Environment and Natural Resources Trust Fund

2024 Request for Proposal

General Information

Proposal ID: 2024-225

Proposal Title: Biomass to Biochar – Maximizing Minnesota's Carbon Value

Project Manager Information

Name: Sebastian Behrens

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: Improving carbon storage, climate resilience, and health of Minnesota's soils by enhancing the carbon value of biochar. Life cycle analysis of biochar technology for effective soil carbon sequestration in Minnesota.

Funds Requested: $543,000

Proposed Project Completion: June 30, 2027

LCCMR Funding Category: Air Quality, Climate Change, and Renewable Energy (E)

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.

Converting biomass to biochar presents exciting opportunities to improve forest and soil health, reduce greenhouse gas emissions, enhance ecosystem services, and revitalize rural economies. Realizing these environmental and societal benefits of biochar production and application will require that revenues can be generated from the multiple goods and services provided by biochar. These products include thermal energy, soil amendments, stormwater remediation, forest restoration, and CO2 removal from the atmosphere. Monetizing CO2 removal through carbon markets has the potential to make biochar production systems profitable and biochar available at prices that are low enough to support widespread use for environmental restoration and conservation in rural and urban areas. Economic viability, while necessary, must be accompanied by other measures of sustainability if the full promise of biochar technology is to be met. These measures include careful consideration of feedstock choices and land use, worker safety, transportation, modes of application, carbon conversion efficiency, GHG emissions, stability of carbon in soil, impact on native soil organic matter reservoirs, and energy use and output. Implementation of this integrated approach over the full life cycle of biochar technology maximizes benefits and ensures successful biomass resource management and soil carbon sequestration for the State of Minnesota.

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.

Biochar technology can play an important role in helping to improve and restore soil health and mitigate climate change. Biochar production and use is a carbon dioxide removal (CDR) technology readily implementable in Minnesota because it is already available at various production scales. The state also has large quantities of waste biomass resources that can be used as feedstocks for biochar production (e.g. crop residues, urban woods waste, forestry biomass). For effective technology implementation and resource management we need to maximize the carbon value of biochar. The most economically viable solutions for widespread adoption and integration of biochar technology are currently post-production strategies focused on producing high-quality organic fertilizer formulations based on compost/biochar mixtures and the development of climate-related markets focused on carbon credits for biochar production and long-term carbon sequestration. To take full advantage of these solutions we need to: (1) Develop practices and protocols for the production and characterization of biochar amended compost products; (2) Quantify the long-term stability of biochar carbon fractions in Minnesota's soils; and (3) Perform life cycle analysis (LCA) to systematically evaluate the cost reduction and carbon sequestration potential of bioenergy-biochar systems for effective, circular waste biomass resource management in Minnesota.

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?

The project integrates critical research needs on the permanence of soil applied biochar with the development of LCA-based assessment of the economic viability of bioenergy-biochar carbon markets. Project outcomes will enhance the value and use of the state's waste biomass resources for the production and application of biochar to ensure maximum impacts on soil carbon stock preservation and climate mitigation. The project will help reducing green-waste by turning it into a value-added product and carbon-sink. This will reduce state carbon emissions by effectively sequestering carbon in soil and reduce nutrient and contaminant runoff for the protection of Minnesota's water resources.

Activities and Milestones

Activity 1: Biochar as additive in organic waste composting

Activity Budget: $198,555

Activity Description:
Production-fresh biochar is not considered a fertilizer and should be combined with organic or mineral fertilizer to improve plant nutrition. Formulations that combine biochar with organic fertilizers and minerals are regarded to be the most economically viable solutions for widespread adoption and integration with existing agricultural practices. The use of biochar as an additive for the composting of organic waste provides favorable conditions that include large porosity and surface area, and high cation exchange capacity, thereby enabling adequate microbial growth in the composting pile, greater retention of plant nutrients and reduction in greenhouse gas emission (GHG). This makes biochar an ideal biological substrate to reduce the length of the composting process and enhance the value of compost. However, the integration of biochar into commercial composting to create nutrient-enriched biochar formulations have not received much attention in laboratory and field-based research studies to date. Specific knowledge gaps remain regarding impact of biochar on the composting process and the mechanisms underlying nutrient retention and GHG emissions. The objectives of this activity are to develop protocols and guidelines for the production and characterization of biochar amended compost products and to evaluate the carbon sequestration potential of biochar-compost formulations as soil amendments.

