Ecosystem Service Valuation Approaches and Carbon Mitigation Considerations for Garden State Agriculture

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I. Executive Summary

The ability of natural and working lands (including forests, farmland, ranchland, grassland, wetlands and urban lands) to sequester, or store carbon can be viewed as an opportunity for mitigating climate change by removing carbon dioxide from the atmosphere and storing carbon in vegetation and soil. New Jersey's forests, agricultural land and wetlands are estimated to sequester 8.1 million metric tons (MMT) of CO_2e, offsetting almost 8% of current greenhouse gas emissions. Without natural carbon sinks, the New Jersey Department of Environmental Protection (NJDEP) notes it would fall short by just under 6 MMT CO_2e of meeting New Jersey's 2050 goal to reduce emissions 80% below 2006 levels, when considering all other emissions reductions measures in its 2050 plan. An analysis by NJDEP finds that if current trends in land development and management remain the same, total sequestration levels are projected to be 8.6 MMT of CO_2e by 2030 (a 0.5 MMT increase) and 9.5 MMT of CO_2e by 2050 (a 0.9 MMT increase). As per a preliminary analysis, NJDEP projects New Jersey could gain an additional 2 to 3 MMT of CO_2e annually in additional carbon sequestration from natural and working lands through reforestation, avoided land conversion, and conservation management of agricultural lands (with estimates pending for proactive forest management as well as salt marsh and seagrass restoration and enhancement).

To better understand opportunities for natural and working lands in New Jersey as a "natural climate solution," we reviewed the mitigation potential of soil carbon in agriculture including knowledge gaps and management practices and methods to increase soil organic carbon. Through literature review and semi-structured interviews with 50 experts in the field of ecosystem valuation programs for natural and working lands from over 30 governmental, nongovernmental, academic, and private sector organizations, we evaluated various payment-for-ecosystem-services models that could be applicable for valuing and thus enhancing and incentivizing carbon sequestration specifically within the New Jersey agricultural sector. We included tillable and grazing land models, but also forest lands and wetlands because: 1) woodlands contiguous to, part of, or beneficial to a tract of land devoted to agricultural or horticultural use can qualify for farmland assessment in New Jersey and therefore could also provide enhanced opportunities for carbon sequestration; and 2) examining models for various natural and working land types could potentially provide transferrable characteristics of these models for agricultural systems. Of note is that approximately 20% of land in use by farms in New Jersey is woodland.

Lastly, we provide a synthesis of considerations for New Jersey agriculture that identifies barriers, gaps, uncertainties, research needs, as well as opportunities for agricultural producers in the Garden State. Interview participants are not identified per the approved Institutional Review Board protocol for this project. A list of organizations whose representatives participated in this study are included as Appendix A. A Glossary of Terms is provided in Appendix B.

Soil Carbon Loss and Restoration

Agricultural emissions represent less than 0.5% of New Jersey's gross greenhouse gas emissions and 10% of U.S. greenhouse gas emissions. This report has deliberately focused on only one aspect of addressing greenhouse gas emissions in agriculture: reducing emissions by

sequestration of carbon. There are many other management practices whereby agriculture can make progress toward reductions of greenhouse gas emissions.

Although estimates of degree of change vary, it is well documented that agriculture and agriculture-driven land use change have caused significant losses of soil carbon due to conversion from perennial vegetation to annual cropping, harvesting, tillage, drainage, and other agricultural practices. Reversing land use and/or modifying agricultural management practices can alleviate some of the deficit, restoring soil carbon reserves to some extent for long-term sequestration. Agricultural management practices and methods with the potential to increase soil carbon include: avoiding conversion of grassland and forest ecosystems; agroforestry (the intentional growing of trees and/or shrubs in combination with or in proximity to crops or forage); conversion of annual cropland to perennial grasses and legumes; inland wetland restoration; reduced tillage or no-till cropland management; crop residue retention; cover cropping; crop rotation; improved grazing management techniques; and organic matter amendment.

The degree to which cropland management strategies can increase soil carbon stock varies across climates, soil types, and use of additional management strategies. Native ecosystems, especially grassland and forest ecosystems, support higher soil organic carbon (SOC) stocks than managed agricultural land. Thus, avoiding conversion is an effective strategy for mitigation.

Mitigation Potential

There remain ongoing debates within the research community regarding the actual mitigation potential of SOC strategies, the feasibility of large-scale implementation of practices thought to increase SOC, and the limitations of quantification and verifiability of change in SOC. In spite of this debate, there is consensus regarding the benefits of practices and land use that can increase SOC.

As SOC increases, incremental gains in SOC become progressively smaller over time as a soil trends towards a new equilibrium where soil organic matter decomposition offsets C inputs. At some point, depending on its texture, minerology, and/or depth, a soil's capacity for sequestering carbon becomes "saturated." This point of saturation means that there is a maximum amount or upper limit of carbon that can be stored in a mineral soil.

Given that mitigation strategies must retain C for extended periods of time, it is important to consider the length of time that carbon remains in the soil when discussing SOC sequestration as a mitigation strategy that is effective in reducing CO_2 in the atmosphere. Carbon that is added to the soil and rapidly released into the atmosphere by respiration (i.e., by microbial decomposition) cannot be counted towards mitigation goals.

Change in SOC occurs slowly, and SOC content can vary widely, even at the field scale. Because of this, a large number of soil samples is often required for monitoring purposes. Requirements for quantifying and verifying increases in SOC to determine payments for sequestration of carbon to mitigate climate change are necessarily stringent, especially when compared to what is necessary for monitoring soil health.

Restoring carbon to agricultural soils is potentially beneficial for many reasons. Management practices that can increase and sequester SOC can also improve soil health by reducing erosion, increasing water infiltration and water holding capacity, improving soil temperature regulation, improving food security in some regions, and reducing the need for irrigation and synthetic chemical fertilizer inputs.

Soil health must be prioritized on agricultural land to maintain sustainable production and other ecosystem services. Because the soil health benefits associated with practices like reduced tillage or no-till, crop residue retention, cover cropping, and crop rotation are highly beneficial for sustaining soil functions regardless of climate mitigation potential, soil carbon sequestration can be framed as a positive co-benefit of adopting this suite of practices rather than a primary goal.

Compensation for Ecosystem Services

Payments for ecosystem services (PES) policies compensate individuals or communities for undertaking actions that increase the provision of ecosystem services such as water purification, flood mitigation, or carbon sequestration. Co-benefits of these services can include improved public health, enhanced biodiversity, and creation of green jobs. California and New Jersey, for example, use co-benefits when evaluating funding priorities for cap-and-trade revenue investments. There are more than 500 PES programs worldwide, covering ecosystems including but not limited to: forests, grasslands, and agricultural lands.

Compensation for ecosystem services in the natural and working lands sector may take an outcome-based approach (quantification of greenhouse gas emissions reductions achieved or amount of carbon sequestered) or a practice-based approach (programs that pay for implementation of practices to sequester carbon or reduce greenhouse gas emissions). Payment rates vary across programs.

Even when PES programs are designed to achieve a specific service, (e.g., such as water quality), multiple ecosystem services may be achieved. For example, programs designed to achieve nutrient reductions in the Chesapeake Bay watershed can improve soil health and capacity for carbon sequestration. US Department of Agriculture-Natural Resources Conservation Service (USDA NRCS) programs such as the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP) provide agricultural producers with financial and technical resources to implement conservation practices to improve resource concerns (e.g., soil health, plant productivity, water quality, air quality, and wildlife habitat, among others) while improving agricultural operations. These USDA practices can also provide further opportunities to avoid greenhouse gas emissions and enhance carbon sequestration.

Both regulatory and voluntary markets drive the purchase of ecosystem services. Regulatory compliance markets include greenhouse gas emissions cap-and-trade programs (e.g., Regional Greenhouse Gas Initiative or RGGI and California Cap-and-Trade Program) and incentive-based programs coupled to water quality pollutant reduction regulatory programs.

A regulated entity can meet its cap-and-trade obligations through carbon dioxide emissions allowances (i.e., it must have enough allowances to cover its emissions), through reduction of on-site emissions, or through offsets. Payment for ecosystem services in cap-and-trade systems

are driven by one of two mechanisms. The first is through direct development of ecosystem service value offset projects that generate credits for sale; these are project-based greenhouse gas emission reductions outside of the capped regulated sector. Purchasers of the offset credits can resell them in the marketplace or "retire" them to meet regulatory requirements. The second mechanism in cap-and-trade systems to drive PES programs is to use the revenue generated from the auction of emission allowances to advance climate progress.

