Hampshire College Healthy Soils Initiative

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Project Description

We are proposing a project which will be identifying best practices for turfgrass lawns to maximizing carbon sequestration through utilizing management regimes that are accessible and replicable at a residential and municipal level. Within the Healthy Soils Action Plan there is an indication that “following land grant university BMPs for turf is shown to increase SOC”, however in the most recent version 1.51 of UMass Extension: Best Management Practices For Lawn And Landscape Turf, there are no specific indications for practices which enable home owners or municipalities to maximize carbon sequestration through increases of SOC. And directly speaking with Jason Lanier an Extension Educator who directly worked on authoring the BMP guide and consulted on the development of the Healthy Soils Action Plan, he indicated that better understanding carbon sequestration potential in turfgrass lawns is an area of great interest and tat he believed that this work would be a fantastic project.

Where there are clear relationships between SOC and the amount of carbon sequestration, the project will be measuring the increase of SOC in the targeted areas. Additionally, in the HSAP there is an indication that “turf sequesters carbon at a rapid rate, and then becomes saturated.” Where there observation have been noted in numerous growing areas [1], as native grasses in the midwest have shown, healthy plant root penetration into the soil and associated soil microbiology is able to deposit carbon to increasingly deeper and deeper depths than the typical 20cm depth which the above mentioned studies examine. Recognizing the successes displayed by natural processes, our measurements will be looking to assess if there are management practices which are less susceptible to hitting the saturation point, but instead continue to increase the SOC through a greater depth of the soil profile.

Translating this directly into the project’s scope, 74 quadrants will be set up throughout the growing area which will each be managed with a unique set of treatment variables, and the

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[1] Claire L. Phillips, et al. “High soil carbon sequestration rates persist several decades in turfgrass systems: A meta-analysis” Science of The Total Environment, vol. 858 part 3, 1 February 2023, p.159974

effects of those treatments will be examined through comparing pre- and post- study findings in terms of the SOC rates in soil cores taken at depths of 0-20cm, 20-40 cm, 40-60cm, 60-80cm, and 80-100cm. Past findings have pointed to these deeper regions within the soil profiles as having a capacity to house considerable quantities of carbon in various settings[2,3], so it is the intention of the project to quantify the total potential for carbon storage within turfgrass lawns.

In addition to the work making quantitative measurements for ways of improving the health of the soil, this project has stimulated a partnership with Hitchcock Center for the Environment, who has agreed to advertise for and host free public educational events that highlight the findings of the project. The hope is that through this meaningful work that best management practices can be identified for turf lawns which improve the health of the soil, maximize carbon sequestration, and have these results communicated to a wide general audience so as to contribute to these practices being adopted by residences, businesses and municipalities across the Commonwealth.

Goals and Objectives

The goal of the project is to identify the best way to care for lawns such that they can realize the greatest rates of soil organic carbon. This work is brought forward under the assumption that turf lawns will persist in the state for the foreseeable future, and likely due to urbanization increase in total acreage; therefore, we aim to show how with locally available resources and no specialized training, homeowners and municipalities can manage those spaces with available resources in a way which contributes to optimal soil health and increased rates of carbon sequestration.

The role which lawns play in a dynamically functioning ecosystem is not as beneficial as those of forests or wetlands, and the rates of carbon that can be contained within the soils and the associated biomass might also not be as significant. However, due to the increased fluctuations of the climate, the potential for drought-stimulated wildfires burning through forest and wetlands is likely to increase, and with that comes the potential for tremendous loss of carbon resulting from those conflagrations. The exploration for how to increase carbon in the

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[2] Zhou, Jingxiong, et al. “Regional Spatial Variability of Soil Organic Carbon in 0–5 m Depth and Its Dominant Factors.” CATENA, vol. 231, Oct. 2023, p. 107326.

[3] Hunter, Brooke D., et al. “Pedogenic Pathways and Deep Weathering Controls on Soil Organic Carbon in Pacific Northwest Forest Soils.” Geoderma, vol. 436, Aug. 2023, p. 116531.

soils within lawns may have proportionally smaller immediate net benefits than those gains identified in forests or wetlands, but because lawns being minimally susceptible to fires, this attention placed towards lawns helps increase overall resilience to any models for future retained carbon.

Through a detailed study of evaluating 72 diverse growing quadrants, within an area chosen for its uniform growing conditions, we will be measuring changes to the SOC within the sites to a depth of 1m, as well as measuring changes to total and active soil microbiology. Existing literature in the field has indicated the rate of sequestration of carbon likely plateaus in turf lawns after a couple decades[4]. Those past studies have only examined the changes in the soil carbon to a depth of 20cm, so we aim to show that with deeper testing, some management practices can continue to allow carbon in the form of humic and fulvic acids, along with any associated microbiology, to percolate deeper into the soil profile and thereby adding to additional carbon sequestration benefits.