Activity Milestones:

Description	Approximate Completion Date
Procuring biochars and composts (Feedstocks, production conditions, mixing ratios)	December 31, 2024
Monitor impact of biochar on the composting process (soluble and gaseous C and N compounds)	December 31, 2025
Quantify key catalytic bioprocesses such as humification, biodegradation, GHG emissions	December 31, 2025
Validate compost maturation indices C/N, DOC, NH4+/NO3- in biochar-compost mixtures	June 30, 2026
Evaluate the carbon sequestration potential of biochar-compost formulations	June 30, 2026
Standards and guidelines for effective integration of biochar in organic waste composting	June 30, 2027

Activity 2: Stability of biochar carbon fractions in Minnesota soils

Activity Budget: $205,554

Activity Description:
Biochar-bioenergy systems have been recognized as valuable negative emission technology for carbon dioxide removal from the atmosphere. Pyrolysis–biochar systems offer potentially a greater carbon-equivalent gain than bioenergy production alone. Biochar, the product of waste biomass pyrolysis, is a tool for long-term soil carbon sequestration but also offers multiple benefits for the conservation and preservation of soil health and fertility. For this to be effective the long-term environmental stability of biochar must be assured. The level of biochar carbon stability in soil is context specific. In the context of climate change mitigation, the focus is on components of biochar carbon that remain in the soil after at least 100 years. Persistent aromatic carbon pools of biochar can have a mean residence time in specific soils >1500 years, which makes the technology competitive with geological carbon storage and suitable for CO2-emission compensation. The stability of biochar carbon fractions in soils depends on both, feedstock and production conditions and the properties of the receiving soil. To develop and inform strategy for using biochar as a carbon sequestration tool and develop carbon credit markets in Minnesota, it is important that the relative stability of different biochar in Minnesota soils can be directly assessed.

Activity Milestones:

Description	Approximate Completion Date
Production and characterization of biochar	June 30, 2025
Accelerated ageing of biochar by thermal and chemical oxidation	June 30, 2026
Determination of biochar carbon stability (elemental ratio analysis O:C, H:C)	June 30, 2026
Comparison with reference materials (graphite, humic acids, natural wildfire charcoal)	December 31, 2026
Statistical analysis and ageing kinetics	June 30, 2027

Activity 3: Life-cycle analysis of biochar

Activity Budget: $138,891

Activity Description:

Biochar-Bioenergy systems have multifunctional values that include energy and biofuel co-production, carbon sequestration, mitigation of GHG emissions, and the application of biochar as soil amendment or adsorbent material to improve soil health or immobilize toxic metals and organic contaminants in soil and water. Achieving the promises of biochar systems can have great impact on the protection, conservation, preservation, and enhancement of the state's air quality, water, and soil resources. To become part of a sustainable, circular carbon economy in Minnesota, biochar systems should bring about a positive overall effect in terms of several factors including economic, energetic, and environmental considerations. A LCA of biochar systems will enable a better understanding of the various aspects such as costs associated with the overall process of biochar production, logistics, utilization energetics, emission of GHGs during pyrolysis, and the multiple end uses of biochar and their respective carbon sequestration potential. While applications of biochar are expanding, the potential environmental impacts of these new end use scenarios have not yet been quantified in life cycle assessment studies. For biochar-based products, the type of biomass, the biochar properties, and the design of the biochar product will significantly influence the environmental footprint of the final product.

Activity Milestones:

Description	Approximate Completion Date
Definition of systems boundaries (e.g. biomass procuring, production, applications, distribution logistics)	December 31, 2025
Inventory analysis of environmental inputs and outputs	June 30, 2026
Life-cycle impact assessment (e.g. bioenergy co-production, carbon sequestration)	December 31, 2026
Data interpretation and publication	June 30, 2027

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Dr. Jason Hill	University of Minnesota, Dept. of Bioproducts and Biosystem Engineering	co-Investigator. Dr. Hill is an expert on the environmental, economic, and energetic costs and benefits of bioenergy systems from a life-cycle perspective. He will lead Activity 3.	Yes
Dr. Kurt Spokas	USDA-ARS	co-Investigator. Dr. Spokas' expertise is in biochar soil amendment practices and their impact in nutrient cycling and carbon degradation in agro-ecosystems. Dr. Spokas co-advise graduate students working on Activities 1 + 2.	No

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?

The results will be disseminated to laboratories, agencies, stakeholders and practitioners through open access publications, direct meetings, and conference presentations. Local project partners will be James Doten, Carbon Sequestration Program Manager for the Minneapolis Health Department and Nicholas Vetsch, Environmental Engineer at Stantec Consulting Services Inc., and the Minnesota Composting Council (MNCC) (see letters of support). Local partners will serve as external advisors to the project and assist with the identification of local feedstock sources, biochar/compost production, and biochar application scenarios. If additional work is needed, funding from University (MnDrive Environment, IonE) and federal sources will be sought.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Monitoring Emerging Viruses in Minnesota's Urban Water Cycles	M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 04c	$416,000

Project Manager and Organization Qualifications

Project Manager Name: Sebastian Behrens

Job Title: Assoc. Prof.

