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Biochar stability and carbon sequestration capacity across a salinity and plant community gradient in New Jersey tidal marshes

Statement of Work

Project Description

Tidal salt marshes are considered one of the most valuable ecosystems of the world due to ecosystem services and functions they provide, such as flood and climate change mitigation, habitat for wildlife, and support of commercially important fish and bivalve species (Barbier et al., 2011). Despite federal policies that protect tidal salt from development, fragmentation of wetland habitat is increasing due to stressors from global climate change (Hartig et al. 2002; Watson et al. 2017). Many wetland restoration projects now focus on long-term strategies for increasing the resiliency of wetlands in the face of climate change, focusing on impacts of sea level rise (SLR) and increasing storm frequency (Sutton-Grier et al., 2015).

Biochar is a soil amendment composed of pyrolyzed carbon that is thought to be beneficial to the restoration efforts of wetlands at large through promoting plant recolonization and increasing the amount of carbon sequestered through the project. Formed from anoxic combustion of organic materials, biochar is an amorphous, porous polyaromatic hydrocarbon (**Fig. 1**). The carbonaceous soil amendment has been used to increase carbon sequestration capacity of soils and reduce overall greenhouse gas emissions (Cayuela et al., 2013; El-Naggar et al., 2015; Ojeda et al., 2016), and to improve soil fertility, demonstrated through enhanced vegetation growth, drought resistance, and buffering capacity (Manickam et al., 2015; Ojeda et al., 2016; Roberts et al., 2015). The irregular shape and porosity of biochar increase the water holding capacity of soils (Liu et al., 2017), and in systems where soils are low in organic matter, biochar can be an important source of organic carbon, as well as some essential nutrients, for both microbial communities and vegetation (El-Naggar et al., 2015; Novak et al., 2009).

However, most biochar studies have been conducted in agricultural landscapes, and little is known about the efficacy of biochar in low-oxygen soil environments, like tidal wetland soils, to increase vegetative productivity and moderate soil chemistry. Additional complications arise when salinity gradients and reduction-oxidation (redox) potential are considered. Detailed studies of biochar and soil

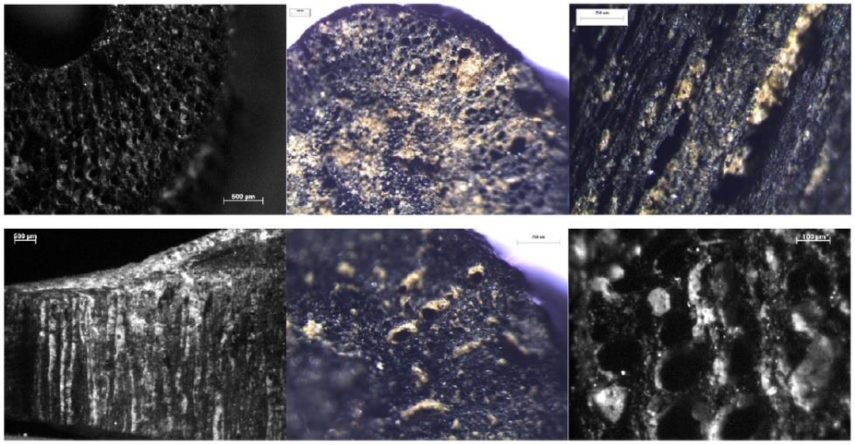

***Figure 1**. Microscopic imagery of biochar particle surfaces and interiors (Sorrenti et al., 2016)*

interactions need to be performed to determine the effective biochar-sediment combinations for enhancing restoration of tidal wetlands and climate change mitigation.

The overall goal of this study is to determine the favorability of using biochar as a long-term soil amendment in tidal marsh restoration projects through long-term *in situ* incubations along the Tuckahoe River in New Jersey. Microbial community make-up has been found to significantly shift dependent upon sediment type, salinity concentration, and inundation levels (Bossio et al., 2006; Lee et al., 2017). As a result, biochar may degrade differently depending on its location of use. Furthermore, redox potential is also location-specific as a result of the complex interplay of aerobic and anaerobic zones of wetlands, and oxidation has been shown to significantly impact the physicochemical properties of biochar particles (Sorrenti et al., 2016). Therefore, it is necessary to examine biochar under the variable salinity and oxidation conditions of tidal soils to determine the degradation rate and subsequent viability of biochar in tidal systems.