In four pilot samples taken and tested from the proposed project site, readings indicated that SOC was found to range between 0.5 and 2.5% throughout the 0.2 to 1.0 meter parts of the soil profile. Because of the existing literature and our firsthand observations, we are confident that carbon does make its way deeper throughout the soil profile, so it is the aim of the project to identify the quantity of carbon which moves into those lower regions of the profile, and the management practices which best support that movement.

Specific areas where this Project will align with or advance the objectives of the HSAP

Forests and wetlands are clear sites for carbon storage, and as indicated in the Natural Carbon Sequestration section of the Decarbonization Roadmap these areas are always at risk of potential catastrophic carbon release in the event of wildfires. Acknowledging that reality within our currently changing climate, turfgrass lawn are focussed on in this project because as indicated in the HSAP,"improved turf management has the highest potential climate impact of any BMP modeled by HSAP."[5]

Among the 'Ambitious Changes' modeled within the HSAP, contributions for the increases of SOC was shown to be coming from trees planted within turf adjacent areas. This project will not directly explore the planting of trees in or around turf lawns, but the turf

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[4] Qian, Yaling, et al. "Assessing Soil Carbon Sequestration in Turfgrass Systems Using Long-Term Soil Testing Data." Agronomy Journal, 94(4), July 2002

[5] Massachusetts Health Soils Action Plan, p. 93

selections utilized, specifically the fescues, have deeper root zones and physiological characteristics specifically suited for both deeper roots to maximize carbon storage, as well as being shade tolerant so as to accommodate survivability in conjunction with any future tree planting. Therefore, where this project is looking at the BMPs within turfgrass lawns without trees, all of the identified approaches from the project would be just as applicable, and likely made even better off, if trees were later incorporated into any of the areas carrying out these practices.

Specifically the Hampshire College Healthy Soils Initiative aligns with and seeks to advance the objectives of the HSAP through identifying BMP for maximizing increased soil organic carbon of turfgrass directly, as well as identifying practices which maximize the microbiological health of the soil, therein providing support to indirectly increase the SOC. These management practices will be carried out at Hampshire College in ways which will be as easily accessible and replicable to individual homeowners, residences and municipalities across the Commonwealth so as to aid in their adoption.

Methodology - Treatment

Within two contiguous turfgrass fields 74, 1,000 sqft transects will be marked out and labeled (these are specifically labeled within APPENDICES A, B, and C). Within the three indicated appendices there are only 72 identified quadrants, however in addition to these there will be two additional locations designated which will be tested without any programmed treatment, so as to serve as controls for the experiment. For ease of treatment protocols the variables identified for each quadrant have been grouped together so as to minimize labor hours required to carry out the study.

Within the ‘Baseline’ plot (APPENDIX A) the principal focus is looking at the difference effects from two selected seed mixtures, one a mixture with Kentucky Bluegrass, perennial rye, and fine fescue, and the other mixture being a similar combination with an addition of white clover. Within the ‘Biochar’ plot (APPENDIX B) the principal focus is looking at the effects of different rates of biochar as well as charged-biochar. Finally, the ‘Compost’ plot (APPENDIX C) places its primary focus around the effects of different rates of compost. Within each of the plots (herein referred to as plot ‘A’, ‘B’ or plot ‘C’), the sites were selected for their similarities in sun, rain, and wind exposure, so that the quadrant variation will be the chief difference within the tested location. Each of the 74 quadrants will measure 25’x40’, so as to minimize the likelihood of neighboring quadrants contaminating results from the tested samples, as well as providing ample room for taking such deep samples..

The sequence of operation for the work will consist of the target area initially being prepped for work through being closely mowed, and with a dethatcher rake being run over the area to expose the soil. Following the site prep work, the 74 quadrants in plots ‘A’, ‘B’ and ‘C’ will be marked out. This will consist of quadrants being outlined with string to ensure specified dimensions are being used, with all of the corners being highlighted with turf marking paint. The string will then be removed, and the corners will weekly receive a fresh application of turf paint so as to ensure the specific location of the quadrants is retained throughout the project

The order of treatment for the plots will follow as: (1.) fertilizer will be applied where applicable, followed by (2.) biochar, (3.) charged-biochar, (4.) compost, (5.) the target areas will be worked over with an aerifier, and finally (6.) the treatment areas will be seeded.

