STATE OF MAINE
DEPARTMENT OF AGRICULTURE, CONSERVATION & FORESTRY
OFFICE OF THE COMMISSIONER
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JANET T. MILLS
GOVERNOR

AMANDA E. BEAL
COMMISSIONER

TO: Joint Standing Committee on Agriculture, Conservation and Forestry

FROM: Department of Agriculture, Conservation and Forestry & Department of Inland Fisheries and Wildlife

DATE: March 1, 2022

RE: *Interim Report for LD 937 - Resolve, To Direct the Department of Agriculture, Conservation and Forestry and the Department of Inland Fisheries and Wildlife To Jointly Develop Recommendations Regarding Carbon Storage Programs and Policies*

Enclosed please find the interim report back to the legislature due on March 1, 2022, relevant to LD 937. The activities to date were coordinated by staff from the Departments of Agriculture, Conservation and Forestry and Inland Fisheries and Wildlife, and the Governor's Office. This work was enhanced by a grant from the US Climate Alliance, allowing the Departments to contract with researchers from the University of Maine to do a rapid assessment of relevant scientific literature for this interim report. The Departments plan to discuss the report with stakeholders and agency partners to further develop collaborations and recommendations on soil carbon incentives.

Increasing carbon storage in soils has two important beneficial outcomes: 1) reducing carbon in the atmosphere, and 2) enhancing the health, sustainability, and resilience of farm, forest, and wetland ecosystems. Our initial work demonstrates areas with some depth of scientific insight to draw on, while other critical areas are emerging priorities in the research community or have only recently been the focus of increased interest.

Many states are engaged in efforts and making investments in their natural resources to contribute to negative emissions and build resilience to a changing climate. This interim report began to look at that body of information and will further evaluate the approaches which might best serve Maine in building on our existing programs.

The Departments envision next-steps in this process to be:

- Using this interim report as a starting point for stakeholder engagement
- Further investigating gaps identified by this interim report

- Submitting a final report to the ACF Committee in September 2022, as prescribed in the Resolve, with a set of recommendations regarding carbon storage programs and policies, including opportunities to embed supportive actions and incentives in existing programs.

We look forward to the Committee’s feedback on the interim report and next steps as described here.

Photo: Johnny Sanchez

An Issue Analysis of Soil Carbon Sequestration and Storage in Maine

Interim Report to the Joint Standing Committee on Agriculture, Conservation and Forestry

March 1, 2022

Acknowledgements

This interim report was written on behalf of the Maine Department of Agriculture, Conservation and Forestry (DACF) and the Department of Inland Fisheries and Wildlife (DIFW) by Ruth Clements, Sonja Birthisel, Ivan Fernandez, Kristen Puryear, and Tom Gordon. Funding for this project is provided by the United States Climate Alliance (USCA) through a grant secured by the Governor's Office of Policy Innovation and the Future (GOPIF).

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Executive Summary

This project seeks to assist Maine policy makers in addressing climate change by developing recommendations for programs and policies to improve soil carbon storage, as outlined in LD 937. The management practices farmers, foresters, and other land managers choose to apply on natural and working lands have substantial ramifications for sequestration (a rate) and storage (a stock) of soil carbon. These represent important opportunities for climate change mitigation in Maine. This interim report describes initial progress on ongoing research to develop recommendations that can inform programs and policies on this issue. This interim report includes: (1) preliminary literature review findings pertaining to management practices that enhance soil carbon in agricultural, forest, and wetland systems; (2) an initial assessment of soil carbon monitoring capacities needed to inform science-based policy; and (3) a summary of ongoing work to identify policies and incentives in other states that could serve as templates for Maine. A final report on this work will be delivered to the Joint Standing Committee on Agriculture, Conservation and Forestry on or before September 1, 2022.

Introduction

About LD 937

This legislation, signed by Governor Janet Mills on June 8, 2021 as Chapter 28 of the Resolves of 2021, directs the Maine Department of Agriculture, Conservation and Forestry (DACF) and the Department of Inland Fisheries and Wildlife (DIFW) to jointly develop recommendations regarding carbon storage programs and policies for the state of Maine. Specifically, the Departments were charged with developing recommendations for the establishment of "*programs and policies to promote and incentivize, where appropriate, practices that increase sequestration of soil carbon on natural and working lands by farmers, landowners and land managers, including, but not limited to, technical assistance and financial incentives for that purpose.*" These objectives are consistent with the goals of Maine's climate action plan *Maine Won't Wait.* This can be achieved by the development of programs and policies that may aid in climate mitigation and resilience by promoting and incentivizing, where appropriate, practices that increase sequestration of soil carbon (the net rate of carbon uptake into soils) and the storage (the total stock of carbon in soil at a given time) on natural and working lands by farmers, landowners, and land managers.

The Resolve became effective October 18, 2021, and the Departments met several times to develop a scope of work for the study. The Governor's Office of Policy Innovation and the Future (GOPIF) initiated a request to the United States Climate Alliance (USCA) for technical assistance. USCA has provided a technical assistance award to DACF for facilitation services and scientific and technical support for the project. The timeline outlined in the Resolve requires this interim report with findings and recommendations be submitted by March 1, 2022 to the Joint Standing Committee on Agriculture, Conservation and Forestry, with a final report to follow on or before September 1, 2022.

Purpose and Scope of Interim Report

DACF and DIFW are working with the University of Maine to provide scientific and technical support to the Departments for this study. The project aims to develop background information in support of recommendations for programs and policies that provide natural and working land stakeholders with incentives to improve soil carbon storage, either by preventing soil carbon loss or increasing soil carbon sequestration. Specific objectives of the study include:

1. Conduct a scientific and technical literature review of existing relevant management practices that enhance soil carbon, with preference given to studies that are conducted in the glaciated Northeast or comparable regions.
2. Explore research and monitoring needs; identify important gaps in knowledge where more research is needed.
3. Identify existing programs, policies, and incentives in other states that could serve as a template or proof-of-concept for similar programs in Maine.