Market-based regulatory compliance programs such as cap-and-trade to date have not offered an opportunity for production agriculture to receive payment for ecosystem services for the purpose of carbon sequestration. A possible exception would be for agricultural producers with woodlands that could qualify for ecosystem services payments for carbon storage benefits of forests on their property as compliance offsets in either the California or Regional Greenhouse Gas Initiative (RGGI) cap-and-trade programs. New Jersey landowners could develop offset projects to sequester carbon through reforestation, improved forest management or avoided conversion of privately owned forested land to a non-forest land use following appropriate protocols that would qualify under the RGGI or California Cap-and-Trade Program (note also that in California, an urban forest protocol allows for municipal, educational campuses, and utility tree planting projects).

Conservation organizations have developed forestry offset projects on their lands (including land in the Northeast) for compliance with the California Cap-and-Trade Program; the offset revenue stream can be used to advance their conservation work. Although no forestry offset projects have been awarded offset credits under RGGI, sequestration of carbon due to reforestation, improved forest management, or avoided conversion of privately owned forested land to a non-forest land use located in New Jersey (or partly in New Jersey and partly in another participating RGGI state) may be eligible for generating carbon offsets acceptable for compliance within the RGGI region, provided they follow all appropriate protocols. In the short term, the incentive for development of an offset project for the RGGI market appears weak for various reasons, including the fact that allowance prices in California are historically higher than RGGI. Also of note is that the RGGI states of MA, NH, and RI no longer award offsets.

In California, Cap-and-Trade auction proceeds support California Climate Investments (CCI). Money raised through auctions goes into the Greenhouse Gas Reduction Fund; the legislature makes appropriations to different agencies to administer programs that facilitate the reduction of greenhouse gas emissions or otherwise align with the purpose of the state's Global Warming Solutions Act of 2006 (AB32). There are numerous programs in various agencies that have been funded with appropriations from the CCI program that relate to natural and working lands, including wetland restoration, forest health, forest resiliency, forest fuels reduction, reforestation, forest research, urban forest management, organics waste management, community composting, adaptation and resiliency (e.g., this adaptation and resiliency program has funded ranchers switching to regenerative grazing to increase drought resiliency, rebuild soil organic matter, increase sequestration of carbon, along with improvements to biodiversity), and the California Healthy Soils Program, which includes agricultural practices for farmers to sequester carbon.

Allocation of revenue from the RGGI program in New Jersey is specified by the Global Warming Solutions Fund Act. With regard to natural and working lands, the statute does carve

out 10% of revenue "to support programs to enhance the stewardship of the State's forests and tidal marshes that provide important opportunities to sequester or reduce greenhouse gases;" this allocation does not include agricultural practices for production agriculture.

Water quality programs that provide incentives for prevention of point sources and non-point sources of pollution to meet and ideally to go beyond a legal requirement to reduce water pollutants (such as nitrogen, phosphorus, and sediment) are another type of regulatory compliance program that provides opportunities to earn payment for ecosystem services in the agriculture sector. The State of Maryland's Water Quality Trading Program (WQTP) sets up a public market for pollutant reduction credits to meet U.S. Environmental Protection Agency total maximum daily loads for the Chesapeake Bay. Regulated entities can purchase pollutant reduction credits to meet regulatory obligations. Although none have yet taken advantage of this opportunity, agriculture operations can participate in Maryland's WQTP through a companion Nutrient Trading Program. Certain agronomic practices, such as planting cover crops, are eligible to produce credits through Maryland's Nutrient Trading Program. The Pennsylvania Clean Streams Law limits pollutant runoff statewide, including into the Chesapeake Bay watershed, and requires an Agricultural Erosion and Sedimentation Control Plan limiting soil loss from plowing or tilling to at or below an established soil loss tolerance (T) threshold. Maryland and Pennsylvania both have financing programs to incentivize agricultural conservation practices to meet water quality requirements. Although these practices - financed in Maryland most recently through the Maryland Clean Water Commerce Act (a carve-out of 35% for agriculture of an annual $20 million appropriation from 2021 to 2030 has been allocated, financed through the Maryland Bay Restoration Fund) and in Pennsylvania through the Resource Enhancement and Protection Program (REAP) in the form of a tax credit - are for water quality benefits, many practices can have carbon sequestration as a co-benefit. The NJDEP has passed through federal Clean Water Act funds as well as other federal and State funds to finance non-point source water quality restoration activities. Although the funded projects that have included BMP implementation on farms in New Jersey were not designed with carbon sequestration as a goal, some of the practices could have benefits for greenhouse gas emissions reduction (e.g., manure management) or for sequestration purposes (e.g., riparian buffer restoration).

Voluntary markets for ecosystem service payments where producers are paid for benefits of greenhouse gas emissions reduction of natural and working lands are driven by various factors, including but not limited to: anticipation of regulatory requirements (e.g., Carbon Offsetting and Reduction Scheme for International Aviation); changes in financial markets (e.g., demands of institutional investors); corporate social responsibility (e.g., Science Based Targets Initiative and CDP) ; and the educational mission of colleges and universities (e.g., Duke Carbon Offsets Initiative). Buyers for these ecosystem services include businesses, governments, universities, and individuals.

Interviewees shared that offsets are typically viewed as a way to meet short-term greenhouse gas emissions reductions goals. Some buyers indicated that their preference is to reduce emissions directly over the long-term through changes in behavior, practices, equipment upgrades, etc.; and they plan to reduce their purchases of offsets over time.

Standards and Protocols

There is no universal standard for how markets are or should be run. When it comes to carbon offsets – in the regulatory compliance and voluntary markets – most programs comply with third-party standards and protocols that require offsets to meet "PAVER" requirements, meaning they are: Permanent; Additional; Verifiable; Enforceable; and Real.

No one standard appears to be preferred among those interviewees who were project developers. Based on interviews, the general process seems to be that: 1) project developers are aware of these standards, but there are no comprehensive studies that compare the benefits/drawbacks of various standards and protocols for different project types; 2) project developers conduct their own internal research to determine which protocol and standard are the most appropriate fit for their project type; and 3) in cases where there is no existing protocol to cover a certain project type, project developers work with a recognized standard to create a new protocol.

It costs money to develop an offset project, with annual reporting and verification tied to PAVER requirements representing a significant portion of the costs. In addition to the cost associated with compliance, PAVER requirements present challenges, particularly for small and innovative landowners. Two issues commonly cited relate to permanence and additionality. Farmers are hesitant to sign on to long-term programs, and additionality disqualifies early adopters of practices that sequester carbon. Additionality can be framed as the practice, change in practice, or management style that would not have occurred during a business-as-usual scenario (i.e., without the motivation of the sale of credits).

Program models such as the Western Sustainability Exchange, Audubon Conservation Ranching, Ducks Unlimited Conservation Program, and The Nature Conservancy's (TNC) Family Forest Carbon Program have developed whereby nongovernmental organizations and private companies invest in landowners by providing technical and financial assistance to implement practices (on primarily forests and grasslands) that meet multiple goals of conservation, soil health, and soil carbon sequestration while providing financial benefits to the producers in terms of reduced operating costs and generation of carbon credits for sale on the voluntary market or for corporations to meet emissions reduction commitments.

Market Design

Representatives from across the agricultural sector are participating in the design of marketplaces for carbon sequestration in agriculture as described by interviewees from BCarbon and ESMC. The practices to be included in these marketplaces include soil management and crop production practices, grazing practices, agroforestry, and storage of carbon on grasslands. In at least one market (ESMC), stacking of credits to include water quality and water quantity assets is of interest to some buyers. Food, agriculture, and beverage companies looking to address Scope 3 "supply chain" emissions would be likely potential buyers of credits from agricultural producers or partners with agriculture to address emissions within their "supply shed." The BCarbon program has developed their own certification entity and will not require what they referred to as "traditional additionality" but will issue credits for carbon that has been added to the soil column in the year the credit is issued. Their program is designed for grasslands and not for plowed soil.

Several programs apply conservation practices to specifically achieve climate benefits among other soil health and ecosystem benefits. These include state incentive programs such as the California Healthy Soils Program (HSP), the Maryland Healthy Soils Program, the New York Climate Resilient Farming Program, as well as healthy soils programs of non-profits such as the Restore California Perennial Farming Initiative and Ducks Unlimited's Cover Crop and Livestock Integration Project.