(1.) The fertilized quadrants will receive an initial application of 0.5 lbs of N just prior to seeding with a follow up of an additional 0.5 lbs of N when new grass matures to two inches in height. The fertilizer is a commercially available 4-6-2 natural based starter fertilizer. The application of the fertilizer will be made with the Spyker P70 Commercial Drop Spreader which has been previously calibrated for the specified rate. The choice of this fertilizer was selected based on it not being generated from fossil fuels, and therefore having a smaller relative carbon footprint than a more conventional salt based fertilizer.

(2.) The biochar will be spread using the Earth and Turf MultiSpread 320, towed with a utility vehicle. The rear gate on the spreader will be calibrated to ensure that the appropriate ¼” or ½” will be applied to the specified quadrants. To increase ease and save time, once the spreader has been carefully calibrated so as to apply the biochar at ¼”, the same spreaded setting will be used over the ½” quadrants, in receiving a double treatment.

(3.) The charged-biochar will be spread using the Earth and Turf MultiSpread 320, towed with a utility vehicle. The charged-biochar will be ‘charged’ through having the biochar spread out with, Soil ReVive Conditioner, and Soil ProVide Inoculum applied as a liquid solution to fill its approximate 85% pore space by volume. The charged-biochar will be spread following a 3-day charging period in the methods similar to that of the compost and the biochar.

(4.) The compost will be spread using the Earth and Turf MultiSpread 320, towed with a utility vehicle. Again the spreader will be calibrated for an application rate of ¼”, with the areas receiving ½” being treated twice.

(5.) The areas being aerified will be treated with a walk behind Ryan Lawnair tow behind aerifier. The quadrants receiving aerification will receive this treatment as an intervention during the onset of the project so as to allow amendments to be worked into the soil profile and through the slight soil disturbance, to increase the soil-to-seed contact with the applied seeds.

(6.) The areas being seeded will also have the seed applied through the calibrated Spyker P70 Commercial Drop Spreader. All overseeding rates will be carried out at 2lbs. per 1,000 sqft, with the ‘turfgrass mixture’ areas receiving a blend of 75% Kentucky bluegrass, 10% perennial ryegrass, and 15% fine fescue, and the ‘diversity mixture’ receiving 5% white clover, 70% Kentucky bluegrass, 10% perennial ryegrass, and 15% fine fescue.

The 8 quadrants within plot ‘A’ treatment approaches will be:
Visual Layout presented in APPENDIX A

A1 - turfgrass mixture
A2 - fertilized, turfgrass mixture
A3 - fertilized, aerified, turfgrass mixture
A4 - aerified turfgrass mixture
A5 - diversity mixture
A6 - fertilized, diversity mixture
A7 - fertilized, aerified, diversity mixture
A8 - aerified, diversity mixture

The 32 quadrants within plot ‘B’ treatment approaches will be:
Visual layout presented in APPENDIX B

B1 - ¼” biochar, aerified, turfgrass mixture
B2 - ¼” biochar, fertilized, aerified, turfgrass mixture

B3 - ¼" biochar, fertilized, turfgrass mixture

B4 - ¼" biochar, turfgrass mixture

B5 - ¼" biochar, aerified, diversity mixture

B6 - ¼" biochar, fertilized aerified, diversity mixture

B7 - ¼" biochar, fertilized, diversity mixture

B8 - ¼" biochar, diversity mixture

B9 - ½" biochar, aerified, diversity mixture

B10 - ½" biochar, fertilized, aerified, diversity mixture

B11 - ½" biochar, fertilized, diversity mixture

B12 - ½" biochar, diversity mixture

B13 - ½" biochar, aerified, turfgrass mixture

B14 - ½" biochar, fertilized, aerified, turfgrass mixture

B15 - ½" biochar, fertilized,turfgrass mixture

B16 - ½" biochar, turfgrass mixture

B17 - ½" charged-biochar, aerified, turfgrass mixture

B18 - ½" charged-biochar, fertilized, aerified, turfgrass mixture

B19 - ½" charged-biochar, fertilized, turfgrass mixture

B20 - ½" charged-biochar, turfgrass mixture

B21 - ½" charged-biochar, aerified, diversity mixture

B22 - ½" charged-biochar, fertilized, aerified, diversity mixture

B23 - ½" charged-biochar, fertilized, diversity mixture

B24 - ½" charged-biochar, diversity mixture

B25 - ¼" charged-biochar, aerified, diversity mixture

B26 - ¼" charged-biochar, fertilized, aerified, diversity mixture

B27 - ¼" charged-biochar, fertilized, diversity mixture

B28 - ¼" charged-biochar, diversity mixture

B29 - ¼" charged-biochar, aerified, turfgrass mixture

B30 - ¼" charged-biochar, fertilized, aerified, turfgrass mixture

B31 - ¼" charged-biochar, fertilized, turfgrass mixture

B32 - ¼" charged-biochar, turfgrass mixture

The 32 quadrants within field 'B' treatment approaches will be:

Visual layout presented in APPENDIX B

C1 - ¼” compost, ¼” biochar, turfgrass mixture

C2 - ¼” compost, ¼” biochar, turfgrass mixture, fertilized

C3 - ¼” compost, ¼” biochar, turfgrass mixture, fertilized and aerified

C4 - ¼” compost, ¼” biochar, turfgrass mixture, aerified

C5 - ¼” compost, ¼” biochar, diversity mixture

C6 - ¼” compost, ¼” biochar, diversity mixture, fertilized

C7 - ¼” compost, ¼” biochar, diversity mixture, fertilized, aerified

C8 - ¼” compost, ¼” biochar, diversity mixture, aerified

C9 - ¼” compost, diversity mixture

C10 - ¼” compost, diversity mixture, fertilized

C11 - ¼” compost, diversity mixture, fertilized,aerified

C12 - ¼” compost, diversity mixture, aerified

C13 - ¼” compost, biochar, turfgrass mixture

C14 - ¼” compost, biochar, turfgrass mixture, fertilized

C15 - ¼” compost, biochar, turfgrass mixture, fertilized, aerified

C16 - ¼” compost, biochar, turfgrass mixture, aerified

C17 - ½” compost, biochar, turfgrass mixture

C18 - ½” compost, biochar, turfgrass mixture, fertilized

C19 - ½” compost, biochar, turfgrass mixture, fertilized, aerified

C20 - ½” compost, biochar, turfgrass mixture, aerified

C21 - ½” compost, diversity mixture

C22 - ½” compost, diversity mixture, fertilized

C23 - ½” compost, diversity mixture, fertilized, aerified

C24 - ½” compost, diversity mixture, aerified

C25 - ¼” compost, ¼” charged-biochar, diversity mixture

C26 - ¼” compost, ¼” charged-biochar, diversity mixture, fertilized

C27 - ¼” compost, ¼” charged-biochar, diversity mixture, fertilized, aerified

C28 - ¼” compost, ¼” charged-biochar, diversity mixture, aerified

C29 - ¼” compost, ¼” charged-biochar, turfgrass mixture, turfgrass mixture

C30 - ¼” compost, ¼” charged-biochar, turfgrass mixture, fertilized

C31 - ¼” compost, ¼” charged-biochar, turfgrass mixture, fertilized, aerified

C32 - ¼” compost, ¼” charged-biochar, turfgrass mixture, aerified

Beyond the above mentioned 72 quadrants, there will be two pre- and post- treatment soil samples taken as controls from locations immediately neighboring the project which have not received any treatment protocols, so as to evaluate any environmental changes, and factor those observed changes against the project results to identify if the changes within the treatment areas where of statistical significance.

Methodology - Testing

The soil samples will be collected from pits dug 1m deep, with samples taken at five depth ranges (0-20, 20-40, 40-60, 60-80, and 80-100 cm). Soil organic carbon (SOC) will be analyzed using the loss on ignition method (LOI)[6]. Soil samples (each treatment and level) will be spread and air dried to arrest biological activity for short term storage and allow it to be sieved as well as inspected to remove rocks and plant material. Weighed crucibles will be filled with ca 5g (roughly pre-weighed) of soil from each sample, then soil subsamples weighed again. They will then be heated in a drying oven for 24 hrs at 105^{o}C to remove water, weighed again, and heated in a muffle furnace at 550^{o}C for 4 hrs to burn off organic carbon. They will receive a final weighing, with the series of result weights (all to 0.0001g) used to calculate both water loss and %SOC (to 0.1%).

Expected Outcomes and/or deliverables

The expectations from the project is that there will be documented and publicized steps which homeowners and municipalities will be able to take to maximize the sequestration of carbon within their turfgrass lawns. The diversity of the 72 unique treatment quadrants in addition to a control, will provide a spectrum of results, with some undoubtedly performing better than others. The expectation is that from this range of outcomes we will be able to quantify the benefits of different treatment interventions. Through the planned educational outreach these findings will reveal both the successes and any identified failure so that informed decisions can

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[6] Hoogsteen et al. ‘‘Estimating soil organic carbon through loss on ignition: Effects of ignition conditions and structural water loss” European Journal of Soil Science, 62(2), February 2015

be made by anyone looking to improve their soils in similar turf applications. Because turfgrass lawns are presently being managed in nearly every town around the Commonwealth, the expectation is that the educational outreach and publication of these results will provide actionable steps for others to take almost immediately.