The purpose of this interim report is to summarize progress to date on completing the three specific objectives outlined above, share initial findings that may be of relevance and interest to policy makers, and outline plans for further research to be completed for inclusion in the forthcoming final report.

About Soil and Soil Carbon

Soil is a widely under-appreciated, complex substance that is essential to human and environmental health as we understand it (Koppitke et al. 2022). Key components of soil include a variety of solids, water, air, and a community of organisms relying on one another for survival and interacting as components of an interdependent system (**Figure 1**). Energy enters the soil system via photosynthesis, through which the sun's energy is leveraged to take carbon dioxide from the atmosphere and add it to the living bodies of plants, both above and below ground. When plants and the animals that ingest them (up the food chain) die and their bodies decay, much of the carbon in their tissues - especially those present in plant roots - remains in the soil system in changing forms, becoming soil organic matter that feeds microscopic life through a complex set of chemical and biological processes.

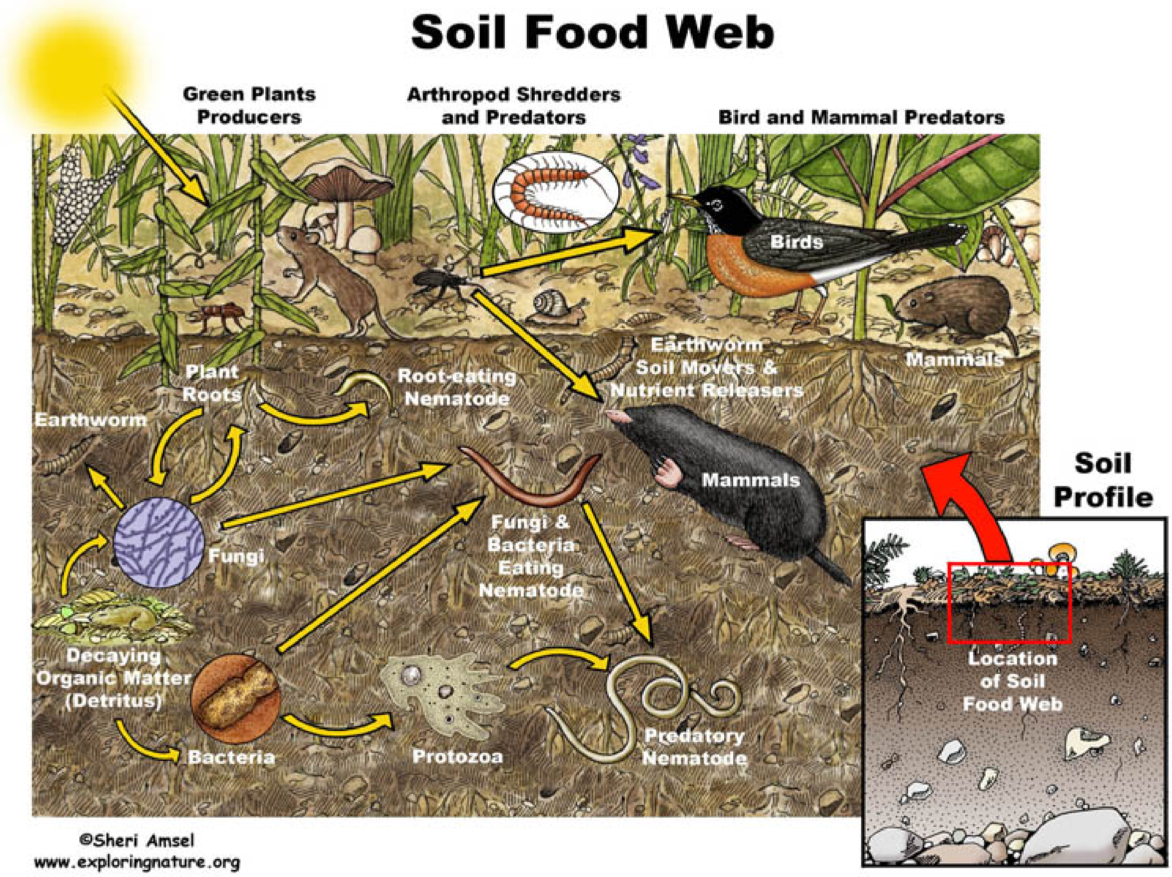

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Figure 1: Diagram illustrating many typical biotic (living) components of Maine soils, and some of the complex ways they interact as an interdependent food web.

At the ecosystem scale, soil is deeply integrated into biogeochemical processes foundational to life on earth. Some of the key functions of soil on which we depend include support for food and fiber (biomass) production, regulation of carbon, nutrient cycling, biodiversity, and water cycling (**Figure 2**).

