range. Individuals will be sampled multiple times to account for different tissues and will be accompanied by local soil samples (all barcoded). Note, if 25 individuals are selected with 4 samples, that species will have ~100 samples, therefore, roughly 10 species can be analyzed per month under activity 1. This would accommodate only ~250 species; sampling within a species will be initially less frequent to accommodate additional species biodiversity. Promising species (showing higher accumulation) will receive additional sampling to best evaluate metal bioaccumulation vs. local soil mineral content.

Activity Milestones:

Description	Approximate Completion Date

Initial target species list development per biome	July 31, 2026
Target species reassessment and expansion/reduction.	April 30, 2028
Survey completion	June 30, 2029

Activity 3: Evaluation of target plant hyperaccumulation capacity in common garden experiments.

Activity Budget: $325,437

Activity Description:
While Activity 2 will identify species exhibiting metal/metalloid accumulation in their native ranges, it is difficult to compare capacity for metal accumulation without: 1) selecting a genetically representative sample of that species; 2) growing them under identical environmental conditions, and 3) providing them with identical levels of bioavailable metals. To do this we will establish a common garden experimental plot and a greenhouse space using soils with various formulations of metals including nickel, copper, cobalt, Rare Earth Elements (REEs), platinum group metals (PGMs), lead, mercury, and cadmium and metalloids arsenic and selenium to test metal accumulation in plants under controlled conditions. Initially, we will grow known metal accumulators that may be adapted to Minnesota and related MN species; we will add promising species from Activity 2 as they are identified. This Activity will be performed at the centrally located Saint Paul campus facilities; we recognize that latter stage experimentation (beyond the scope of this proposal) will need to include additional replicated sites that include targeted mineral soils and environmental conditions (for which we plan to work with Research and Outreach Centers). Plant grown within these controlled growth experiments will be sampled and evaluated for metal accumulation via Activity 1.

Activity Milestones:

Description	Approximate Completion Date
Generate list and start collection of MN-adaptable hyperaccumulators and their MN relatives	July 31, 2026
Determine metal/metalloid soil concentrations and chemical form for test plots and containment methods	July 31, 2026
Establish MN-adaptable hyperaccumulators and their MN relatives in common garden/greenhouse plots	June 30, 2027
Collect and transfer promising species from Activity 2 to common garden/greenhouse	June 30, 2028
Complete assessment of plant hyperaccumulation capabilities from common garden experiments	June 30, 2029

Activity 4: Testing biomass conversion strategies and envisioning cropping systems and scalability

Activity Budget: $201,314

Activity Description:
Much of this activity will depend on the plant material and the metals accumulated, which are currently unknown. We can anticipate that experimentation will be needed to evaluate the best options for cropping systems and biomass harvest as well as conversion strategies for biomass into usable metal refining source materials. These activities will be accomplished in collaboration with the Agricultural Utilization Research Institute (AURI) or comparable consultant contractor as species with metal accumulation potential are identified. A graduate student will be the lead for this activity as suitable research questions will arise from this activity and carry forward into subsequent research as part of their PhD thesis. Regular formal project meetings are proposed as milestones but informal communication around experimental design will also occur late in the project in preparation for subsequent experimental and funding plans.

Activity Milestones:

Description	Approximate Completion Date

Contract bidding process for consulting on biomass conversion and research translation	September 30, 2026
Project initiation meeting with consultant (AURI or alt.)	December 31, 2026
Annual project meeting with consultant	May 31, 2027
Annual project meeting with consultant	May 31, 2028
Final phase 1 project meeting with consultant	May 31, 2029

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Dr. Brandon Miller	U of MN, Department of Horticultural Science	Co-PI (Assistant Professor) Brandon Miller's research program centers on the identification, assessment, and characterization of unique, underutilized woody and herbaceous ornamental perennials for resiliency in landscapes. He is the Curator of Plant Collections at the Minnesota Landscape Arboretum and will direct plant collection and common garden activities (Activities 2&3).	Yes
Dr. Luca Zullo	The Agricultural Utilization Research Institute (AURI)	Dr. Zullo is the Sr. Director of Science and Technology at AURI. He brings experience in the petrochemical industry (Shell) and in bioprocessing (Cargill) and a Ph.D. in Chemical Engineering. He and AURI and will be engaged in testing biomass-conversion strategies and envisioning cropping systems and scalability (Activity 4).	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?

State of the art instrumentation (ICP-MS) for metal analysis will be installed, operated, and maintained on a fee-for-service basis in the Plant Metabolomics Laboratory on the UMN Saint Paul campus. Metal analysis capabilities and MN botanical metal accumulation surveys constitute the initial phase in establishing a UMN Center for Phytomining and Bioremediation that will work alongside the Forever Green Initiative, the MDA, AURI, the MN Mining Industry,and others to improve MN environmental health and support the Bioeconomy. We will pursue US-DOE's Advanced Research Projects Agency-Energy's (ARPA-E) PHYTOMINES program, industry, and other funding to support our continued efforts.