Specifically, the outcome from this work will generate a quantitative assessment for the direct enhancement of soil organic carbon, as well as the increased active biology within the monitored soil profile. Through the increasing of the soil's cation exchange capacity being brought on with the increase to the soil organic carbon, it should follow that the soil's nutrient holding capacity will be improved as well as its ability to be buffered from pH fluctuations, and from too much or too little water, therein making those treated spaces more resilient with fewer external inputs. Additionally, through the increase in the active soil microbiology and the enhancement to the rhizosphere the plants will be able to better access water and nutrients, also contributing to the space's enhanced resilience to fewer external inputs.

These outcomes will be the direct product of the treatment and testing outlined within the 'methodology' section of the application. Beyond those measured findings, the deliverables which will be made available to the public will come through a series of public educational programs at the Hitchcock Center for the Environment. Through partnering with this local non-profit, these findings will have a forum wherein leveraging the popularity of the organization's educational outreach, the findings are expected to be disseminated to a wide regional audience. The Hitchcock Center has agreed to put on the programs for free to the public so as to ensure minimal obstacles will be present for attracting and welcoming individuals to the educational programs.

Budget - Funding breakdown details for entire project

The budget for the project to be carried out in fiscal year 24' is $33,741. The budget is laid out into four main divisions to better track the tasks and respective parties carrying out the specific operations. This breakdown identifies $760 for treatment, $7,540 for testing, $360 for educational outreach, and $25,081 for administrative coordination.

Beyond this programmatic expenses there are also 24 hours of supplemented work being carried out and recognized in the form of in-kind donations. The entire budget can be seen in an itemized breakdown in APPENDIX D.

Organizational capacity

The project will be carried out in four respective parts (treatment, testing, education, and administrative coordination), each of which are headed up by seasoned staff possessing years of experience in successfully managing similar projects.

The treatment component of the project will be led up by James Sanner, Hampshire College head of grounds who for over a decade carried out similar soil research studies while at UC Berkeley. Most similar to the project at hand was a multi-year study funded through the California Green Initiative Fund, which examined the effects of different rates of compost, compost teas and seed varieties. This project's findings identified best practices for turfgrass lawns to improve surface density and recovery while also highlighting methods of minimizing needed irrigation use in drought conditions. Through that project, methods were identified which realized an irrigation reduction potential of 22% when factoring for precipitation. With over fifteen years managing turf James has used all the equipment identified in the project as well as trained staff in their successful operation and calibration. Working directly with the grounds department there is complete confidence that the college staff will effectively be able to execute all steps of the project.

The testing of the soil samples will be carried out by Hampshire College faculty who routinely measure SOC% and have all the necessary equipment (e.g., crucibles, scales, oven, and furnace) in the college's organic chemistry lab. Agroecology professor Brian Schultz, who is collaborating on the project, will incorporate these tests into his spring research course, with the help of Laboratory and Instrumentation Manager Sarah Steely (who programs the furnace) and organic chemistry professor Rayane Moreira. All statistical analysis of the findings will be organized with and compiled by Brian.

The education part of the project will be presented by James Sanner and Brian Schultz at the Hitchcock Center for the Environment, an educational center specializing in coordinating and communicating similar environmental insights out to the regional community for the past 60 years. We will be working with Community Programs Education Manager Casey Beebe, around sending out public announcements, setting up registration for the event, as well as hosting the free events at the center. The announcements will go out to their extensive mailing list publicizing the event which will highlight the identified best practices and how home-owners and municipalities can implement these methods so as to maximize the sequestration of carbon within their respective turf lawns.

The administrative coordination will also be carried out by James Sanner. He has helped coordinate with over $1.1M in grant funded projects including a multi year FEMA funded project. With over a decade project management experience, and past work serving as a treasurer for a scientific research based non-profit, he has experience organizing, documenting, and reporting findings from similar projects.

Project timeline and milestones

The project will be coordinated through the four above mentioned major divisions of treatment, testing, education, and administration. Within each of these respective area however, there are milestones identified which allow easy tracking of the project's progress and can be observed in the GANTT chart illustrated in Appendix E. For uniformity, ease of tracking, and to ensure timelines are adhered to, the project timeline illustrated in APPENDIX E parallels the budget illustrated in APPENDIX D.

