Environment and Natural Resources Trust Fund

2027 Request for Proposal

General Information

Proposal ID: 2027-058

Proposal Title: Planting for Mineral Extraction and Soil/Water Improvement

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: To identify Minnesota-hardy plants for multiple land use cases for extraction of toxic or economically valuable metals, and to test processes for metal enriched plant biomass conversion and metal extraction.

ENRTF Funds Requested: $498,000

Proposed Project Completion: June 30, 2030

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.

Different types of plants have the ability to hyperaccumulate specific metals and are used in other parts of the world for soil/water remediation and mineral extraction (phytomining). For remediation, an appropriate plant is grown on contaminated soil to sequester toxic metals (like lead). The plants are harvested and safely disposed to affect net soil detoxification. For phytomining, plants that accumulate strategically important minerals such as rare earth elements (REEs) can be used as an alternative to large-scale ore excavation with its potential negative environmental impacts. Mineral extraction could also be accomplished in multi-use landscapes by employing cropping strategies compatible with function (urban residential, recreational, agricultural, forestry, parkland etc.) For example, cover crop species with the ability to hyperaccumulate REEs could be used in corn/soy agricultural setting to add economic value through marketable REE-enriched biomass for subsequent extraction. Alternatively, a lead-accumulating turfgrass could be used with clipping removal to remediate contaminated soils in contaminated urban areas. Despite the economic and environmental potential, little is currently known about which plants would be suitable for these applications in our region, how they might best be incorporated into different land-use scenarios, or what the major economic limitations would be for their use.

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 identify MN-hardy metal hyperaccumulating plant species, explore their incorporation into different land-use scenarios, and examine the feasibility of their use for phytomining. We will address the knowledge deficit regarding Minnesota-hardy metal hyperaccumulating plants by testing accumulation capacity in a broad sampling of Minnesota native and adapted plants. Known 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. Plant species capable accumulating toxic metals like lead, mercury, and cadmium, and metalloids like arsenic, selenium from soils will be identified for phytoremediation when grown followed by biomass harvest, processing, and safe disposal. Other plant species will be identified with the capacity for extracting strategically important nickel, copper, cobalt and Rare Earth Elements (REEs). Once usable plants are identified, strategies to integrate them into different land use cases compatible with biomass recovery will be designed to accommodate different remediation or extraction goals. Integration of phytoremediation and phytomining strategies into agricultural systems will be tested with the Agricultural Utilization Research Institute. For phytomining applications, we will develop small-scale sustainable processes for critical mineral concentration and recovery to assess overall economic feasibility.

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?

Major economics activities such as agriculture and mining can have significant negative impacts on soil and water quality. These impacts can be minimized by establishing best practices, monitoring soil and water quality and enforcing regulations. But impacts can still appear over time as contamination accrues or as historical impacts are discovered. By identifying a series of economically feasible hyperaccumulator plant/cropping system/land use case/biomass processing pipeline scenarios for phytoremediation and phytomining activities we are providing commercially viable tools for soil and water protection and a less environmentally risky mechanism for strategic mineral extraction than conventional mining operations.

Activities and Milestones

Activity 1: Survey and evaluation of target plant hyperaccumulation capacity for metal and metalloid accumulation

Activity Budget: $150,000

Activity Description:
Minnesota is estimated to have around 2,100 species of plants with ~300 of these being rare/endangered and another ~300 non-vascular plants (mosses etc.). Of the ~1,400 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. Metal accumulation capacity will be assessed in experimental plots or greenhouse space using soils with various formulations of metals including nickel, copper, cobalt, Rare Earth Elements (REEs), lead, mercury, and cadmium and metalloids arsenic and selenium to test metal accumulation in plants under controlled conditions. This Activity will be performed at the 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 ICP-MS.

Activity Milestones:

Description	Approximate Completion Date
Initial target species list development per biome and begin collection	July 31, 2027
Determine metal/metalloid soil concentrations and chemical form for test plots and containment methods	August 31, 2027
Establish MN-adaptable hyperaccumulators and their MN relatives in common garden/greenhouse plots	June 30, 2028
Survey completion	June 30, 2030

Activity 2: Testing biomass conversion strategies and envisioning cropping systems for different land use cases and scalability

Activity Budget: $140,000

Activity Description:
We will perform a broad based, multi-pipeline feasibility study, to examine different ways of employing hyperaccumulating plant species for phytoremediation and phytomining in different land use situations (urban residential, recreational, agricultural, forestry, parkland etc.). Much of this activity will depend on the plant materials and the metals accumulated, which are currently unknown. We will begin work using by documenting existing soli contamination and metal extraction opportunities in different landscapes and then match them with plants identified in Activity 1. We can anticipate that experimentation will be needed to evaluate the best options for cropping systems in different land use cases, and for biomass harvest and conversion strategies 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, 2027
Project initiation meeting with consultant (AURI or alt.)	January 31, 2028
Annual project meeting with consultant	May 31, 2028
Annual project meeting with consultant	May 31, 2029
Final phase 1 project meeting with consultant	May 31, 2030

