Environment and Natural Resources Trust Fund

2022 Request for Proposal

General Information

Proposal ID: 2022-214

Proposal Title: Phytoremediation for Extracting Deicing Salt

Project Manager Information

Name: Bo Hu

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

Office Telephone: (612) 625-4215

Email: bhu@umn.edu

Project Basic Information

Project Summary: We propose to develop application methods to apply native plants that can adsorb salts to be planted on the roadside to address the environmental concerns over deicing road salts.

Funds Requested: $507,000

Proposed Project Completion: June 30 2025

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

Project Location

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

Statewide

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

Statewide

When will the work impact occur?

During the Project and In the Future

Narrative

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

The icy conditions of Minnesotan winters require aggressive applications of road salts to melt the snow on sidewalks and roads. The continued contamination of salt can negatively affect the health of surrounding ecosystem. It is easy to leach into lakes, rivers, and groundwater, causing significantly increased salinity. Many lakes (for instance, Loring pond and Diamond lake) around the Twin Cities have already been reported to have chloride concentrations consistently surpassing the environmental standard of 230 mg/L. High salt conditions can also negatively affect both plant growth and soil structure. Contaminated soil can affect up to 10 m off of a roadside increasing soil density and alkalinity causing problems with erosion and vegetation. Phytoremediation is an emerging method to extract salts from the soil by utilizing the growth of certain plants and then remove salts by harvesting the plant biomass. These plants are typically halophytes, which excrete salt ions through specialized leaf glands. The harvested halophytic plant biomass may have some industrial applications, for instance, serving as animal feed or energy source. Phytoremediation has numerous advantages over the conventional techniques for salt remediation, such as removing the contaminated soil to landfill while replacing it with clean soil, leaching, chemical amendments.

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

LCCMR funded our research project (July 2019-June 2022) to study possible native plants that can be used for phytoremediation of road salts. With this support, we have developed an inventory list of possible native halophytes, are testing several potential top roadside plant species in the greenhouse study, and are planning to grow these plants outside on the roadside in collaboration with MnDOT. The outcome of the current project provides a solid foundation for this approach and we are requesting a continuation of the project support to further develop application methods to be use for roadside for salt remediation. The continuation project will first study how these halophytes will survive and interact with other roadside vegetation; we will also study how these interactions will affect the overall road removal efficiency. We will then apply ecological engineering principles to develop different application methods, for instance rain gardens for roadside soil and floating islands for water bodies, for use as remediation solutions. Finally, as a way to optimize the effectiveness of salt uptake by plants, we will explore how soil microbial communities can help plants assimilate salts with the goal of developing biofertilization approaches for salt remediation on Minnesota roadsides.

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?

This project is based on our current research and will provide a comprehensive methodology to apply native halophytes to the roadside environment for salt remediation. The specific outcomes of the project include three aspects to the road-salt phytoremediation: 1, information on how to mix the halophytes with current roadside plants and how they adapt to the local environment; 2, what ecological design methods are available to apply halophytes for roadside salt remediation; 3, a new microbial biofertilizer to increase and maintain the plant capability for salt tolerance and assimilation.

Activities and Milestones

Activity 1: Field study of halophyte mixed with roadside plants on different soils

Activity Budget: $166,000

Activity Description:
We are currently working with MNDOT to move some of our best plant species to the field testing stage in summer 2021. In the next step, we want to study different establishment and harvest methods to reach the optimized salt removal from roadside soil and water. We will plant single species, mixtures of halophytes, and mixtures of halophytes with non-halophytes at MnROAD Albertville roadside testing sites, representing at least 2 different soil types. We want to understand how competitive halophytes will be with other plant species and what harvest frequency is needed so that they will be able to remove salt in different growth environments. The selected specimen from the lab tests will be planted in the spring on this pilot testing lot and monitored for the entire growing season. We will measure the plant biomass, nitrogen (TN), phosphorus (TP and PO4-P), and the salt concentration in the shoots, roots, and soil. We will use this information to develop an implementation plan for how this species will be added into current regional seed mixtures for plantation diversity and how to maintain their growth.