Several of the specific milestones within each of the major areas of the projects are:

In the treatment part of the project, the exact starting date for the project will itself be a significant milestone. To ensure the greatest degree of overall success from the project the temperature of the soil as well as the level of soil saturation will be closely monitored. Each of these factors are highly variable in relation to the experienced weather and precipitation events. Working of the sites too early can lead to compaction and suboptimal growing conditions for the seeds, which will negatively skew any tallied results. Therefore as conditions become more favorable in March and April daily soil temperature tests will be taken. Once the seed is in the ground the on-staff turf experts will daily monitor the conditions to identify the necessary rate of cut and if during the initial grow-in, supplemental irrigation would be warranted.

Within the testing part of the project, the collecting of the core samples will be a major milestone, both times they are collected. The amount of labor involved for taking these samples is factored into the scope of the project, however the difficulty incurred when encountering any large rocks in the ground can create scenarios wherein a sample hole needs to be abandoned and restarted. One of the reasons for the sizing of the quadrants as they are, is to accommodate the ability to select from a novel core site as needed during each round of sampling.

Within the educational part of the project, coordinating with the Hitchcock Center about the findings of the samples will be a milestone, so the educational program can be developed. Another milestone will be the communication's staff disseminating the public notice, through their vast mailing lists and public channels. Additionally, the actual educational event will be a major step in that it will highlight all of the work which has been carried out, and provide valuable feedback as to how likely the findings will be adopted by regional residences and municipalities.

Within the administrative part of the project, the ordering and receiving the materials and equipment is a significant milestone which will be watched. With most of the pandemic related supply chain disruptive bottlenecks having worked themselves through the system, concerns over delays in receiving supplies are minimal. However, because many aspects of the project are time sensitive, to ensure as few challenges as possible and to insulate against any experienced delays, the appropriate orders will be placed as early within the start of the project as possible.

Project evaluation and monitoring

The breakdown of the project's sequence is outlined within the APPENDIX E and specifies the sequential steps which will be followed in carrying forward the project. The areas where careful focus will be directed is in getting the materials and equipment set up as early in the project as possible, due to the subsequent amending and seeding steps being delayed if the dates and milestones for receiving supplies are missed.

Additionally, the soil temperatures will be closely monitored as hitting the 50 degree F. threshold will be the trigger for initiating the soil amending and seeding. Beyond the temperature however, the soil's moisture field capacity will be evaluated to ensure that the work and used equipment brought onto the treatment area will not be creating unnecessary compaction and thereby removing pore space which could negatively contribute to the health of the soil.

Once the soil is amended and the seeds are set, the area will receive regular evaluation to assess how changing environmental conditions are affecting the area. Specifically, if the spring season is overly dry, supplemental irrigation will be included to ensure the best opportunity for the success of the plants' growth. Supplemental irrigation is not a variable which was specifically highlighted within the project nor is any irrigation intended to be used except as needed to prevent drought stress or wilting, however due to its importance in establishing new plants and the uncertainty regarding the amount of received seasonal rainfall, it is something which will be constantly monitored with interventions only coming as needed.

As the plants grow it will also be important to monitor how they are growing, with specific focus placed around the height of the plants. The plants will benefit in receiving mowing as early and often as appropriate, in that it will support the plants' tillering, and as the stem and leaf surface increase there will be a somewhat proportionate increase in the root growth and increase to the soil organic carbon. The mowing height is going to be set at 3.5" which is at the top end of selected species favorable range. This height will allow for greater photosynthetic potential, and thereby increased carbon sequestration, while also reducing the frequency of mowing and associated releasing of GHG emissions.

Also, part of the treatment protocol calls for the sections receiving the fertilizer to have a second application when the grass has reached 2 inches in height. Therefore, a close monitoring of the growth of the grass will help provide clear guidance for when the second fertilization is called for, as well as the overall frequency at which the turf will be cut.

Sustainability plan – Post grant project sustainability assessment

To ensure that the benefits of the project are carried forward within Hampshire College a meeting with the grounds department will be carried out to highlight the successes and challenges identified in the project. The expectation and verbal agreement from senior leadership is that the identified best practices will be brought to as much of the college's 800 acre campus as practical. The college is invested in ensuring that their grounds are managed as sustainability as possible, and this fits into that existing framework. The grounds department have already been consulted about this project and have expressed interest in committing to the needed time involved in the project, and in seeing how similar practices can be implemented as new SOP. Additionally, in relation to the testing work there has been expressed interest to continue this data collection forward into the future so as to continue to take samples as research opportunities and grow the project into a longitudinal study to supply a foundational understanding about the relationship between turfgrass management and its potential for sequestering carbon within the soil.

Partners involved – Community engagement

The work carried out at the Hitchcock Center has directly engaged the community for several decades around leading practices which enable the wider community to understand how they can contribute to effecting meaningful change. Through verbal agreements with the center the expectation is that the results which will come from this initial project, as well as findings from ongoing future testing will themselves also be brought forth to the public through outreach programming. Through executive dialogs it was identified how making public programming available about the benefits of healthy soils was a focus of the center, and that communicating the findings from this would help support their mission.