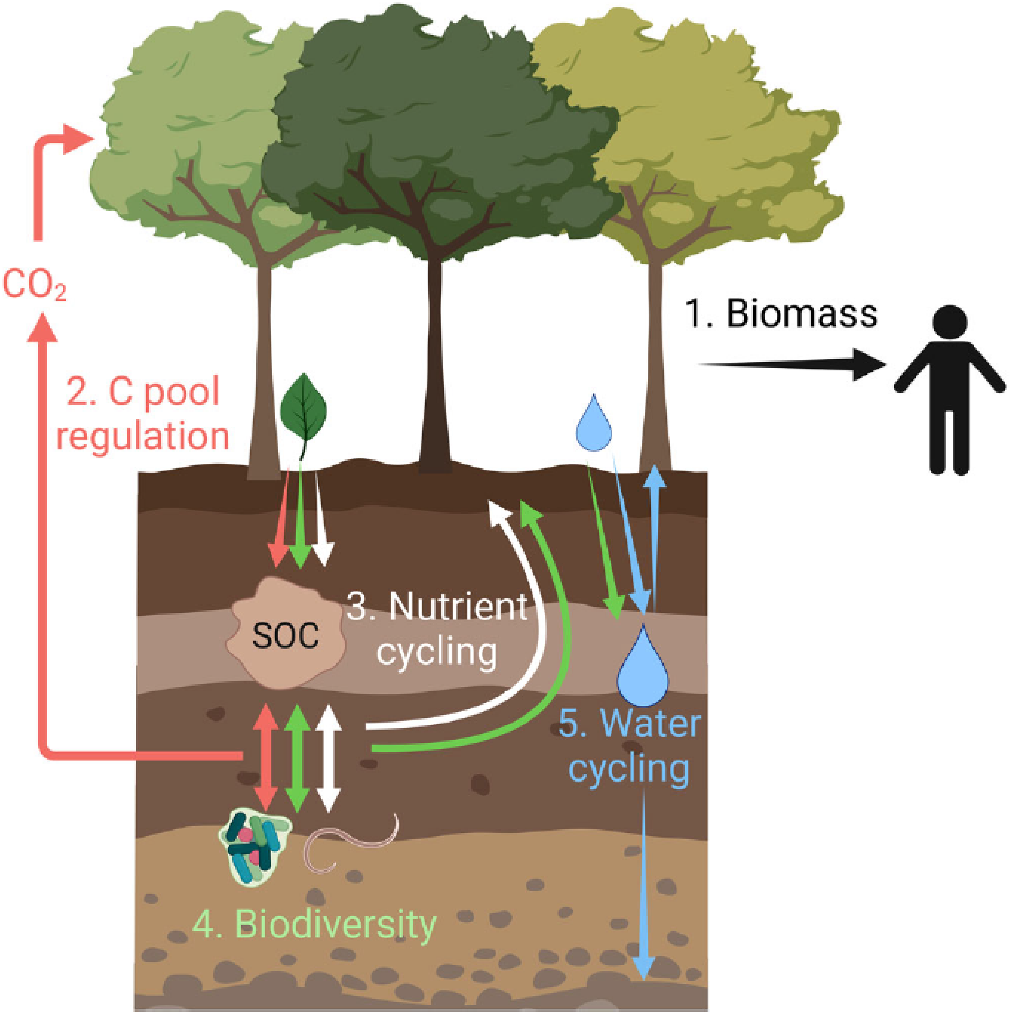

Figure 2: Diagram illustrating five key functions of soil (From: Koppitke et al. 2022).

The function of soil most directly relevant to this study is carbon pool regulation. Soil carbon can include both inorganic and organic forms of carbon (the latter of which is often called soil organic carbon or SOC). Although SOC is a term used primarily in scientific contexts, many gardeners will be familiar with the related term soil organic matter, which in a farm or garden setting is a benchmark for soil health. SOC is simply the portion of soil organic matter that is made up of the element carbon - generally upwards of 50%. The SOC portion of organic matter contributes substantially to the soil health benefits of organic matter, resulting in improvements to the water-holding capacity and structural stability of soils, which in turn increases resilience to moisture extremes and, in a variety of direct and indirect ways, supports plant growth and provides food and habitat for other beneficial soil organisms. The focus of potential new management opportunities for soil carbon related to climate change mitigation and resilience here is on SOC, and not inorganic carbon found in carbonate rocks and minerals in soils and their parent materials.

Soil carbon has clearly understood relationships to atmospheric greenhouse gas concentrations. Carbon atoms trapped in soils as inorganic or SOC are *de facto* not present in the atmosphere as greenhouse gasses such as carbon dioxide and methane (Oertel et al. 2016). Given the ubiquity of soils worldwide, soil carbon pools represent a crucial buffer against anthropogenic climate change, storing more organic carbon than the atmosphere and all the vegetation on earth combined, and providing an economic value estimated at $3.5 trillion annually on a worldwide scale (Jonsson and Davıðsdottir 2016; Koppitke et al. 2022)

Soil carbon stores are not only vast, they are also dynamic. An estimated 7% of the atmospheric carbon pool cycles through soils annually through a variety of processes (Lehmann and Kleber 2015). Land management practices greatly impact soil carbon pools, and represent key opportunities for climate change mitigation. When considering the complex interactions between climate, soil carbon, and land management, it can be useful to divide management actions into two broad categories: (1) those aimed at conserving carbon stocks already present in soils, and (2) those aimed at restoring or adding to existing stocks.

As is clear from **Figure 3**, there are considerable carbon stocks already present in Maine soils, and especially forest soils. Many land management practices relevant to agriculture, forestry, and wetlands can impact carbon “fluxes” - either additions to or subtractions from - soil carbon stocks. The literature review below provides an initial overview of relevant management practices that can conserve or add to carbon stocks in Maine natural and working lands.