Activity 3: Rare Earth Elements (REEs) as a model for developing sustainable critical mineral concentration and recovery strategies

Activity Budget: $208,000

Activity Description:

An integrated processing platform will be established to recover REEs from biomass while maximizing biomass utilization, solvent recyclability, economic viability and minimizing environmental footprint. The first pathway will apply a green hydrometallurgical strategy to extract REEs from milled biomass. Environmentally benign lixiviants, including organic acids and deep eutectic solvents, will be systematically evaluated based on leaching kinetics, complexation strength, selectivity against competing metals such as calcium, iron, and aluminum, and solvent stability. A structured experimental design using factorial or response surface methodology will optimize key parameters, including pH, temperature, solid to liquid ratio, particle size, agitation speed, and residence time. Metal recovery efficiency, selectivity coefficients, and solvent reuse performance will be measured to guide process improvement. Following leaching, REEs will be purified through selective precipitation or green solvent extraction to obtain high purity fractions. Demineralized biomass will be valorized through enzymatic hydrolysis and fermentation to produce ethanol and bio-based solvents that offset process energy demand. Techno economic analysis and life cycle assessment will be developed based on experimental data as well as legit assumptions to quantify capital cost, operating cost, energy balance, and environmental impacts to support process optimization and scale up.

Activity Milestones:

Description	Approximate Completion Date
Develop and optimize an environmentally friendly hydrometallurgical process to extract REEs from the collected biomass	July 31, 2028
Convert the biomass residue after bioleaching into bioenergy and bio-based solvents	July 31, 2029
Develop TEA and LCA models to access the economic and environmental benefits of phytomining	June 30, 2030

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Dr. Xiaowen Chen	Department of Bioproducts and Biosystems Engineering	Co-PI (Assistant Professor) Will be leading Activity 3 to develop a sustainable process for critical mineral concentration and recovery, and co-advising the graduate student working on this project.	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

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.
Results from this project will be documented and published in peer-reviewed scientific journals. Findings will be communicated to Extension personnel on an annual basis for communication to the general public. Outreach will also be coordinated with the Forever Green Initiative and AURI.

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?
Metal analysis capabilities, MN botanical metal accumulation surveys and sustainable processes for critical mineral concentration and recovery constitute the initial phase in establishing a UMN Center for Phytomining and Phytoremediation 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, USDA-Strengthening Agricultural Systems program, industry, and other funding to support our continued efforts.

Project Manager and Organization Qualifications

Project Manager Name: Adrian Hegeman

Job Title: Interim Department Head, Department of Horticultural Science; Professor, Department 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								
Research Professional 6-Analytical Chemist		Perform metals analysis and extraction of plant materials			36.6%	1.35		$153,405
Graduate Research Assistant		Biomass production and conversion			24.2%	3		$128,963
Undergraduate Research Assistant		Work with graduate student on Biomass production, collection and conversion			0%	0.09		$8,262
							Sub Total	**$290,630**
Contracts and Services								
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		$100,000
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 on a fee per sample basis that typically ranges between $20 and $100 per sample by analysis type.				0		$3,600
Greenhouse and Field plot fees	Internal services or fees (uncommon)	Fees to cover greenhouse and field plot space and support. 230 square feet greenhouse bench space ($3,250 per year, $9750 total). 1 acer field plot @$250 per acer per year ($750 total).				0		$12,000
							Sub Total	**$115,600**
Equipment, Tools, and Supplies								
	Tools and Supplies	Lab and field supplies	Supplies for samples collection extraction and analysis including					$27,991

			argon gas for ICP-MS operations. Metal standards for quantification and common garden experiments. Field and greenhouse and plant collection supplies. Supplies and reagents for testing biomass conversion.					
							Sub Total	**$27,991**
Capital Equipment								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	$800 total for: lodging for ~3 overnight plant collection trips in Minnesota with $110 per trip ($330 per year); $68 M&IE per diem ($204 per year); and $0.725 per mile in personal vehicle (total 367 miles totaling $266).	plant collection trips around Minnesota					$2,400
							Sub Total	**$2,400**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
		Graduate Student Tuition	Pay for graduate student tuition so that they can focus on research project					$61,379
							Sub Total	**$61,379**

							Grand Total	**$498,000**

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: $498,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 9b2f6e47-7e9.pdf

Alternate Text for Visual Component

Visual shows a scheme of a plant removing metals (either toxic or valuable) from the soil and accumulating them in the above ground tissues, pictures of nickel mining operations overseas, locations of biomes from which hyper accumulating plants will be identified in Minnesota, and lists project activities....

Supplemental Attachments

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

Title	File
UMN institutional Letter of support	d861ffe7-e7f.pdf
AURI Letter of Support	927b9131-7b1.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