Risk assessment for Project, partners, timeline

This work will be carried out within the grounds of Hampshire College and has received approval from appropriate representatives of the college's Trustees to proceed. All physical modifications to the built environment have received approval to move forward for the duration of the project, and there has similarly been approval for the continued monitoring and taking of samples from the site. The expectation is there are no constraints foreseen which will obstruct the successful carrying out of the outlined project, nor the sustained continuance of the treatment methods identified through the project.

Identification of risk considerations

The majority of the physical work carried out in the treatment areas will only affect the top few inches of the soil profiles and therefore will not pose any concerns around damaging any existing campus utilities. The testing work will be engaging in digging a series of 1 meter deep holes which could pose a risk related to any existing buried utilities, however, the specifically selected treatment area was chosen because it was free of any belowground hazards.

With a major portion of this work looking to see what the effects of the growing plants have on the storage of carbon within the soil, the tacit acknowledgement which comes through this approach is that there will be a successful growing of the plants. The selected cold-season grasses prefer to germinate and display optimal root growth with soil temperatures in the 50-65 degree F. range, so for the seeded plants to have the greatest change for success, the soil temperatures will be closely monitored.

In acknowledgement of these thermal parameters, the historical window for when those soil temperatures occur is around the last week in March. As this aspect of the work is contingent upon the outside temperatures and the type and quantity of precipitation, there are several variables which are outside of anyone's control. With a recognition of these risks, the existing plan is to pivot the start of the project slightly as needed if the treatment area is found to be either too cold or too wet, so as to ensure the greatest likelihood for overall project success.

APPENDIX A

Baseline Plot

Treatment		Turf mixture	Diversity mixture
		A 1	A 5
Fertilizer		A 2	A 6
Fertilizer	Aerify	A 3	A 7
	Aerify	A 4	A 8

APPENDIX B

Biochar Plot

		1/4" Biochar	1/4" Biochar	1/2" Biochar	1/2" Biochar	1/2" Charged-Biochar	1/2" Charged-Biochar	1/4" Charged-Biochar	1/4" Charged-Biochar
		Turf mixture	Diversity MIxture	Diversity MIxture	Turf Mixture	Turf Mixture	Diversity MIxture	Diversity Mixture	Turf Mixture
		B1	B5	B9	B13	B17	B21	B25	B29
ertilizer		B2	B6	B10	B14	B18	B22	B26	B30
ertilizer	Aerify	B3	B7	B11	B15	B19	B23	B27	B31
	Aerify	B4	B8	B12	B16	B20	B24	B28	B32

APPENDIX C

Compost Plot

		1/4" Compost, 1/4" Biochar	1/4" Compost, 1/4" Biochar	1/4" Compost	1/4" Compost	1/2" Compost	1/2" Compost	1/4" Compost, 1/4" Charged-Biochar	1/4" Compost, 1/4" Charged-Biochar
		Turf mixture	Diversity Mixture	Diversity Mixture	Turf Mixture	Turf Mixture	Diversity Mixture	Diversity Mixture	Turf Mixture
		C1	C5	C9	C13	C17	C21	C25	C29
Fertilizer		C2	C6	C10	C14	C18	C22	C26	C30
Fertilizer	Aerify	C3	C7	C11	C15	C19	C23	C27	C31
	Aerify	C4	C8	C12	C16	C20	C24	C28	C32