The specific aims of this study are to **(1) examine the effects of inundation patterns on the fractionation of biochar particles over time, (2) describe the effects of a salinity gradient on the degradation rate of biochar, (3) determine the effects of redox potential on biochar stability, and (4) evaluate seasonal effects on biochar degradation.** To answer these aims, samples of hardwood biochar will be monitored in incubation bags inserted in soils of the Tuckahoe River, NJ tidal marshes. Incubation bags will be collected in batches over time to measure the change in mass and carbon content as a result of varying biogeochemical parameters. **I hypothesize that areas of inundation will have increased occurrence of biochar particle fractionation due to physical stress. Secondly, I expect there will be a significant effect of salinity on the degradation rate of biochar due to the shifts in vegetative communities and soil biota. Additionally, I expect that redox potential will have a secondary effect on the stability of biochar, and biochar incubated in more oxidized conditions will have a higher rate of degradation. Lastly, I predict variations in biochar degradation rates as a result of seasonal effects on water quality chemistry.**

Methods

Incubation bags containing commercially-available hardwood biochar samples will be deployed at four sites varying in salinity ranges along the Tuckahoe River in New Jersey (39°18’41” N, 74°41’42” W). Tuckahoe River is a blackwater river that extends for approximately 44 km through the Pine Barrens of New Jersey. The river exhibits a salinity range of fresh to polyhaline as the mouth of the river opens to the Great Egg Harbor Bay and the Atlantic Ocean and offers an ideal site for testing biochar degradation in both freshwater and brackish marshes. Three sites will be chosen based on the salinity conditions (fresh, mesohaline, polyhaline), and one additional site acting as an upland comparison. Biochar will be incubated for one year, starting early in the growth season in 2021.

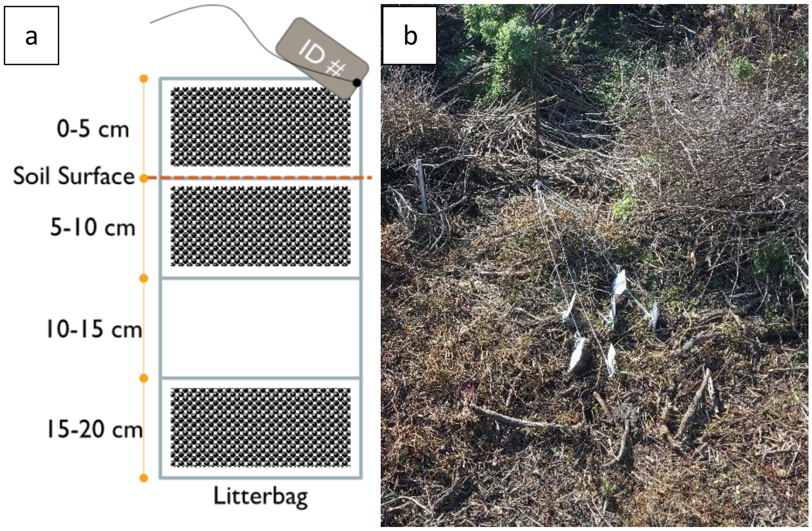

Figure 2. *Diagram of incubation bag with biochar samples inserted (a) and field set up where incubation bags are placed in the soil and tied to a permanent marker (b).*

Incubation bags will be crafted from sail material, as this material allows water to pass through while preventing plant material from growing into the bag (which my mentors have observed in coarser mesh material). The litterbags will be sewn into 20 cm long by 10 cm wide pouches, with three chambers from 0-5 cm, 5-10 cm, and 15-20 cm (**Fig. 2a**). Biochar will be sifted to obtain a size class in the range of 4-8 mm and will be measured for initial total carbon content using a Flash 1120 Elemental Analyzer. The biochar will then be dried at 100 °C for 72 hours and weighed out into 2 g (dry weight) samples, which will be inserted into the three pockets of the litterbags and sewn closed. The incubation bags will be inserted vertically 15 cm into the soil at each site, with the top chamber exposed to determine surficial degradation rates. Bags will be installed within a square meter plot with a permanent marker to ensure successful retrieval (**Fig. 2b**). After collection, bags will be rinsed with DI water to remove excess sediment and frozen at -80 °C until analysis. The biochar will then be dried, weighed, and analyzed for final total carbon to create a measure of carbon loss over time.