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

The project team consists of Dr. Sebastian Behrens (Dept. of Civil, Environmental, and Geo-Engineering, University of Minnesota), Dr. Jason Hill (Dept. of Bioproducts and Biosystem Engineering), and Dr. Kurt Spokas (Dept. Soil, Water, Climate; USDA-ARS). Dr. Behrens is an expert on soil-biochar-compost applications, nutrient cycling, and soil microbial ecology. Dr. Hill's research focuses on the consequences of food, energy, agriculture, and natural resource use from a life-cycle perspective. Dr. Spokas studies the impact of biochar soil amendment practices on the cycling of carbon and nitrogen and the emission of greenhouse gases in agricultural systems. Dr. Behrens will have responsibilities for overall project coordination, reporting, and dissemination of project outcomes. He will oversee the biochar-compost and soil carbon stability experiments in close collaboration with Dr. Spokas. Dr. Spokas will serve as co-advisor of the graduate students working on Activity 1 and 2. Dr. Hill will lead the life-cycle analysis and advise a graduate student working on Activity 3 efforts. Regular project team meetings among principal investigators and graduate students will be used to coordinate efforts, discuss, and exchange data, and to ensure critical project milestones and deliverable will be met.

Organization: U of MN - College of Science and Engineering

Organization Description:
The University of Minnesota is the State's main research and graduate teaching institution. The University partners with communities and governmental agencies across Minnesota to engage students, faculty, and staff in addressing society's most pressing issues. The Department of Civil, Environmental and Geo-Engineering focuses on collaborative and interdisciplinary research within critical areas such as managing and sustaining water and land-use infrastructure, mitigating disaster of the natural and built environments, engineering and developing earth resources, and designing renewable energy systems.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Faculty		Principle Investigator			36.8%	0.24		$56,630
Faculty		co-Principle Investigator			36.8%	0.12		$19,000
3 Graduate students		Experimental data acquisition, analysis, and publication			24.1%	3.5		$379,370
							Sub Total	**$455,000**
Contracts and Services								
							Sub Total	-
Equipment, Tools, and Supplies								
	Tools and Supplies	Reagents/chemicals, plastic/glassware, consumable/lab supplies, lab service fees, instrument time, and instrument repair/maintenance costs (for 3 students over 7 years at ~$11,215 per year)	for biochar/compost analysis (certificate testing), water chemistry analysis, ion/gas chromatography, FIA, MS, CSIA, NMR, DOC, nutirents, XPS, DNA/RNA extraction, UMGC DNA sequencing services, soil analytical laboratory, UMN CharFac Characterization Facility					$78,500
							Sub Total	**$78,500**
Capital Expenditures								
							Sub Total	-
Acquisitions and Stewardship								
							Sub Total	-
Travel In Minnesota								
	Conference Registration	2 trips, ~200 miles per trip, 2 students	Conference registration fees, meals and lodging to allow students to					$3,000

	Miles/ Meals/ Lodging		participate in local conferences and meetings to present research on this grant.					
	Miles/ Meals/ Lodging	6 trips, <100 miles per trip, 2 students	Field sampling					$2,500
							Sub Total	**$5,500**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Publication fees international scientific journals ($2000 for years 2 +3)	Dissemination of project results					$4,000
							Sub Total	**$4,000**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$543,000**

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	Indirect costs for this proposal, though not allowed, are listed as in-kind contribution of 55% MTDC which is the Federally Negotiated rate with the U of MN. The indirect is proportionate to the awarded funds at a rate 55% so if the award is reduced the F&A would be reduced.	To pay for administrative and facility expenses for this project	Secured	$233,247
			Non State Sub Total	**$233,247**
			Funds Total	**$233,247**

Attachments

Required Attachments

Visual Component

File: f45548c7-559.pdf

Alternate Text for Visual Component

Biochar is a carbon negative, charcoal-like, soil amendment that can help to preserve soils by increasing soil water holding capacity and enhancing fertility, while also generating renewable energy co-products during its production. The full life cycle of biochar technology maximizes benefits and improves biomass management and carbon sequestration in Minnesota....

Optional Attachments

Support Letter, Photos, Media, Other

Title	File
Letter from fiscal agent - SPA_UoM	2fd20dbe-115.pdf
Letter of Support - Carbon Sequestration Program Manager, City of Minneapolis	28cc2a23-fcd.pdf
Letter of Support - Stantec Consulting Services	fd09b245-1be.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?

Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

Does your project include the design, construction, or renovation of a building, trail, campground, or other capital asset costing $10,000 or more?

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?

No