Activity Milestones:

Description	Completion Date
Field study of halophytes growing with native roadside plants	June 30 2023
Harvesting methods for halophytes and native roadside plants	June 30 2023
Adaptation of halophytes to different types of roadside soil	June 30 2023

Activity 2: Application methods for roadside soil and waterbody

Activity Budget: $169,000

Activity Description:
We will use ecological design principles to develop application strategies, for instance, rain garden design for road side soil and floating islands placed in storm water ponds. Besides salt removal, we will investigate the nutrient removal efficiencies. For example, will nitrification (and loss of N to the atmosphere) be accounted for in the nutrient removal efficiencies, or will it be assumed that the plant used this portion of the N? Depending on the locations where we want to work on our field trial, we may either build a rain garden or wetland that halophytes will be planted in order to calculate the salt remediation as well as nutrient removal. This design is totally determined by the local hydrology conditions and we will consider the soil structure properties in the experiments. Designs will be modeled before construction to optimize the design efficiency and to provide modeling guidance for practitioners. The plan will also consider effects of this species on the roadside stabilization and safety, a better outcome for NPDES permit compliance for obtaining a uniform, perennial cover, changes to standard specification for construction activities, structural root system enhancement that increase the shear resistance for reducing soil slides, flood overtopping stability, etc.

Activity Milestones:

Description	Completion Date
Ecological designs of roadside soil application	January 31 2024
Aquaponics study for halophytic plants	March 31 2024
Floating island designs for nearby waterbody	June 30 2024

Activity 3: Fertilization microbes to enable plants for higher salt assimilation

Activity Budget: $172,000

Activity Description:

This activity will focus on a new perspective to fertilize or even enable current roadside plants for better salt tolerance and assimilation. Several microorganisms, including plant growth-promoting bacteria and arbuscular mycorrhizal fungi, have been shown to alleviate salt stress in various plant species. However, in nature, organisms exist in complex communities, and rhizosphere microbes may act synergistically to alleviate abiotic stresses. Our goal of this step is to elucidate the role of the rhizosphere microbial community in conferring salt tolerance to roadside plants and develop fertilization approaches to enable roadside plants for better salt assimilation. The research will include breeding a salt-tolerance microbiome through multiple generations of artificial selection, Identifying key microbial taxa and genes involved in microbially-mediated salt tolerance, and testing synthetic communities of microorganisms for their ability to assimilate salt into roadside plants. Microbiome engineering has been used to breed microbiomes associated with specific phenotypic traits in Arabidopsis and recently to confer salt tolerance in the model grass, Brachypodium. We expect that this approach will also work to breed a rhizosphere microbial community that increases salt assimilation to many roadside plants such as turf.

Activity Milestones:

Description	Completion Date
Microbial community to enable plants for salt assimilation	January 31 2025
Biofertilizer for roadside plant revitalization and halophytic maintenance	May 31 2025
Roadside application of microbial biofertilizer for halophytes	June 30 2025

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
John A. Chapman	University of Minnesota	Co-PI	Yes
Eric Watkins	University of Minnesota	Co-PI	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 be funded?

The project will have a broad impact on both academia and industry. The results will provide methods to apply these native plants to mobilize and excrete salt from the roadside soil and water environment. The possible applications will contribute to the sustainable developments in road salt management and agricultural practices, and alleviate the deteriorating conditions related to road salt application and improper irrigation. With the completion of this project, we will seek continuation funds from MnDOT for the specific implementation of this methods at different locations.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Next Generation Large-Scale Septic Tank Systems	M.L. 2014, Chp. 226, Sec. 2, Subd. 08g	$258,000
Biofilm Technology for Water Nutrient Removal	M.L. 2015, Chp. 76, Sec. 2, Subd. 04b	$281,000
Extracting Deicing Salt from Roadside Soils with Plants	M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 04i	$360,000

Project Manager and Organization Qualifications

Project Manager Name: Bo Hu

Job Title: Professor

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

Dr. Bo Hu is a Professor at Department of Bioproducts and Biosystems Engineering, University of Minnesota. With more than 20 years of active research experience specifically in bioprocessing development, nutrient removal, and waste management, he is leading projects to remove phosphorus from wastewater and assist plants for better uptake, projects on bioconversion of agricultural residue to value-added bioproducts, and projects on synthetic ecology in lichen biofilm formation by co-culturing mixotrophic microalgae and filamentous fungi. He has finished projects to develop a community microbial electrochemical septic system and a fungal biofilm system for water treatment. Dr. Hu's team at UMN has developed several bioconversion platforms, such as lichen biofilm co-cultivation of fungi and microalgae, pelletized fungal fermentation, and solid and hemi-SolidSF of filamentous fungi, to produce bioprducts and biofuel from agricultural waste and residue, and to remove nutrients and pollutant from contaminated water.