More than 27 practices are eligible for the California HSP; practices include cover crops, no-till, reduced till, mulching, compost application, and conservation plantings, among others. Program outcomes are quantified using the COMET-Planner Tool which was developed through a partnership between Colorado State University and the USDA NRCS and customized for California, working with the California Department of Food and Agriculture. Pursuant to 2018 legislation, a technical assistance grant program was created to aid farmers and ranchers applying to a "climate smart agriculture program" such as the HSP as well as alternative manure management programs and water efficiency and enhancement programs; this new program prioritized funding for organizations directly working with socially disadvantaged farmers and ranchers.

Maryland's Healthy Soil Program was created by legislation in 2017 to improve health, yield, and profitability of soils; to increase biological activity and carbon sequestration in Maryland soils by promoting practices based on emerging soil science; and to promote more widespread use of healthy soils practices among farmers in Maryland. Maryland Department of Agriculture (MDA) is evaluating existing programs to maximize co-benefits of practice adoption for water quality, soil health, and climate change. It has expanded its long-standing cover crop program (which also complemented the USDA EQIP program) that was explicitly tied to nutrient reduction for water quality purposes. MDA has multi-year projects underway on 2,700 acres across the state to explore additional soil health practices (e.g., multi-species cover crops, conservation tillage, variable rate technology for applying nutrients, composting, forest and biomass plantings, nutrient management, prescribed grazing). MDA is also exploring incorporation of coefficients for emissions reductions and carbon sequestration from soil health practices by integrating information from the COMET-Planner tool into the Nutrient Tracking Tool for evaluating a farm with respect to not only nitrogen and phosphorus benefits, but also for carbon emissions reduction and sequestration benefits. MDA has been evaluating projected avoided emissions and carbon sequestered from conservation practices installed statewide, as well as anticipated greenhouse gas reductions through 2030 in the state's "2030 Greenhouse Gas Reduction Action Plan (GGRA)."

The New York State Department of Agriculture and Markets and the New York State Soil and Water Conservation Committee (NYSSWCC) oversee the New York Climate Resilient Farming Program, a competitive grant program which cost-shares implementation of BMPs that sequester carbon, reduce greenhouse gas emissions, and improve on-farm climate adaptation and resiliency through practices done to USDA NRCS standards. Projects applications are ranked based on a scoring method that considers two distinct but complementary goals: mitigation and adaptation/resiliency. Farmers who are trying to accomplish both goals will rank higher. Projects with a broader societal benefit, such as an economic benefit, will also rank higher. New York's program also quantifies greenhouse gas emissions reductions achieved under the program using

COMET-Planner; state officials are in conversation with the Colorado State University developers of COMET-Planner about the potential to modify the tool to incorporate more New York-specific coefficients.

Quantifying Soil Carbon Stocks and Sequestration

There are several key unknowns with respect to the duration of carbon accumulation and persistence in soil caused by agronomic practice changes and regarding quantification of carbon stored at a particular site beyond a baseline. Increased monitoring, reporting, and verification (MRV) of soil carbon that are necessary for creating marketable credits can be costly as well as challenging, particularly for landscapes that are heterogenous. Interviewees observed that carbon market emissions measurements are better suited for point sources than measurements on natural and working lands.

Work to quantify soil carbon stocks, sequestration rates and sequestration potential on agricultural and forest lands is ongoing in New Jersey including that by USDA NRCS and scientists at Rutgers University. Understanding the complex processes within the soil component of the carbon cycle is also essential for accurate modeling and for generating recommendations to improve carbon sequestration underground. Working with partners from throughout the New Jersey agricultural community, USDA NRCS-New Jersey is directing the development of a Soil Health Strategic Plan to help identify focal areas based on soil types and various cropping practices that require more conservation to increase overall soil health. As per colleagues at USDA NRCS-New Jersey, the plan will assess where and what conservation practices and programs need to be implemented across the landscape in New Jersey. This plan, anticipated in late spring/early summer 2022, will help inform priorities for USDA NRCS-New Jersey as well as other agricultural partners regarding targeted outreach efforts and needed conservation initiatives.

Incentives

While the longer-term benefits of implementing practices to sequester carbon in soil are not realized immediately, the intention of incentive programs is for producers to understand and receive economic benefits of such practices so that they will continue to maintain or expand the practice and perhaps adopt other practices independent of incentive payments. Numerous interviewees at the federal, state, and local level identified the need to better quantify the economic benefits of soil health practices in addition to their environmental benefits. Interviewees cited the importance of quantifying the co-benefits from PES programs to build support for these programs.

Factors positively influencing farmer uptake of Best Management Practices include: interpersonal contact between conservation agencies/local organizations and farmers; farmer-to-farmer communication; extension education; access to crop advisors, extension agents, and local soil and water conservation district staff; adoption by neighbors; knowledge about the impact of BMPs on the environment; and financial incentives. Demonstration projects involving peer-to-peer farmer education are employed in Maryland and California to show farmers successful practice implementation and to motivate other growers to conduct these practices. Encouragement for farmers to implement practices can also come from technical service

providers; however, several interviewees noted that farm service providers in New Jersey have little knowledge of carbon sequestration.

Financial incentives are known to influence adoption of BMPs. There are a variety of programs available to monetarily support farmers in transitioning to BMPs; however, there does not appear to be a comprehensive database of such programs available to New Jersey farmers.

The California HSP is funded through a portion of the proceeds of California's Cap-and-Trade Program, but has also received funding from the California Drought, Water, Parks, Climate, Coastal Protection and Outdoor Access for All Act of 2018. New York State's Climate Resilience Farming Program is supported through its Environmental Protection Fund financed in large part through a dedicated portion of real estate transfer taxes. Both the California HSP and the New York Climate Resilience Farming Program allow participating farmers to combine USDA NRCS grant funds with their respective state program funds.

A New Jersey-based interviewee suggested that County Agriculture Development Boards have authority under the Agriculture Development and Retention Act (N.J.S.A. 4:1C-15) to consider supporting stewardship. Other opportunities for financing or prioritizing projects to enhance carbon sequestration on farmland and forested areas might be available through State Agriculture Development Committee (SADC) Soil and Water Conservation Grants, as well as New Jersey's Blue Acres and Green Acres programs.

Innovative financing ideas include consumer- or community-supported programs. A consumer-driven complement to the California HSP is the Restore California Program, managed by the nonprofit Zero Foodprint (ZFP). Farmers can receive grants for carbon sequestration relying on the conservation practices of the California HSP. Funding comes through ZFP members (restaurants, packaged food and beverage suppliers, produce distributors, composters and other related business in exchange) who assess a 1% surcharge on consumer bills. A New Jersey-based interviewee suggested the formation of a non-profit carbon mitigation bank supported by the public and/or Community-Supported Agriculture members who might, for example, offset their own travel emissions by donating funds to the bank that would then be used by their farmers to implement practices to sequester carbon.

A number of interviewees noted that the cost of specialized equipment can be a barrier to implementing agricultural BMPs. New Jersey farms tend to be relatively small in acreage with much soil and crop diversity, which discourages a farmer from investing in new equipment needed to modify management practices due to uncertainty of its benefits or other impacts to the farm operation. This situation may be especially felt by organic producers, who often have the smallest operations and therefore greatest trepidation about purchasing an expensive piece of equipment. In these cases, a cost-share or rent-to-own option could be a possible solution. Several states in the Northeast offer grants, loans, and tax incentives to offset equipment purchases, examples include Maryland's Low Interest Loans for Agricultural Conservation (LILAC), the Maryland Income Tax Subtraction Modification for Conservation Equipment, the New York Climate Resilient Farming Program, and the Pennsylvania REAP and Conservation Excellence Grant programs.

The concept of leveraging current and emerging programs for climate benefits was evident from several interviews. The Pennsylvania REAP program helps farmers comply with the Pennsylvania Clean Streams Law which, as previously noted, requires an Agricultural Erosion and Sedimentation Control Plan limiting soil loss from plowing or tilling agricultural fields to at or below an established soil loss tolerance (T) threshold for the specific soil(s). Eligibility for most USDA conservation assistance programs allows twice the soil loss tolerance threshold (2T), but NRCS employees in Pennsylvania plan for the more restrictive Pennsylvania threshold to ensure farmers are in compliance with the state regulations. An interviewee suggested that New Jersey could reduce soil loss and further improve soil health and enhance carbon sequestration if it were to consider approaches for a more protective soil loss tolerance threshold like that established in Pennsylvania.