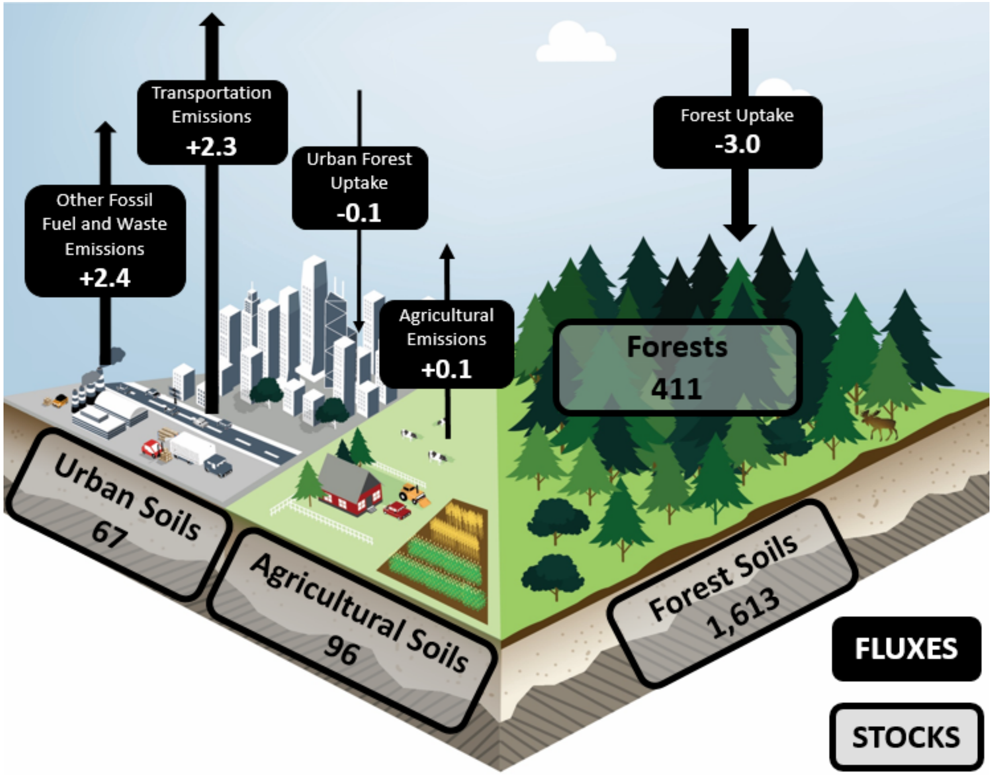

Figure 3: A summary diagram showing soil carbon stocks in forest, agricultural, and urban soils in Maine, and important processes through which carbon moves (fluxes) between these soils and the atmosphere (From: The State of Maine Carbon Budget, Version 1.0; data shown in million metric tons of carbon or MMTC).

Literature Review

The literature review included in this interim report represents a brief overview and summary of topics to be further described in the forthcoming final report. This initial review is divided into three major sub-sections, corresponding to the objectives outlined in the "Purpose and Scope of Interim Report" section above.

1. Soil Carbon Management Practices

1.1 Agriculture

Overall, there exists a large body of literature relating to the role of agricultural management practices on soil carbon stores, including many excellent syntheses and meta-analyses (Bai et al. 2019; Griscom et al. 2017; Jian et al. 2020; Paustian et al. 2016; Paustian, Larson, et al. 2019). The following is a high-level summary of some key initial findings and considerations relevant to management practices impacting carbon pools in agricultural systems, as well as a summary of additional literature review work planned for inclusion in the final report.

Increasing stores of carbon in agricultural soils acts to mitigate the amount of carbon in the atmosphere and to maintain or improve crop productivity by positively contributing to soil health. Management practices that store carbon in agricultural soils rely on either increasing SOC or reducing loss of SOC already present (Paustian, Larson, et al. 2019). Practices that may increase SOC include use of natural mulches, cover crops, and additions of organic amendments including manure and biochar. Practices that minimize soil disturbance help to conserve as well as add SOC to the system. Key practices fitting this latter description include no-till and reduced-tillage cropping practices, and conversion of land from annual to perennial crop production. Critical to conserving existing SOC is the avoidance of the loss of agricultural soils to development. Many of these practices also have known benefits beyond building SOC. By keeping the soil covered, certain practices including cover cropping and reduced- or no-tillage help prevent erosion and soil loss. In addition, organic amendments and the incorporation of crop residues in the soil help build soil organic matter. Emphasizing these soil health and SOC co-benefits in future policy and program-building efforts could help improve practice adoption by farmers.

Of practices proposed for increasing or retaining SOC stores in agricultural soils, cover cropping and reduced tillage have appeared most often in the literature reviewed thus far (e.g., Bruner et al. 2020; Jian et al. 2020; Paustian et al. 2016; Bai et al. 2019; Hopwood et al. 2021; Lal 2004; Lal et al. 2015). Other practices that generally fall under the related umbrellas of climate-smart farming (Paustian et al. 2016), conservation agriculture (Bai et al. 2019), and natural climate solutions (Griscom et al. 2017) have also been extensively studied for their effects on SOC, and their potential use in Maine agricultural systems and import for policy-making efforts will be evaluated as part of our final report. Natural climate solutions are a suite of land stewardship practices meant to build carbon storage or reduce greenhouse gas emissions; in agricultural settings, these include the practices of biochar application, incorporating trees in croplands, nutrient management, grazing management, and avoiding the conversion of grasslands.

Several studies have noted that biochar applications have some of the highest potential for soil carbon sequestration among relevant agricultural practices, including cover cropping and reduced tillage (Bai et al. 2018; Griscom et al. 2017; Paustian et al. 2016). Biochar is a charcoal-like organic material created by burning biomass, such as crop residues, wood chips, or manure, in environments with little-to-no oxygen. This process chemically converts the carbon stored in biomass into a stable form that cannot be easily converted back to CO_2 and released into the atmosphere, which normally occurs as plant or animal materials decompose. Biochar acts to sequester carbon and has been suggested as a carbon dioxide removal (CDR) technology (Schmidt et al. 2021).

While biochar can provide agronomic co-benefits (Schmidt et al. 2021), at the global scale, practices such as nutrient management and agroforestry may be more cost-effective for farmers depending on the context (Griscom et al. 2017). However, a recent analysis of natural climate solutions relevant to Maine agriculture and forestry suggests that biochar and conversion to perennial crops were theoretically among the most cost-effective practices considered that are relevant to the goal of SOC sequestration and storage (**Figure 4**). Although biochar utilization in agriculture is a growing practice globally, biochar application is not widely practiced in Maine at present (Daigneault et al. 2021; Birthisel et al. unpublished data). There are many unknowns about this practice that should be addressed through field and laboratory research to verify promising theoretical results before appropriate policy mechanisms can be developed to support adoption of this practice. It is important to note that biochar is not a singular material, but represents a category of substance with widely varying composition depending on feedstock and production process. Considering the energy required to produce various sources of biomass will be necessary to more fully understand the potential of biochar to lead to net reductions in greenhouse gas emissions (Gaunt and Lehmann 2008).