Dr. John Chapman is an Assistant Research Professor at Department of Bioproducts and Biosystems Engineering, University of Minnesota. He has more than 25 years of research and design experience in soils and stormwater. Specifically he has researched ecohydraulic interactions between vegetation and water flow and contaminant loading in stormwater. He has also lead hundreds of workshops for technology transfer to practitioners on stormwater management.

Dr. Eric Walktins is a Professor at Department of Horticultural Science, University of Minnesota. He leads the turfgrass

science program where his research interests are focused on the development and utilization of low-input turfgrasses for cold climates. His group conducts research ranging from plant adaptation to shade, plant-microbe interactions, germplasm improvement, plant genomics, to lawn water conservation education and species recommendations for Minnesota roadsides. He has led multiple successful multidisciplinary grant proposals, and is active in outreach to Minnesota stakeholders through blog posts, professional trade magazine articles, in-person seminars, and site visits.

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

Organization Description:
As the core department of UMN to tackle Agricultural engineering and environmental engineering issues, Bioproducts and Biosystems Engineering Department has very dynamic research activities and numerous excellent scientific researchers have received grant supports from LCCMR program. UMN Sponsored Projects Administration (SPA) will be the entity authorized by the Board of Regents to manage the project agreements with LCCMR program.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Three Co-PI's		Lead project, research, supervise, analyze - summer salary only			36.5%	0.66		$91,904
One research professional		research - new hire			36.5%	3		$208,872
One graduate student		research			45%	1.5		$150,951
One - two undergraduate students		research assistance (academic year only - approx 430 hours per year)			0%	0.6		$15,302
							Sub Total	**$467,029**
Contracts and Services								
University of Minnesota	Internal services or fees (uncommon)	lab services				-		$9,214
							Sub Total	**$9,214**
Equipment, Tools, and Supplies								
	Tools and Supplies	lab supplies- sensors, etc	needed for research					$24,636
							Sub Total	**$24,636**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**

Travel In Minnesota								
	Miles/ Meals/ Lodging	approx 10,930 miles	mileage to sites					$6,121
							Sub Total	**$6,121**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$507,000**

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	**-**

Attachments

Required Attachments

Visual Component

File: b660045b-2c6.pdf

Alternate Text for Visual Component

We propose to develop implementation approaches to apply halophytes for road side phytoremediation of de-icing salt...

Optional Attachments

Support Letter or Other

Title	File
Institutional Approval to Submit	73bb3404-841.pdf
Approval for re-using the supporting letter	21b8c805-b17.pdf
Recent communication with MnDOT for field testing site	53e0f9e1-d6e.pdf
MNDOT original supporting letter	f234f4b7-818.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

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

No

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

N/A

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

N/A

Does your project include original, hypothesis-driven research?

No

Does the organization have a fiscal agent for this project?

No

Phytoremediation for Extracting Deicing Salt

Bo Hu, Bioproducts and Biosystems Engineering, University of Minnesota

Environment and Natural Resources Trust Fund-2022

Effects of de-icing agent on the vegetation of the road shoulder (photo courtesy from Stenlund, Dwayne

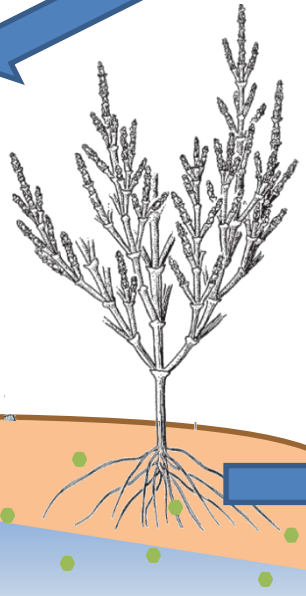
Glasswort *Salicornia Rubra* is a native plant growing in a few salty lakes in Western Minnesota

Harvest

Recycle for road salts
Animal feed
Energy source

Road salts

Transfer salt above ground to plant tissues



Increase soil salinity

Leaching to the rivers, lakes, and groundwater

Salt uptake by roots

Rain Garden / Floating Islands

Activity 1: Grow halophytes with roadside plants

Activity 2: Develop roadside application methods

Activity 3: Develop microbial biofertilizer for halophtes