Farmers in California have successfully coupled CCI-funded alternative manure management practices to CCI-funded on-farm composting to increase organic matter and carbon sequestration. New Jersey interviewees mentioned the opportunities within the equine industry to develop compost from manure that would improve soil health and foster carbon sequestration while also reducing greenhouse gas emissions from manure. Coupling manure management to programs that also incentivize compost application to improve carbon sequestration can help producers realize multiple benefits. A 2020 New Jersey law requiring large generators of food waste to source, separate, and compost or otherwise recycle their food waste (provided there is a facility within 25 miles and the cost is less than current disposal costs) could provide impetus for development of organics recycling facilities in New Jersey that could utilize organic feedstock from New Jersey farmers, while also generating compost that could enhance sequestration on New Jersey lands, realizing multiple climate-positive benefits.

Precision agriculture technologies can assist in responsiveness to climate change by optimizing output, reducing loss, and conserving resources. Exploring opportunities for coupling these technologies with practices that could address, for example, soil erosion can also ultimately enhance sequestration.

Interviewees noted the need to explore opportunities for producers to be recognized for implementing soil health practices that help to store carbon, among other benefits. For example, Audubon's Conservation Ranching Initiative certifies cattle raised on "bird-friendly" land and the Western Sustainability Exchange's certification of ranches, farms and food businesses that meet sustainability criteria including soil health practices.

Representatives of the New Jersey Department of Agriculture and the SADC noted that climate change brings new challenges to agriculture for which farmers will need to prepare for and adapt and the potential for carbon farming and reforestation in the right instances can allow landowners to benefit financially. SADC representatives noted that one option producers may consider for adapting cropland vulnerable to climate impacts such as flooding is conversion to forested buffers and/or woodland. However, producers have noted an obstacle to the conversion of modified agricultural wetlands to woodland that emanates from NJDEP interpretation of its freshwater wetlands rules. If a producer lets their land go fallow for more than five years, they will lose their ability to convert back to agricultural land in the future because it is no longer considered by NJDEP to be in "active" agricultural use. SADC representatives noted that if these

fields are converted to a forest crop and managed in accordance with a woodland management plan or forest stewardship plan (each approved by NJDEP), then a producer could transition to silviculture, which technically is active agricultural use. SADC representatives noted that if properly highlighted this alternative viewpoint of NJDEP's rules could lead to a comprehensive discussion with NJDEP.

Challenges and Opportunities

SADC representatives also noted challenges to reforestation on preserved farmland that arise from the farmland preservation deed of easement, which is "first and foremost focused on promoting production agriculture." They noted that the long-standing practice of the SADC has been that reforestation has been limited to uplands where NJDEP's wetlands rules do not apply; it has been seen as problematic if the owner of a preserved farm cannot convert woodland back to cropland or pastureland if necessitated by the needs of future generations. As such, the SADC representatives noted that a dialogue with NJDEP over the potential for managed modified agricultural wetlands, for example as silviculture, would be prudent to open up opportunities for sequestering carbon and providing income opportunities for farmers related to wood products and/or carbon markets.

As for the upland portions of preserved farms, the SADC representatives noted that clearer guidance is necessary to determine the amount of preserved farmland that could be converted to forestry and if said conversion has to produce a timber crop (i.e., woodland management) or if other management objectives can be realized, such as the provision of habitat for sensitive species, groundwater recharge, etc. (i.e., through forest stewardship), particularly in marginal agricultural areas, such as steep slopes or highly erodible lands. SADC interviewees noted that the time may be right to think of farmland preservation from a "whole farm" easement concept of a parcel during the land preservation process, including valuing the farm, and consequently the Farmland Preservation Program easement, for its worth not only in perpetuating production agriculture, but also for a farm's contributions toward soil health, addressing nonpoint source pollution, carbon sequestration, species habitat, well-head protection, etc. Programs like the USDA NRCS Conservation Reserve Enhancement Program (CREP) do pay farmers to remove environmentally sensitive land (and often marginal agricultural land) from production and implement practices for 10 to 15 years, such as creating stream buffers to improve water quality; these practices also have other benefits, such as conserving topsoil and sequestering carbon. However, SADC representatives noted that these conservation practices could be better aligned with permanent preservation programs to facilitate holistic resource management in perpetuity. There is an opportunity to contemplate a different type of agreement with a landowner when a farm is preserved so that the farmer might agree to, and in return be compensated for, the creation/maintenance of grassed waterways, riparian buffers, habitat protection, etc. in addition to production agriculture.

The SADC representatives also mentioned the Preserve NJ Act of 2016 which allows Corporate Business Tax (CBT) funds to be used by the SADC for stewardship purposes (e.g., grants to farmers for soil and water practices) on already-preserved farms, which now includes expenditures for "projects that improve the resiliency of farmland soils." However, it needs to be determined if the CBT funds could be used to fund the purchase of conservation tillage equipment for use on preserved farmland. If so, this would have the dual benefit of

conserving valuable soil resources while enhancing farm viability given the labor savings associated with conservation tillage.

New Jersey's high land values place additional challenges to agriculture; property owners are known to hold on to farmland for future development purposes while leasing their land to farmers until such time that they may decide to sell. Approximately 54% of the farmland acreage in New Jersey is leased, while 67% of New Jersey farmers are "part-time farmers", i.e., farming is not their primary occupation. In such cases, the land may be less viable as a candidate for investment in new practices, programs, or equipment that could increase the potential for carbon sequestration because of the leasing farmers' uncertainty of gaining benefits during their tenure on the land, and non-farming landowners perceive that development may be more lucrative than farming. In addition, the long-term viability of carbon sequestration on such parcels is at greater risk from disturbance due to future development, than compared to a farm that is not leased or in farmland preservation.

Despite this overarching challenge, a scan of the landscape of payment-for –ecosystem-services models has been informative in characterizing opportunities for terrestrial agriculture and carbon mitigation. Our review has identified examples of the various programs related to regulatory compliance, non-regulatory incentive-based programs, as well as emerging marketplaces and partnerships among the private sector, nongovernmental organizations, and the public sector to align sustainability goals with conservation goals that can further sequestration of carbon in the agriculture sector.

Table ES-1 is a synthesis of opportunities for enhancing carbon mitigation through ecosystem service valuation in New Jersey agriculture identified through this study.

Table ES-1. Considerations for New Jersey Agriculture

CATEGORY	OPPORTUNITIES
A. Carbon Sequestration Potential/Quantification Considerations	Establish an authoritative baseline of carbon stocks, identify and further assess priority areas for increasing soil carbon, and conduct scenario analyses of potential carbon gain pathways on agricultural lands in New Jersey, building upon research underway and working through continued collaboration between USDA NRCS-NJ and academic research partners.
	Determine the most appropriate conservation practices based on the specific soil, terrain, and agriculture type to assist the farming community in pursuing soil carbon gain pathways.

	Customize programs and practices with consideration of the unique character and features of agriculture in New Jersey: dominance and variety of specialty crops, as opposed to large-scale commodity crops; small acreage of many farms; proportion of part-time farmers; high percentage of leased farmland; strong organic agriculture niche.
	Evaluate the relative efficacy and impacts of different tillage practices across various soil types to maximize carbon storage. This could be based on sampling at various soil depths and understanding the impacts of tillage frequency.
	Evaluate the effects of different grazing systems on forage production and quality, below-ground contributions of nutrients and carbon, SOC stock, and other associated greenhouse gas emissions associated with livestock production.
	Assess root contributions of C from various plant species, multi-species cover crop, and crop rotations to rhizosphere dynamics and related effects on the soil microbiome, soil food web, and ultimately soil carbon stocks; analyze effects of root structure and exudates on soil structure and water retention and drainage.
	Conduct analyses regarding current and projected climate change impacts on factors that influence soil carbon sequestration processes in New Jersey, such as temperature, water availability, water runoff and erosion, and soil health, coupled with an assessment of how New Jersey agriculture can prepare for these impacts while minimizing greenhouse gas emissions.
	Assess conditions under which soil amendments such as biochar and compost improve soil conditions such that plant carbon uptake is increased; comparison of amendment characteristics (including C footprint) and their effects on soil and SOC stock for development of appropriate protocols and application rates of soil amendments for New Jersey soils.
	Establish sentinel sites across the country and perhaps by county in partnership with land grant universities (as suggested by one interviewee) as a way to establish a database of values for carbon sequestration by agronomic practice and determination whether localized factors could be applied to models to reduce the expense of field sampling. For New Jersey, one approach could be to