Project Manager and Organization Qualifications

Project Manager Name: Adrian Hegeman

Job Title: Professor, Departments of Horticultural Science and Plant and Microbial Biology

Provide description of the project manager's qualifications to manage the proposed project.

Hegeman has been the co-director of the Plant Metabolomics Laboratory in the College of Food, Agriculture and Natural Resource Sciences at the University of Minnesota (2011–2025). He has extensive leadership experience having served as PI and Co-PI on numerous research grants from industry and federal and state agencies totaling over $30M since joining the UMN faculty in 2007. As an experienced Biochemist and Plant Metabolomics researcher residing in the Department of Horticultural Science he has mostly been involved in interdisciplinary collaborative projects on various subjects from fruit aroma chemistry, insect pest control, equine poisoning by Box Elder seeds, to discovering new plant pigment molecules. He also maintains a core research program that has developed new strategies for using stable isotopes of carbon, hydrogen, nitrogen, oxygen and sulfur coupled with mass spectrometry to study fundamentals of plant and animal (sometimes even human!) biology.

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

Organization Description:

Plant Metabolomics Laboratory in the College of Food, Agriculture and Natural Resource Sciences on the UMN Saint Paul campus is directly adjacent to multiple Departments with faculty expertise in plant materials, plant breeding, biochemistry, soil science, forestry, cropping systems, applied economics, and biomaterials processing to facilitate the exchange of ideas needed to fully explore the potential of phytomining and phytoremediation approaches. The broader UMN-Twin cities campus (all within a 20-30 min bus ride) hosts additional colleagues with further expertise and

resources in geology, chemistry, chemical engineering, biochemistry, environmental health and social sciences which can be called upon as the project develops.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Staff Member To Be Determined		Other Professional/Plant Sampling and Common Garden Set-up and Maintenance			36.6%	3		$339,448
Staff Member To Be Determined		Other Professional/Plant Sampling			36.6%	1		$115,084
Staff Member To Be Determined		Postdoctoral Associate/ Operation of ICP-MS, sample and data processing			25.9%	3		$246,376
Staff Member To Be Determined		Graduate Student/ Common garden design and coordination with analysis			23.2%	1.5		$123,609
Staff Members To Be Determined		Undergraduate Students/ assist with collection, plant propagation and analysis			0%	1.74		$64,800
							Sub Total	**$889,317**
Contracts and Services								
Agricultural Utilization Research Institute	Service Contract	Professional and consultation services will be provided by AURI to aid in biomass processing strategies, translation to subsequent industrial applications and social and economic feasibility studies				0		$110,000
Mass spectrometry and soil analysis service fees	Internal services or fees (uncommon)	Funds are requested for external verification of metal analysis protocols via soil analysis lab and analysis of non-metal analytes via mass spectrometry lab services				0		$2,400

Greenhouse and Field plot fees	Internal services or fees (uncommon)	Fees to cover greenhouse and field plot space and support				0		$32,000
							Sub Total	**$144,400**
Equipment, Tools, and Supplies								
	Equipment	ICP-MS Metal Analysis Instrumentation and Microwave Digestion apparatus	Instrumentation for sample processing and metal analysis. ICP-MS cost has a quote from Agilent attached for $295,650. Several options for the Microwave Digester are widely available (lowest cost for $17,115). Both items will be placed in a shared use facility (Plant Metabolomics Lab) where they will be operated and maintained on a fee for service basis after the completion of the project.					$312,765
	Tools and Supplies	Lab and Field supplies	Supplies for samples collection extraction and analysis including argon gas for ICP-MS operations. Metal standards for quantification and common garden experiments. Field and greenhouse and plant collection supplies.					$80,000
							Sub Total	**$392,765**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	$1,400 for lodging for ~14 overnight trips around Minnesota; mileage for multiple excursions around	Plant collection excursions					$5,600

							Sub Total	**$5,600**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
		Repairs and maintenance	Pay for minor remodeling such as electrical and ventilation for ICP-MS instrumentation and minor repairs					$1,900
		Graduate Student Tuition	Pay for graduate student tuition so that they can focus on research project					$59,018
							Sub Total	**$60,918**
							Grand Total	**$1,493,000**

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				
			Non State Sub Total	**-**
			Funds Total	**-**

Total Project Cost: $1,493,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: a7d4fc8e-a6c.pdf

Alternate Text for Visual Component

Visual shows pictures of nickel mining operations overseas, locations of biomes and Duluth Complex in Minnesota, and lists project activities....

Supplemental Attachments

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

Title	File
Letter of Support_UMN AOR	349b4c32-be8.pdf
ICP-MS Instrumentation Quote	dee3d851-07c.pdf
AURI Letter of Support	d66299c7-2b4.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?

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?

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:

none

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

Yes, I understand