Environmental parameters, such as ambient and soil temperature, soil conductivity, soil redox potential, and water chemistry, will be monitored during the incubation period. Ambient temperature will be measured using ONSET HOBO pendant temperature loggers stationed at each site. Soil conductivity and redox potential measurements will be made in the field during each site visit. Thermochron iButton temperature loggers will be inserted into the ground at each site at two depths, 5 cm and 10 cm, to monitor general soil temperatures corresponding to the depths of the incubation bag chambers. HOBO water level and conductivity loggers will additionally be stationed at each site to monitor inundation rates and salinity. Loggers will be replaced or calibrated during each collection event. Lastly, water samples will be collected throughout the incubation period to monitor water pH and salinity.

Completed Work

Preliminary short-term greenhouse mesocosm incubations that I have conducted have shown that hardwood biochar is relatively stable in coastal sediments. Incubations were monitored for three months for CO_2 and CH_4 emissions, and no significant differences were found between incubations with and without biochar additions. Furthermore, biochar carbon emissions did not differ in either high or low dosage amounts. This suggests that hardwood biochar may persist in wetland soils and significantly contribute to long-term storage of carbon stocks. However, because these mesocosm incubations were conducted under controlled flooding and salinity parameters, these stability results are likely not fully representative of field conditions. A long-term incubation would elucidate the effects of more complex environmental fluctuations on the stability of biochar.

Benefits to Coastal Wetland Research & Policy

New Jersey tidal wetlands are at high risk of being lost to SLR within the next century and much of the state lies at or below sea level. As a result, coastal cities are highly vulnerable to increased flooding and storm damage, especially as global climate change increases the frequency of severe storms. Much of the New Jersey coastline relies on the salt marshes to act as a buffer between the cities and incoming storms and wave action. Increasing the resiliency of these tidal marshes is a necessary action in order to maintain the current ecosystem services and functions these wetlands provide. This study intends to investigate the impacts and viability of adding biochar as a soil amendment to enhance wetland restoration projects within New Jersey. New Jersey is an ideal place to study this issue, as the State has recently re-joined the Northeast Regional Greenhouse Gas Initiative (RGGI), a carbon market, and has committed to increasing carbon sequestration in wetlands and forests as part of its commitments. Long-term, effective solutions to wetland degradation are increasingly important, and the results of this study could greatly benefit the New Jersey Department of Environmental Protection (NJDEP) and other New Jersey tidal wetland managers.

Budget Justification

Funding received from The Garden Club of America will be used to pay for elemental analysis, necessary to describe the properties of aging biochar in coastal soils. A soil conductivity field meter and a soil redox potential field probe will additionally be needed to characterize the localized soil conditions in which the biochar will be incubated. The scholarship will also support payment for any field and lab supplies (soil sample storage, nylon string, reagents, gloves, etc.). Lastly, the scholarship will assist in funding my attendance to the Joint Aquatic Sciences Meeting in 2022 in Grand Rapids, Michigan.

Outreach

Results of this study will be shared with the NJDEP, as they are a co-sponsor of the project. This study will support the salt marsh enhancement efforts of the NJDEP and will be utilized to inform future restoration efforts. Additionally, this study is expected to be presented at the Joint Aquatic Sciences Meeting, which will take place in Grand Rapids, Michigan from May 16-20, 2022. Organized by the Consortium of Aquatic Science Societies (CASS), the meeting will be attended by ecological scientists and practitioners from across the nation. This will be a highly appropriate conference to present these findings, as many of the attendees of the conference will be interested in coastal wetland restoration practices and improvements. Presenting at this meeting will greatly support my future career as a wetland scientist, as I will have the opportunity to network and discuss my research with well-established practitioners and scientists.

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