	conduct a feasibility analysis and create a workplan to establish sentinel sites tailored to the most viable agricultural practices likely to result in the highest opportunity for carbon sequestration.
	Explore potential collaboration with USDA and Colorado State University to tailor the COMET-Planner Tool for New Jersey that would provide localized estimates of potential carbon sequestration and greenhouse gas reductions from USDA NRCS conservation practices.
	Facilitate information and data sharing among New Jersey-based scientists and practitioners conducting carbon sequestration research on New Jersey agricultural land to enhance practice implementation in New Jersey.
B. Market-Based Regulatory Cap-and-Trade Program Considerations	Generation of carbon offsets acceptable for compliance in the California Cap-and-Trade Program - through reforestation, improved forest management, avoided conversion of forestland to a non-forest land use, or urban forestry projects - can be an opportunity for New Jersey landowners to sequester carbon through regulatory compliance markets.
	Generation of carbon offsets acceptable for compliance within the RGGI region - through reforestation, improved forest management, or avoided conversion of land located in New Jersey - is a potential (albeit considered unlikely) avenue for New Jersey landowners to sequester carbon through regulatory compliance markets.
C. Voluntary Market Opportunities	Farmers and landowners can generate carbon offsets for the voluntary market through practices that help to sequester carbon; these include but are not limited to: improved agricultural management (reduced fertilizer use, improved water management, reduced tillage, improved crop planting and harvesting, improved grazing practices), avoided conversion of grasslands, avoided conversion of forest land, and compost addition to grazed grasslands.
	Partnerships between conservation organizations, or in some cases private-sector project developers, and property owners enable landowners to produce carbon offsets (e.g., forest carbon sequestration or grazing practices on grassland) for sale on voluntary markets whereby conservation organizations and/or offset developers provide technical, financial, and administrative

	assistance, while landowners can realize agricultural, conservation, and financial benefits.
	Farmers have opportunities for direct support for conservation practices (such as reduced tillage and precision nutrient management) from corporations seeking to meet CSR goals to address greenhouse gas emissions if they are within the "supply shed" (i.e., within the group of suppliers providing similar goods and services within the company's supply chain) of the entity seeking to reduce its supply chain emissions.
	Aggregation of smaller farmers within a supply shed may provide additional opportunities for agricultural producers to participate in the voluntary carbon market.
	Emerging voluntary marketplaces for ranchers and farmers are piloting ecosystem service credit generation with carbon sequestration as an explicit credit type.
	Consider an evaluation of both the level and duration of incentive that will result in producers changing practices long-term to provide stability in the market, allowing for the incentive to be removed once the practice is firmly established.
	Development restrictions (e.g., to minimize forest loss, such as those provided for by Maryland's Forest Conservation Act) provide opportunities for land mitigation banks to conserve lands, generate credits for landowners, and provide multiple ecosystem services, including carbon storage.
D. Voluntary Practice-Based Opportunities	Develop a regional testing program where, for example, Cooperative Extension (as suggested by an NRCS interviewee) could test out various practices on New Jersey farmland and conduct more demonstrations and on-farm trials to help farmers understand which practices work.
	Develop a deeper understanding of agricultural producer uptake for incentive programs (including state-based and non-profit funded), including an evaluation of the payment level and duration of incentive necessary to make participation in agricultural practices that can enhance sequestration worthwhile in order to

	expand participation in current programs or in designing and implementing complementary programs.
	Consider establishing a New Jersey Healthy Soils or Climate Smart/Resilient Farming program as a complement to, and potential expansion of, practices in current federal program offerings, including practices that allow whole farm climate benefits - to sequester carbon, mitigate greenhouse gas emissions, and enhance climate resiliency - in addition to soil health. Such a program can be informed by the anticipated Soil Health Strategic Plan for New Jersey and include an assessment of best practices to increase soil carbon sequestration and mitigate greenhouse gas emissions.
	Consider components of such a program that would include: -Flexibility to adapt to changing conditions (e.g., wildfires, pandemics) that could delay program completion; -User-friendly application processes and tools (e.g., California's Healthy Soils RePlan Tool noted previously, which automates mapping for applicants and identifies areas eligible for compost); -Resources that enable technical service providers to support and assist farmers in navigating applications, planning, and practice implementation.
	Quantify and communicate economic benefits of Best Management Practices that can sequester carbon, including but not limited to improved crop yields, machinery cost savings, reduced nutrient losses, reduced labor costs, increased income, etc.
	Develop a methodology for assessing co-benefits of ecosystem services, including public health, habitat, climate resiliency, and other endpoints, and quantify and communicate these co-benefits to the public, legislators, and other key constituencies.
	Support demonstration projects such as those funded through the California Healthy Soils program that take field measurements, showcase practices, conduct analysis on cost/benefits, demonstrate sequestration potential for other practices for which greenhouse gas quantification methods are not currently available, and require peer-to-peer outreach.

	Expand training of New Jersey-based technical service providers regarding carbon sequestration management practices and methods. Such a program could build off the Northeast Climate Adaptation Fellowship Program which is piloting training for technical service providers (including those in New Jersey) and producers on climate adaptation and mitigation.
	Support technical service providers in assisting agricultural producers with implementing best management practices for carbon sequestration, healthy soils, and/or climate resilient farming techniques.
	Cap-and-trade programs offer opportunities for investment of proceeds in agricultural practices that foster carbon sequestration as well as in research to support climate action in ecosystems, as is being currently implemented in California. New Jersey could explore the suite of programs that the California Climate Investments offer to address natural and working lands, including agriculture, as opportunities for furthering climate mitigation, as well as resiliency.
	Explore opportunities for county boards of agriculture to advance stewardship and support programs that further carbon sequestration on agricultural lands.
	Explore opportunities for financing or prioritizing projects to enhance carbon sequestration on agricultural lands, including woodlands, perhaps through a combination of sources such as new or extant state programs (e.g., state water quality programs, State Agriculture Development Committee soil and water conservation grants, New Jersey's Green Acres and Blue Acres programs) and enable pooling of federal resources.
	Explore partnering with Zero Foodprint or a Restore California-like program for New Jersey that would engage with consumers, food service businesses, restaurants, and other food service institutions in a table-to-farm model that provides social-impact financing to implement agricultural practices that can sequester carbon.
	Consider creation of a nonprofit natural and working lands carbon mitigation bank supported by donors, including Community Supported Agriculture members, who may want to offset their

	personal greenhouse gas emissions (e.g., travel) by donating funds that would be reinvested in implementing carbon sequestration practices on participating farmers' land.
	As recommended by a New Jersey-based NRCS interviewee, consider a regional program where producers could work with Extension to test out equipment on their land.
	Consider opportunities to provide for equipment purchases, lending, or rental, as well as trade-in or selling of equipment by New Jersey producers for practices that enhance carbon sequestration through state grants, loans, or tax incentives such as those provided in other Northeastern states (e.g., the Maryland LILAC and Income Tax Subtraction Modification for Conservation Equipment, the New York Climate Resilient Farming Program; and the Pennsylvania REAP and Conservation Excellence Grant programs).
	Develop a catalogue of opportunities (pollutant reductions, carbon, other PES) and provide assistance to producers to navigate programs and pool funding to implement practices that will enhance carbon storage.
	Explore opportunities to reduce soil loss, improve soil health, and enhance carbon sequestration by establishing a more protective soil loss tolerance threshold in New Jersey (similar to that in Pennsylvania) that could be incorporated into NRCS-NJ conservation programs and practices.
	Explore opportunities to couple practices and initiatives that realize greenhouse gas emissions reductions (such as alternative manure management to produce compost) with those that sequester carbon (such as on-farm application of compost) to realize even greater climate benefits for agricultural producers.
	Survey the current state of adoption and implementation of precision agriculture technologies and develop training and programming to guide program uptake.
	Identify and explore opportunities to leverage practices with emerging programs (such as the development of compost or other organic soil amendments in New Jersey to comply with recent

	food waste legislation) to reap multiple producer and climate benefits.
E. Marketing Opportunities	Explore opportunities for growers to be recognized for social and environmental benefits of conservation practice implementation, including development of a marketing medium/platform that can serve as a communications tool demonstrating social and environmental benefits generated by growers.
F. New Jersey Agricultural Land Considerations	Explore policy/regulatory changes and potential need for legislation to further carbon sequestration through reforestation on agricultural land (preserved farmland as well as farmland not in the Farmland Preservation Program), striking an appropriate balance between retaining land for agricultural food production versus the provision of ecosystem services.
	Explore consideration of a "whole farm" easement approach that would value preserved farmland for production agriculture, as well as conservation practices that provide ecosystem services such as soil health, water quality and water quantity benefits, and carbon sequestration.
	Explore development of potential changes to statutes and/or rules, if necessary, to improve soil resiliency through the Preserve NJ Act and evaluate the authority to fund equipment to implement concomitant soil conservation practices.