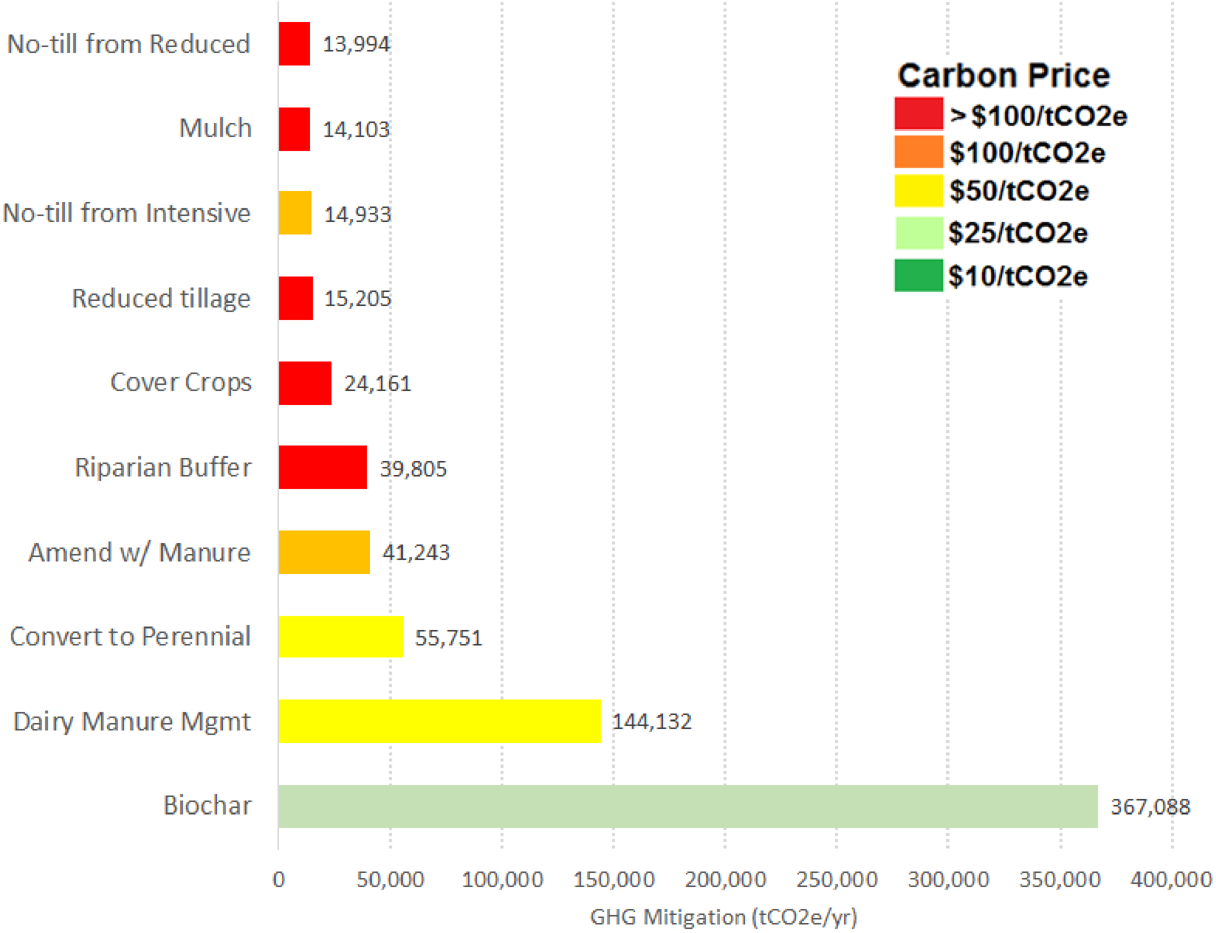

Figure 4. Total greenhouse gas mitigation potential and estimated carbon price of several ‘natural climate solutions’ estimated for agricultural land in Maine. Practices shown here that are relevant to soil organic carbon sequestration and storage include: no-till, mulch, reduced tillage, cover crops, conversion to perennials, and biochar (From: Daigneault et al. 2021)

1.2 Forestry

There is a less extensive scientific literature pertaining to forest management practices on SOC sequestration and stocks as compared with agriculture, though several excellent synthesis and meta-analysis papers have been written recently and can inform policy-making efforts (Devi 2021; James et al. 2021; Kaarakka et al. 2021; Mayer et al. 2020; Nave et al. 2010; Nave et al. 2019; Nave et al. 2021; Ontl et al. 2020). The limited body of research on this topic reflects the focus on aboveground forest carbon as influenced by forest management, the costs of forest SOC research given the extent and depth of the resource typically of concern, and the limited intensity of management applied to this resource on a per acre basis compared to agricultural systems. The following is a high-level summary of some key findings and considerations relevant to management practices impacting carbon pools in forest systems, as well as a summary of additional literature review planned for inclusion in the final report.

The largest carbon stores in forests are found in the soil, including here in Maine (Fernandez 2008; Nave et al. 2018), as opposed to above ground plant and animal life. Keeping these existing carbon stocks in the soil is thus a key goal of forest soil carbon management practices. In addition, forests often hold the greatest potential for SOC sequestration compared to croplands, wetlands, and other natural lands, with forest management pathways accounting for over 60% of the climate mitigation potential of cost-effective natural climate solutions globally (Griscom et al. 2017).