APPENDIX D

Budget

	Treatment	Treatment	Treatment	Testing	Testing	Testing	Outreach	Outreach	Outreach	Administrative Coordination	Administrative Coordination	Administrative Coordination
Action/Activity		Time/Materials	Budget		Time/Materials	Budget		Time/Materials	Budget		Time/Materials	Budget
Meet and coordinate with grounds staff										x	4 hours	$160
Mark out 74 quadrants in treatment area	x	4 hours	$160									
Meet and coordinate with lab staff										x	4 hours	$160
Collect initial soil samples - 74				x	30 minutes per 74, 3' samples	$1,480						
Test initial soil samples for carbon				x	30 minutes per sample	$1,480						
Labeling and mailing samples to biology testing lab				x	20 min per 3 samples	$40						
Test initial soil samples for biology				x	$150 per test [1]	450						
Compile test findings				x	4 hours	$160						
Order - Pickup biochar										x	1 hour	In-kind dontation
Purchase biochar										x	48 yards of biochar [2]	$6,000
Order - Pickup 30 yards of compost										x	1 hour	In-kind dontation
Purchase compost										x	$65 per yard + 2 $110 delivery fees [3]	$2,170
Order - Pickup fertilizer										x	1 hour	In-kind dontation
Purchase fertilizer										x	$30 per bag with 64 bags [4]	$1,920
Order - Pickup seed										x	1 hour	In-kind dontation
Purchase seed										x	seeding rates of 2 lbs per 1,000sqft each	$1,014
Order - Pickup dropspreader										x	1 hour	In-kind dontation
Purchase dropseeder										x	Spyker P70 Commercial Drop Spreader [(	$600
Order compost/biochar spreader										x	1 hour	In-kind dontation
Purchace spreader										x	Earth and Turf MultiSpread 320 [7]	$7,190
Order biochar soak										x	1 hour	In-kind dontation
Purchase soak										x	5 gallon Soil ProVide, 5lbs. Soil ReVive [8	$207
Spread out and soaking biochar	x	2 hour	$80									
Calibrate spreader	x	1 hour	In-kind dontation									
Apply fertilizer	x	1 hour	$40									
Apply biochar	x	2 hour	$80									
Apply charged-biochar	x	2 hour	$80									
Apply compost	x	2 hour	$80									
Order - Pickup Aerifier		[9]								x	1 hour	In-kind donation
Purchase aerifier										x	Ryan Lawnaire 36" [10]	$4,700
Aerify	x	4 hour	$160									
Calibrate spreader	x	1 hour	In-kind donation									
Apply seed	x	2 hour	$80									
Monitor and mow accordingly	x	12 hour	In-kind donation									
At 2" leaf height reapply fertilizer	x											
Collect second soil samples - 74				x	30 minutes per 74, 3' samples	$1,480						
Test second sample for carbon				x	30 minutes per sample	$1,480						
Labeling and mailing samples to biology testing lab				x	20 minutes per sample	$40						
Test second samples for biology				x	$150 per test	$450						
Compile test findings				x	4 hours	$160						
Compare pre and post treatment results				x	8 hours	$320						
Meet and coordinate with educational outreach staff										x	4 hours	$160
Send public anouncement for educational programming							x	3 hours	$120			
Organize registration for free public evenet							x	3 hours	$120			
Event setup and hosting							x	2 hours	$80			
Educational instruction										x	2 hours	In-kind donation
Event cleanup							x	1 hour	$40			
Collect findings, prapare, submit final report and receipts										x	20 hours	$800
Total Budget												
$33,741			$760			7540			360			$25,081
In-kind Donations												
24 hours		21 hours									3 hours	

APPENDIX E

Timeline

	Week of March 11th	March 18th	March 25th	April 1st	April 8th	April 15th	April 22nd	April 29th	May 6th	May 13th	May 20th	May 27th	June 3rd	June 10th	June 17th	June 24th
Meet and coordinate with grounds staff	-----															
Mark out 74 quadrants in treatment area		-----														
Meet and coordinate with lab staff	-----															
Collect initial soil samples - 74		-----														
Test initial soil samples for carbon		-----														
Labeling and mailing samples to biology testing lab		-----														
Test initial soil samples for biology		-----														
Compile test findings			-----													
Order - Pickup biochar	-----															
Purchase biochar	-----															
Order - Pickup 30 yards of compost	-----															
Purchase compost	-----															
Order - Pickup fertilizer	-----															
Purchase fertilizer	-----															
Order - Pickup seed	-----															
Purchase seed	-----															
Order - Pickup dropspreader	-----															
Purchase dropseeder	-----															
Order compost/biochar spreader	-----															
Purchace spreader	-----															
Order biochar soak	-----															
Purchase soak	-----															
Spread out and soaking biochar			-----													
Calibrate spreader			-----													
Apply fertilizer				-----												
Apply biochar				-----												
Apply charged-biochar				-----												
Apply compost				-----												
Order - Pickup Aerifier	-----															
Aerify				-----												
Calibrate spreader				-----												
Apply seed				-----												
Monitor and mow accordingly					-----	-----	----	----	----	----	----	----	----	----	----	----
At 2" leaf height reapply fertilizer								-----								
Collect second soil samples - 74													-----			
Test second sample for carbon													-----			
Labeling and mailing samples to biology testing lab													-----			
Test second samples for biology													-----			
Compile test findings														-----		
Compare pre and post treatment results														-----		
Meet and coordinate with educational outreach staff	-----													-----		
Send public anouncement for educational programming											-----	----	----			
Organize registration for free public evenet														-----		
Event setup and hosting															-----	
Educational instruction															-----	
Event cleanup															-----	
Collect findings, prapare, submit final report and receipts																-----