II. Overview

The ability of natural and working lands (including forests, farmland, ranchland, grassland, wetlands and urban lands) to sequester, or store carbon can be viewed as an opportunity for mitigating climate change by removing carbon dioxide from the atmosphere and storing carbon in vegetation and soil.[1] New Jersey's forests, agricultural land and wetlands are estimated to sequester 8.1 million metric tons (MMT) of CO_2e, offsetting almost 8% of current greenhouse gas emissions.[2] Without natural carbon sinks, the New Jersey Department of Environmental Protection (NJDEP) notes it will fall short by just under 6 MMT CO_2e, of meeting New Jersey's 2050 goal to reduce emissions 80% below 2006 levels, when considering all other emissions reductions measures in its 2050 plan.[3] An analysis by NJDEP finds that if current trends in land development and management remain the same, total sequestration levels are projected to be 8.6 MMT of CO_2e by 2030 (a 0.5 MMT increase) and 9.5 MMT of CO_2e by 2050 (a 0.9 MMT

increase).[4] As per a preliminary analysis, NJDEP projects New Jersey could gain an additional 2 to 3 MMT of CO_2e annually in additional carbon sequestration from natural and working lands through reforestation, avoided land conversion, and conservation management of agricultural lands; NJDEP notes estimates are pending for salt marsh and seagrass restoration and enhancement, and for proactive forest management.[5]

In an effort to better understand the various models that could be applicable for valuing and thus enhancing and incentivizing carbon sequestration specifically within the New Jersey agricultural sector, an evaluation of related payment for ecosystem services (PES) approaches was undertaken. In addition to tillable and grazing land, models for valuing ecosystem services for forest lands and wetlands were also explored for two reasons: 1) woodlands contiguous to, part of, or beneficial to a tract of land devoted to agricultural or horticultural use can qualify for farmland assessment in New Jersey and therefore could also provide enhanced opportunities for carbon sequestration; and 2) examining models for various natural and working land types could potentially provide transferrable characteristics of these models for agricultural systems.[6] Of note is that approximately 20% of land in use by farms in New Jersey is woodland.[7]

First, a review regarding the mitigation potential of soil carbon in agriculture is provided, including knowledge gaps and management practices and methods to increase soil organic carbon. This is followed by a discussion of examples of various models of ecosystem services in the United States from agriculture, forestry, and wetlands, with a primary focus on enhancing the use of agricultural land as a carbon sink. Lastly, a synthesis of considerations for New Jersey agriculture identifies barriers, gaps, uncertainties, research needs, as well as opportunities for agricultural producers in the Garden State.

Methods included literature reviews and semi-structured interviews with 50 experts in the fields of ecosystem valuation programs for natural and working lands from over 30 governmental, nongovernmental, academic, and private sector organizations. Pursuant to the Rutgers University Institutional Review Board, interview study subjects' identities are confidential. Literature citations are provided where appropriate; other information provided was obtained through confidential interviews. A list of organizations whose representatives participated in this study are included as Appendix A. A Glossary of Terms is provided in Appendix B.

Agricultural emissions represent less than 0.5% of New Jersey's gross greenhouse gas emissions and 10% of U.S. greenhouse gas emissions.[8] [9] This report has deliberately focused on only one aspect of addressing greenhouse gas emissions in agriculture: reducing emissions by sequestration of carbon. There are many other management practices whereby agriculture can make progress toward reductions of greenhouse gas emissions.[10]

III. Carbon Sequestration in Agriculture as a Carbon Mitigation Strategy

A. Introduction

In the past several decades, researchers studying carbon cycling and soil carbon have identified the potential for soils to act as a carbon sink,[11] [12] [13] thus reducing the amount of CO_2 in the

atmosphere and contributing to mitigation of ongoing greenhouse gas emissions.[14] [15] Globally, soils represent a carbon stock three times larger than the atmosphere[16] and represent the largest terrestrial carbon stock,[17] as organic matter generally makes up about 1 to 10% of the total soil mass, and approximately 50 to 60% of the mass of soil organic matter is carbon.[18] [19] Agriculture and agriculture-driven land use change over the course of the last 12,000 years, and especially in the last 200 years, has caused a loss of an estimated 133 Gt (a gigaton equals 1 billion metric tonnes; it is also referred to as a petagram, Pg) of carbon stocks from soils alone[20] and a 145-Gt loss from both woody biomass and soil carbon stocks between 1850 and 2015.[21] Because of this known deficit, it is widely believed that by changing land use and agricultural management practices, carbon could be re-integrated into soils[22] [23] and sequestered for an extended period of time.[24] Restoring carbon to these agricultural soils is viewed as potentially beneficial for many reasons, since management practices that can increase soil organic carbon (SOC) can also improve soil health by reducing erosion,[25] increasing water infiltration and water holding capacity,[26] improving soil temperature regulation,[27] improving food security in some regions,[28] and reducing the need for chemical fertilizer inputs.[29] Outside of agriculture, other land use and land management opportunities for carbon sequestration include reforestation, forest maintenance,[30] and wetland preservation and restoration.[31] Forested land can sequester more carbon than agricultural land due to the high capacity for woody biomass, namely trees, to store carbon aboveground for long periods of time.[32] A key distinction though is where in the ecosystem carbon is stored, and this report focuses on agricultural land, and more specifically on agricultural soils. Further, agricultural practices and land use change have been the primary causes of a reduction in soil carbon content, and a reversal of this depletion would lead to an increase in sequestered carbon.[33]

Because it is widely agreed upon that land use and agricultural management changes can sequester additional carbon, recent years have seen global initiatives focusing on soil carbon as a mitigation strategy to counter excess CO_2 in the atmosphere. These include: the French Ministry of Agriculture's "4 per mille" initiative,[34] which has the goal of increasing global SOC stocks by 0.4% per year; the Intergovernmental Panel on Climate Change (IPCC) updated guidelines for countries to estimate their reporting data for greenhouse gas emissions, including change in SOC estimates based on how changes in land use and/or management affect default reference SOC stocks;[35] and the FAO's Global Assessment of SOC Sequestration Potential (GSOCseq) program.[36] Though these initiatives are gaining traction globally, there remain ongoing debates within the research community regarding the actual mitigation potential of soil carbon strategies,[37] [38] the feasibility of large-scale implementation of practices thought to increase soil carbon,[39] and the limitations of quantification and verifiability of change in soil carbon. [40] [41] These interwoven issues manifest as an ongoing conversation regarding the utility of soil carbon sequestration as an effective tool for mitigation. Aside from the aforementioned debate, there are notable research gaps regarding soil carbon dynamics and storage potential (including responses to tillage management, and cover cropping, as well as the effects of organic management and the role of the soil microbiome on carbon storage).[42] [43] Importantly, the debate surrounding the utility of soil carbon sequestration as a mitigation strategy and the existing knowledge gaps amount to two separate issues and should not be conflated.[44]

Soil health is the capacity of a soil to function within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support

human health and habitation.[45] [46] There is wide consensus regarding the many soil health benefits associated with the practices that have potential to sequester carbon.[47] [48] [49] Soil health benefits both ecosystems[50] and food security[51] insofar as healthy soils provide critical ecosystem services including clean water, carbon sequestration, and habitat,[52] as well as provisioning services including food and fiber production. Soil health must be prioritized on agricultural land to maintain sustainable production and other ecosystem services. Thus, some have recommended framing soil carbon sequestration as a positive co-benefit to adoption of soil health practices (including reduced tillage or no-till, crop residue retention, cover cropping, and crop rotation) rather than a primary goal of adopting this suite of practices.[53] [54] [55] [56] For example, Poulton et al. (2018) suggest that rather than promoting practices that increase SOC as mitigation strategies, they should be promoted for their ability to preserve and improve the functioning of soils, both for sustainable food security and wider ecosystem services.[57] Similarly, Bradford et al. (2019) argue that the need to rebuild soil carbon in degraded agricultural soils is often framed as a climate change mitigation strategy, and that the relative scientific contention surrounding the efficacy of this strategy detracts from the need to rebuild soil carbon for sustainable land stewardship and soil health.[58]