In the literature reviewed to date, practices with potential to increase forest SOC mainly involve reforestation (Griscom et al. 2017; Nave et al. 2019), avoiding forest conversion to other land uses (Catanzaro and D’Amato 2019; Griscom et al. 2017), and harvest timing and techniques (Covington 1981; Nave et al. 2019; Nave et al. 2021). Among these practices, there are certain trade-offs; while avoiding harvesting timber allows greater stores of carbon to accumulate in the soil, active harvesting also can lead to greater carbon sequestration as young cohorts of trees develop (Catanzaro and D’Amato 2019). Natural (forests without prior agriculture) and harvested forests (shrub/scrub or having evidence of past agriculture) result in soils that may contain greater carbon stores than reforestation projects (**Figure 5**). Besides management factors, forest tree species composition, soil conditions, climate, and topography of a forest all influence SOC and contribute to variation in SOC content among stands (Devi 2021; Nave et al. 2019). Wildfires, prescribed fires, and other natural disturbances may also have ramifications for SOC dynamics (Nave et al. 2021; Pellegrini et al. 2017; 2020; 2021; Pellegrini, Harden et al. 2021; Wei et al. 2021). For the final report, further literature review will be targeted toward understanding these patterns in the context of Maine forest systems and the important distinctions between rates of SOC sequestration and standing SOC stock in soils so results are as targeted and relevant as possible to policy making efforts.

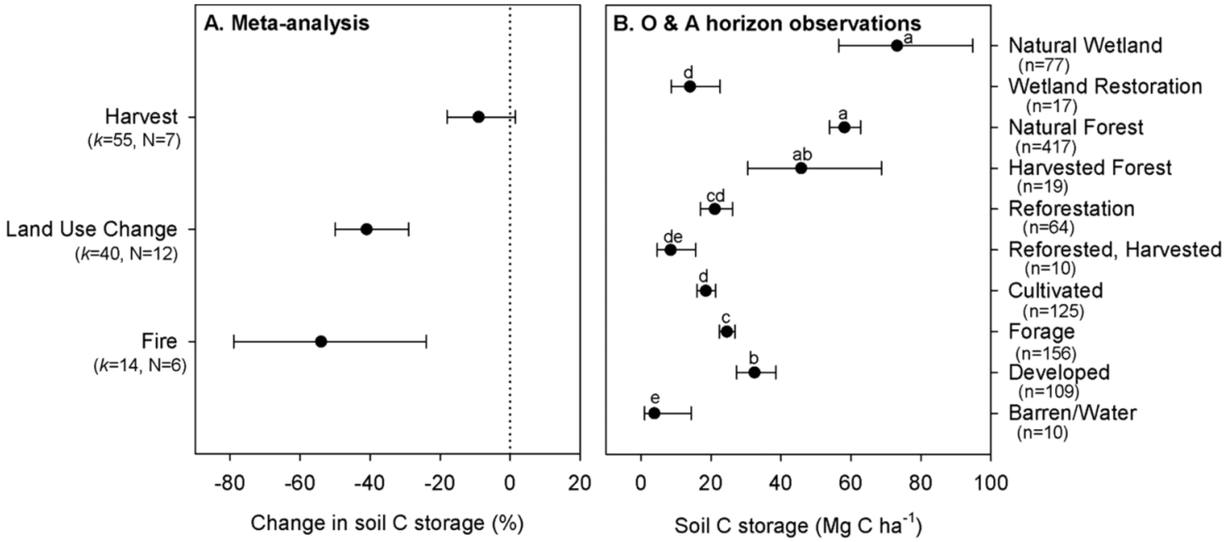

Figure 5. (A) Changes in the amount of soil carbon stored with different disturbances to a forest system, and (B) measurements of soil carbon stored in different land use types including several categories of wetland, forest, and agricultural land (From: Nave et al. 2019).

1.3 Wetlands

The literature on management impacts to wetland SOC pools is scant in comparison to the bodies of work that exist related to agricultural and forest management. This represents a key knowledge gap which will require considerable field and laboratory research by the scientific community. The following is a high-level summary of some key findings and considerations relevant to management practices impacting SOC pools in wetland systems, as well as a summary of additional literature review planned for inclusion in the final report.

Undisturbed wetlands act as large SOC sinks (**Figure 5**), and therefore are critical to keep intact to avoid releasing stored carbon (Limpert et al. 2020). Much research has been done on SOC dynamics in wetlands (e.g., Kayranli et al. 2010; Krauss [Ed.] 2021; Nahlik and Fennessy 2016; Salimi et al. 2021; Yu et al. 2012), though less specifically on wetland management practices that influence SOC. Rehabilitating wetlands from previously degraded or disturbed sites, however, has been cited as being effective in increasing soil carbon sequestration (Limpert 2020). Soil organic carbon density has also been found to be greater in less disturbed wetlands compared to highly disturbed sites (Nahlik and Fennessy 2016), supporting the concept that avoiding wetland disturbances before complete rehabilitation is even necessary is an effective

SOC management strategy (Krauss [Ed.] 2021). Policy-making efforts that support existing programs that fund wetland conservation, such as the Maine Natural Resource Conservation Program, could be beneficial in preventing wetland disturbance.

Despite an extensive body of research on SOC dynamics within wetlands, there appears to be little specific information on management practices to maintain or increase SOC storage. This may in part be due to the fact that there are fewer ‘techniques’ for managing wetlands as compared to forests and farmland. However, recent studies investigating the impact of nutrient enrichment in coastal marshes have shown effects that could have implications for wetland carbon storage, including reductions in belowground plant biomass (Alldred et al. 2017), and increases in microbial respiration that could potentially lead to greater carbon emissions over time (Geoghegan et al. 2018). Research on the impact of management practices beyond limiting nutrient inputs or simply conserving natural and buffered wetland areas for carbon storage represents a key knowledge gap at this time. Constructed wastewater wetlands and stormwater detention ponds are just being considered for their potential to have added benefits of sequestering and storing carbon, and in doing so act as net carbon sinks (Moore and Hunt 2011).