B. Soil Carbon Sequestration

Carbon stocks in soils are determined by the relationship between carbon inputs (assimilation) and decomposition/respiration.[59] Thus, in order to sequester carbon, the input rate must be greater than the decomposition/ respiration rate.[60] Soil carbon sequestration refers to the "process of transferring CO_2 from the atmosphere into the soil of a land unit, through plants, plant residues and other organic solids which are stored or retained in the unit as part of the soil organic matter."[61] Many factors interact to determine how the SOC stock will be affected by change in either C inputs or decomposition; cycling of soil organic matter is a complex process involving the interaction of soil moisture, temperature, porosity,[62] composition of the soil microbiota,[63] and C input via root litter and exudates, above-ground litter,[64] and organic amendments.[65] In contrast to soil carbon sequestration, carbon storage is the increase in SOC stocks over time in the soils of a given land unit, not necessarily associated with a net removal of CO_2.

Many estimates of global SOC sequestration potential have been undertaken in the last two decades, resulting in a range of values reflecting the biophysical potential for managed cropland and/or grassland systems specifically to store additional carbon. Estimates vary, but many fall within a range of 2-5 Gt CO_2 per year sustained for a limited time period, on the order of 2 to 3 decades before decreasing, as SOC levels approach a new equilibrium.[66] Importantly, these estimates assume almost complete adoption of sequestering practices, and therefore represent the upper bound of C sequestration potential. The "4 per mille" initiative has suggested a global rate of 12.6 Gt CO_2 per year to offset most of the current annual increase in atmospheric CO_2,[67] but the possibility of this rate of sequestration is widely debated.[68] [69]

C. Factors Affecting Soil Carbon Sequestration

C.1 Saturation

As SOC increases, incremental gains in SOC become progressively smaller over time as soils trend towards a new equilibrium where soil organic matter decomposition offsets C inputs. At some point, depending on its texture, minerology, and/or depth, a soil's capacity for sequestering

carbon becomes "saturated."[70] This point of saturation means that there is a maximum amount or an upper limit of carbon that can be stored in a mineral soil[71] [72] (soil primarily composed of mineral matter i.e., sand, silt, and clay particles) - as opposed to organic soils (which contain a large amount of slowly decaying organic matter) which do not have a SOC saturation point. The amount of time or amount of C needed to reach saturation differs based on climate, soil type (specifically surface area of mineral particles), and the extent to which the soil has been degraded.[73] Agricultural management practices including cropping decisions, and geographical conditions are additional factors that make the saturation level difficult to define for each situation. Soils with a theoretically high capacity for sequestration include those containing clays and high surface area, which allow for increased organic matter protection via interaction with soil mineral surfaces.[74] The organic matter which is protected in this way is referred to as mineral-associated organic matter (MAOM), and though relatively stable, the mineral association does not confer complete stability or an ability to persist in the soil indefinitely. The matter of soil environmental properties and their relationship to carbon saturation is not settled; indeed, researchers continue to call for further research regarding the relationship between soil type, climate, and saturation.[75] [76] Some suggest that this information could be used for targeting increased C inputs for maximum sequestration by location and soil type[77] [78] while others suggest that practices should be targeted in areas with larger initial C deficits, as they have the largest potential for gain.[79]

C.2 Permanence

Given that mitigation strategies must retain C for extended periods of time, it is important to consider the length of time that carbon remains in the soil when discussing soil carbon sequestration as a mitigation strategy. Carbon that is added to the soil and rapidly released into the atmosphere by respiration (i.e., by microbial decomposition) cannot be counted towards mitigation goals.[80] [81] Discussions of long-term, soil-based natural climate solutions have often been structured around the concept of permanence, which often requires that C remain sequestered during the period of offset credits, which is typically 100 years for forest systems.[82] However, researchers have recently suggested a change in understanding regarding the persistence and permanence of SOC; instead of the view that splits SOC into three pools based on turnover times ranging from <1 year (active pool), 20-50 years (slow pool), to >1,000 years (passive pool)[83], a model of dynamic stability is favored.[84] [85] Rather than viewing MAOM as permanent, this new perspective states that "soil C longevity can best be conceptualized as persistence, in which the long-term sequestration of SOM results from the flow of C throughout a complex soil environment, where it can be transformed by soil microbes and interact with soil minerals and physicochemical structures."[86] Whereas the policy view of "permanence" is based on permanent use of a practice and assumes loss of SOC if and when the practice ceases to be used, this new vision regarding SOC "persistence" suggests that along with its biochemical transformations, C moves through the soil profile and may experience increased longevity in the soil at deeper soil horizons.[87] In fact, several studies have shown that infrequent use of tillage has not resulted in a significant C loss relative to no-till.[88] [89] This can be understood based on the concept of persistence, rather than permanence. Persistence suggests that the movement of C deeper into the soil horizon over time may help to facilitate long term sequestration.

C.3 Measurement and Verification

Quantification and verification of change in soil carbon represents a significant challenge considering the fact that change in soil carbon occurs slowly[90] and soil carbon content can vary widely, even at the field scale.[91] Significant changes in SOC are difficult to detect before 7 to 10 years, even with very intensive sampling.[92] Direct measurement of SOC involves quantification of (a) fine earth (<2 mm) and coarse mineral (>2 mm) fractions of the soil; (b) organic carbon (OC) concentration (%) of the fine earth fraction; and (c) soil bulk density.[99] Due to high spatial variability, a large number of soil samples is often required.[100] Additionally, sampling depth is an important factor to consider when evaluating change in SOC content. Change at many levels of the soil profile must be accounted for, and the effects of some interventions may be more apparent only at the 0 to 30 cm depth, rather than deeper in the soil profile.[101] [102] This level of sampling/testing is both time-intensive and expensive, and thus monitoring, reporting and verification must be paired with modelling and remote sensing approaches. Smith et al. (2020) outline how a robust system of benchmark test sites in a soil monitoring network could be combined with remote sensing data, modelling, and machine learning technology to generate estimates of change in SOC.[103]

Quantification and verification requirements of SOC increases for mitigating climate change through sequestration are necessarily stringent, especially when compared to what is necessary for improving soil health. Total SOC stock must be increased, rather than just increasing the concentration of carbon in the soil.[93] The carbon increase in soils must also be "additional," meaning that the C would otherwise have been atmospheric CO_2, rather than a different form of terrestrial carbon.[94] Retaining SOC can require continuation of practices that either increase C inputs or avoid releasing additional C into the atmosphere,[95] though research has documented instances in which cessation of a sequestration practice or re-integration of a carbon releasing practice (such as tillage) has not led to decreased SOC relative to the baseline.[96] [97] However, failure to maintain modified management practices may result in reversal of any potential SOC gained.[98] Quantification and verification of change in SOC is especially important to consider in situations where there is intention to quantify change in SOC as a mitigation strategy either for payment or as a part of a policy of climate change mitigation.[99]

In contrast, soil health benefits from increased soil organic matter and the associated SOC are often of greater interest to farmers when not participating in carbon markets or goal-based incentives to enhance carbon sequestration. Soil organic matter contributes to improving many soil properties that are considered indicators of soil health. Enhanced microbial activity is often the first response observed after additions of organic matter, and the biological processes facilitate soil aggregation and structural stability. Improvements in soil structure in turn have the potential to promote infiltration and plant-available water holding capacity. Improved root growth, plant nutrition, and resilience to drought are cascading benefits.[100]

C.4 Modeling

Process-based biogeochemical models are used to extrapolate from measurements taken at specific sites and times to project the data to large regions over longer periods of time.[101] This effort is helpful in an agricultural context to understand outcomes of various conservation management practices and to evaluate their effectiveness in terms of soil health benefits and greenhouse gas mitigation. Two commonly used models for this purpose are Denitrification

Decomposition (DNDC) and DayCent (which operates as a part of the greenhouse gas quantification tool COMET-Farm).