2. Monitoring and Research Needs

Long-term, regional-scale SOC monitoring techniques and networks are needed in order to assess the status of SOC across natural and working lands and monitor changes that occur based on evolving management practices over time. Numerous techniques for measuring and modeling SOC are already established and are also an active area of research, but monitoring programs at the scale needed to inform science-based policy now and over time have not been actualized. Researchers have highlighted an urgent need for coordinated efforts to monitor SOC across larger scales (Harden et al. 2017, Smith et al. 2020; **Figure 6**) so that data on baseline conditions and changes in SOC over time with management interventions can be used to iteratively improve policy-making efforts. Existing networks that provide monitoring of other soil characteristics, such as the Northeast Soil Monitoring Cooperative and the National Coordinated Soil Moisture Monitoring Network, could provide helpful frameworks for developing similar efforts for SOC. A body of literature on the topic of soil monitoring exists and will be evaluated and summarized in the final report (e.g., van Ardenne et al. 2018; Bai and Fernandez 2020; Cao et al. 2019; Cosh et al. 2021; Craft et al. 1991; Gholizadeh et al. 2020; Harden et al. 2017; Heckman et al. 2021; Hikouei et al. 2021; Holmquist et al. 2021; Hoover [Ed.] 2008; Lalimi et al.

2018; Lawrence et al. 2013; Lei et al. 2021; McBride 2021; Mobley et al. 2019; Nave et al. 2020; Paustian, Collier, et al. 2019; Possinger et al. 2021; Ross et al. 2021; Seaton et al. 2021; Slaton et al. 2021; Smith et al. 2020; Vohland et al. 2022; Zeraatpisheh et al. 2021; Woo et al. 2021).

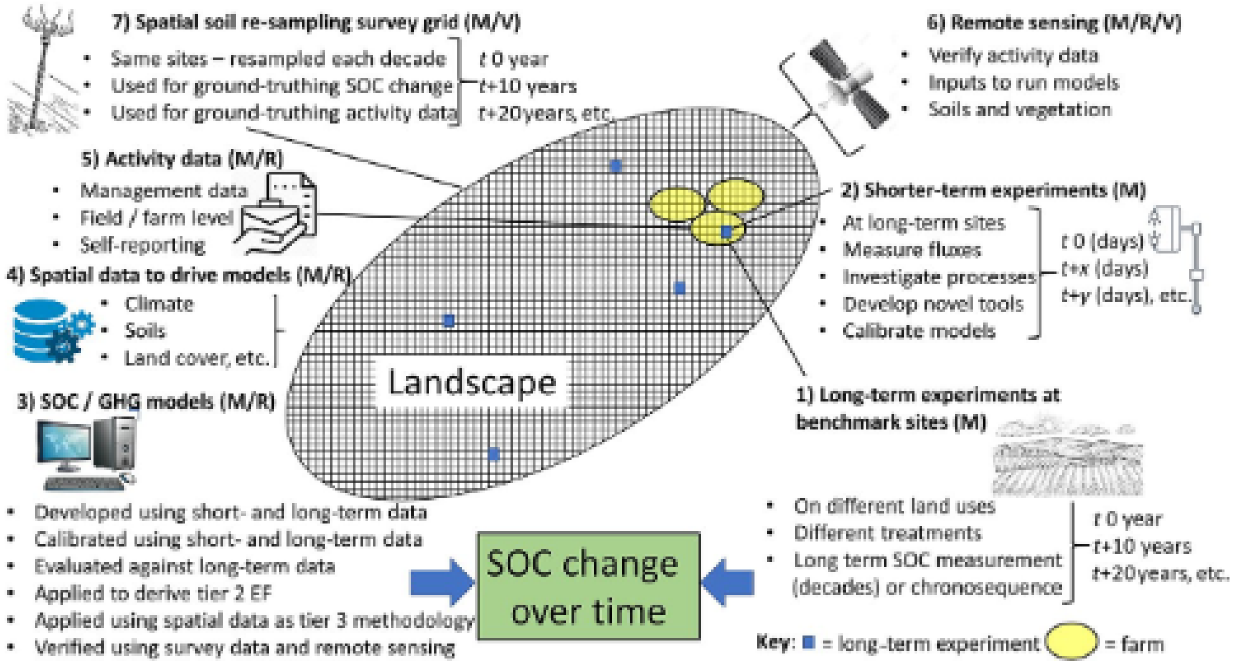

Figure 6. A conceptual framework illustrating the potential infrastructure and coordinated approach needed to develop a landscape-scale soil organic carbon (SOC) monitoring program (From: Smith et al. 2020).

3. Existing Soil Carbon Policies and Programs in the United States

Many programs across the United States have been, or are being, developed to provide support for natural and working land stakeholders to establish soil carbon–building practices. These programs could provide insights and frameworks for developing similar programs in Maine, and expanding existing programs. **Table 1** summarizes several examples of programs developed in other states, with a focus on programs enacted by other states in the Northeast region. The programs range from focusing solely on soil carbon to those that promote long standing soil conservation practices but include carbon sequestration as a co-benefit.

In the final report, programs will be highlighted that use new and innovative approaches, such as quantifying changes in SOC in response to management practices, as opposed to programs that focus on conventional methods of building soil health. This initial survey and review of existing policy mechanisms will be further developed through a comprehensive search for relevant programs in all 50 states, with findings of particular relevance to Maine natural and working lands distilled into policy recommendations applicable to Maine as a component of the final report.

Table 1. Programs that provide support for adopting soil organic carbon management practices.

Program:	**Affiliated Agencies / Organizations:**	**Description:**
New York Soil Health	New York State Department of Agriculture and Markets; Cornell College of Agriculture and Life Sciences; USDA Natural Resource Conservation Service	Develops publications and outreach programs for farmers and agriculture professionals regarding soil health, with goals to improve soil health management practices, climate resilience and water quality, perennial and urban agriculture, and soil health assessments.
Climate Resilience Farming Grant Program	New York State Department of Agriculture and Markets	The goal of CRF is to promote climate change mitigation through greenhouse gas emission reductions and increase farmer resiliency to the effects of climate change in New York. CRF provides grants for farmers who want to adopt practices related to: 1) manure management; 2) water management; and 3) soil health. Since 2015, CRF has awarded $8 million to 121 farms in New York.
California Healthy Soils Program	California Department of Food and Agriculture	The California HSP supports farmers in building soil health through the HSP Incentives Program and the HSP Demonstration Projects. The Incentives Program provides financial assistance to farmers for implementing practices that will improve soil health, sequester carbon, and reduce greenhouse gas emissions. The Demonstration Projects program funds on-farm data collection and/or demonstrations of management practices

		that reduce greenhouse gas emissions and improve soil health.
Massachusetts Healthy Soils Program	Massachusetts State Commission for Conservation of Soil, Water and Related Resources	Legislation recently passed; ramifications are yet to be fully understood.The purpose of the Massachusetts Healthy Soils Action Plan is to provide evidence-based recommendations that help people better manage soils of five major land types including: Forests, Wetlands, Agriculture, Turf and Ornamental Landscapes (developed open space), and Impervious and Urbanized Lands.
Vermont Environmental Stewardship Program	State of Vermont Agency of Agriculture, Food and Markets	The VESP is a pilot voluntary certification program for farmers who meet specific environmental standards in soil management, water quality, air quality, and pesticide management. Farmers who meet these standards receive a five-year certification as a Certified Vermont Environmental Steward, and are provided with technical and financial support for implementing or maintaining practices regarding nutrient management, sediment and erosion control, soil health, greenhouse gas emissions, and carbon sequestration.
Connecticut Soil Health Initiative	Connecticut Resource Conservation and Development Connecticut Council on Soil and Water Conservation	In partnership with USDA NRCS professionals, Connecticut's Soil Health Initiative program provides interactive demonstrations and other outreach events for farmers on terminating cover crops, simulating rainfall on healthy vs. poor soils, and understanding soil properties by investigating soil pits. The Council is tasked with advising the commissioner of the Department of Energy and Environmental Protection (DEEP) on soil health matters and implementation of related programs.
Maryland Healthy Soils Program	Maryland Department of Agriculture	Provides technical and financial assistance to farmers through the Farming for Healthy Soil grant, which pays farmers $10 to $55 per acre for implementing conservation tillage, multi-species or extended season cover crops, prescribed grazing, or precision nutrient management practices.
Oklahoma Carbon	Oklahoma Conservation	The OCP is a carbon sequestration

Program	Commission	certification program that provides state-backed, fee-based verification of carbon offsets for aggregators who have carbon contracts with agricultural or forestry stakeholders. The program aims to encourage the adoption of agricultural and forestry conservation practices that reduce greenhouse gas emissions.
Healthy Soils Hawaii	Hawaii Office of Planning	HSH was a one-year pilot program (2019) established through the Hawaii State Greenhouse Gas Sequestration Task Force, with the goal of identifying best management practices (BMP) for soil carbon sequestration, soil health, and greenhouse gas emission reductions. HSH provided technical support for 10 farmers and ranchers to implement potential best management practices on their land, then used soil health data collected from the experimental sites and interviews with growers to make BMP recommendations for the state.
New Mexico Healthy Soils Program	New Mexico Department of Agriculture	The New Mexico HSP provides funding to organizations and individuals who seek to improve soil health on the land they own or manage. Funded projects must implement one or more of the following principles: 1) keeping soil covered; 2) minimizing soil disturbance on cropland and minimizing external inputs; 3) maximizing biodiversity; 4) maintaining a living root; and 5) integrating animals into land management.

Conclusions and Next Steps

The management practices employed on natural and working lands by farmers, landowners, and land managers have substantial ramifications for sequestration of SOC. Policies and incentives that conserve carbon stocks already present in soils and restore or add to existing stocks may aid the State of Maine in achieving its climate change mitigation goals. This interim report to the Joint Standing Committee on Agriculture, Conservation and Forestry shares progress on ongoing research to develop findings and recommendations regarding programs and policies to aid in climate mitigation and resilience by promoting and incentivizing practices to increase sequestration of SOC on natural and working lands in Maine as put forth in LD 937. A final report expanding the work begun as described in this interim report will follow on or before September 1, 2022.

Preliminary results of our ongoing comprehensive literature review related to management practices that enhance carbon in agricultural, forest, and wetland soils suggest that a deep body of research exists with regard to this topic for agriculture and substantial information with utility to inform policy exists for forestry, but comparably little relevant research has been conducted in wetland systems. It is also important to identify our state-of-knowledge from the body of scientific literature overall, as well as the evidence for how this science can be applied to Maine natural and working lands, our economy, and the communities that depend on them. A comprehensive framework or functioning network for statewide soil carbon monitoring to inform policy and management at all relevant scales and define science-based best practices does not yet exist. However, well-developed theoretical frameworks and practices can serve as templates for creating the infrastructure to conduct such ongoing monitoring, should funding and support be allocated to this important work. Many other states are enacting policies to support soil carbon storage, including nearby Vermont and Massachusetts. Some of the most developed and effective policies reviewed to date have been developed in California, New York, Maryland, and New Mexico, while other New England states are in various stages of developing healthy soil policies and programs.

Beyond expanding the scope of literature review and further developing assessments of programs and policies highlighted in this interim report, additional topics not yet addressed that we intend to include in the forthcoming final report include (1) the complex effects and feedbacks of climate change itself on soil carbon, and (2) the impacts of invasive earthworms and other invasive species on soil carbon dynamics.

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