Originally developed to predict nitrous oxide (N_2O, a greenhouse gas and catalyst of stratospheric ozone degradation) emissions in agricultural cropping systems,[102] DNDC is a process-based model that simulates carbon and nitrogen cycles in agricultural systems. Since its origination, DNDC has been updated and is now capable of predicting changes in N_2O, CO_2 and methane (CH_4, another greenhouse gas) fluxes from soils and can be used for cropping systems, rice paddies, grazed pastures, forests, and wetlands.[103] Two components comprise DNDC: the first predicts crop growth and soil environmental factors (i.e., temperature, moisture, pH), and the second simulates emissions of greenhouse gases using the soil environmental factors predicted by the first component.[104]

COMET-Farm is a model-based web tool for farm-wide greenhouse gas quantification. The tool can assess CO_2, CH_4 and N_2O sources as well as CO_2 sinks from a wide variety of management practices including cropping systems, livestock, and on-farm energy use. COMET-Farm integrates activity data, which are supplied by the user and are specific to the land use and management practices used, with emission rate models that estimate greenhouse gas fluxes as a function of the activity data and the climate and soil conditions at a particular location.[105] The DayCent model is used to estimate SOC stock change within the COMET-Farm tool. DayCent is a daily time-step model of Carbon and Nitrogen dynamics, including CO_2, CH_4 and N_2O emissions.[106] Both models have been investigated for their ability to accurately predict soil carbon change, crop yield, and greenhouse gas emissions.[107] [108] Smith et al. (2012) found that when the DayCent and DNDC models were used to estimate change in SOC based on crop residue removal and compared to actual change in SOC, both models simulated the hypothesized trend in SOC change, with DayCent slightly overestimating the average effect of residue removal on SOC, and DNDC underestimating the effect on SOC.[109]

D. Management Practices and Methods to Increase SOC

D.1 Maintenance and Improvement of Native Ecosystems and Perennial Cropping

Native ecosystems, especially grassland and forest ecosystems, support higher SOC stocks than managed agricultural land.[110] [111] Thus, avoiding conversion is an effective strategy for mitigation.[112] Agroforestry and natural forest management both present opportunities with relatively high mitigation potential,[113] with agroforestry referring to the intentional growing of trees and/or shrubs in combination with or in proximity to crops or forage for the purposes of increasing production, protecting soil and water resources, conserving energy, improving ecosystem diversity, creating additional wildlife habitat, and/or increasing landscape diversity.[114] Trees keep more carbon in the soil and biomass than is possible on annual crop land and offer more permanent carbon storage. [115] Co-benefits associated with forests include erosion control, increased habitat for wildlife, increased biodiversity, and potential for income diversification.[116] Time since the change was implemented is the main factor influencing above-ground carbon sequestration, while climate is the main factor influencing soil carbon sequestration, with some climates creating conditions much more conducive to accumulation of SOC than others.[117]

Conversion of cropland to perennial vegetation, including grasses or trees, can lead to increased soil C inputs from roots and litter associated with production of aboveground C,[118] as well as a

reduction in soil disturbance since perennials require soil disturbance only at planting and not usually again during years or decades of their life cycles.[119] Carbon stocks decline after land is converted from grasslands and pastures to cropland and increase when the process is reversed,[120] with accumulation continuing for several decades, and ultimately approaching levels of native SOC stock.[121] A recent study using global data found that during a 20-year period encompassing a change from annual to perennial crops, soils experienced an average increase in SOC at both shallow (0-30cm) and deeper (0-100cm) depths of soil profiles.[122]

Inland wetland restoration is another management practice with the potential to sequester CO_2 by increasing total SOC stock. Wetland soils, including those classified as "Histosols," or peat soils, are characterized by high organic matter content (> 20% - 35% minimum by mass, depending on depending on texture of the mineral fraction),[123] in contrast to mineral soils which normally have organic matter percentages <10% and frequently <5% (mass). The periodic or continual saturated state of wetland areas creates anaerobic conditions that impede decomposition of organic matter, allowing accumulation of SOC. When artificially drained, wetland soils can be extremely productive as agricultural land, but this conversion results in large losses of SOC, as high as 40-80 t CO_2 ha^{-1} y^{-1}, as introduction of air/oxygen into the soil allows the organic matter to oxidize (decompose) more rapidly.[124] Thus, just as conversion from cropland to grassland can cause an increase in SOC, restoring hydrologic conditions for inundation or rewetting of these organic soils to convert them back into wetlands offers the potential for net annual CO_2 removal, though the extent of this removal depends on area of drained wetlands to be rewetted, and the effects of rewetting on CH_4 and N_2O emissions remain unclear.[125] These greenhouse gases are potential products of the slower, less efficient process of anaerobic decomposition and metabolism of nitrogen under oxygen-limited conditions of wet/saturated soil. Since CH_4 and N_2O are more potent greenhouse gases than CO_2 (Box 1), increases in emissions of CH_4 and N_2O resulting from restoration of wetland areas may negate the benefits associated with an increase in sequestered C.

Box 1. Agricultural Greenhouse Gas Emissions

Agricultural activities along with forestry and land use changes contribute to greenhouse gas emissions. The greenhouse gases emitted by agriculture include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), which contribute to global warming. Different greenhouse gases have different Global Warming Potentials (GWPs). Two factors contribute to the global warming potential: (1) the strength of a greenhouse gas, and (2) its lifetime in the atmosphere. These Global Warming Potential values are calculated for either 20 years or 100 years, representing the average Global Warming Potential value over those time periods. The unit of Global Warming Potential is a ***"carbon dioxide equivalent",*** because the other gases are compared to CO_2. Therefore, over 100 years, the Global Warming Potential of CO_2 is 1. Methane over 100 years has a Global Warming Potential value of 34 because it is 34 times more potent than CO_2. Nitrous oxide over 100 years has a Global Warming Potential value of 298. To convert tons of methane to CO_2e, multiply by 34. To convert tons of nitrous oxide to CO_2e multiply by 298. In summary, CH_4 and N_2O are far more potent than CO_2 as greenhouse gases.[126] The three major agricultural greenhouse gases should be considered together; if a practice decreases CO_2 significantly, but increases N_2O or CH_4 output, since N_2O and CH_4 are more potent GHGs, the amount of mitigation is reduced.

Global Warming Potential (GWP) of Greenhouse Gases Relevant to Agriculture

GHG	GWP (20 year time scale)	GWP (100 year time scale)	Source[127]
Carbon Dioxide (CO_2)	1	1	IPCC. AR5. 2014
Methane (CH_4)	86	34	IPCC. AR5. 2014
Nitrous Oxide (N_2O)	268	298	IPCC. AR5. 2014

D.2 Agricultural Management Practices

Apart from the carbon that can be sequestered in native ecosystems, either by preserving or improving them, a number of agricultural management practices (Table 1) have demonstrated the potential to increase SOC.[128] Importantly, the degree to which cropland management strategies can increase soil carbon varies across climates, soil types, and use of additional management strategies.[129] Practices such as reduced tillage or no-till, crop residue retention, cover cropping, and crop rotation to increase crop residues have a positive impact on soil health[130] by reducing erosion,[131] [132] increasing soil fertility and soil water holding capacity,[133] preserving or building soil structure and improving resilience to stressors such as drought.[134] These benefits are in addition to the potential for increasing SOC.[135] Even small additions of SOC can have positive impacts on the quality and functioning of many soils,[136] which is to say that even if SOC is not increased in a way that is meaningful as a mitigation strategy, it can still have a positive impact on ecosystem functioning and agricultural production and sustainability.

Agricultural management activities such as tillage, cover cropping, enhanced crop rotations, and grazing management should be studied both independently of one another to establish mitigation estimates, co-benefits, and tradeoffs for each practice, and in concert to determine additive or synergistic effects.[137] Depending on the place, climate, soil type, crop, and combination of practices used, the aforementioned practices can have very different impacts on soil organic carbon, N_2O emissions[138] and yield.[139]

Tillage

Tillage is a practice used by farmers to prepare land for seeding, control weeds, incorporate fertilizers and other inputs, and manage soil moisture and temperature. It is the main source of soil disturbance in annual croplands. This disturbance leaves the land vulnerable to erosion and reducing tillage can restore soil structure and aggregate stability.[140] Under no-till management, improved aggregate stability is thought to be the mechanism for promoting increased C storage.[141] Studies have shown that SOC changes caused by use of no-till vary based on climate,[142] [143] soil type,[144] [145] depth in soil profile,[146] [147] specific type of tillage practice,[148] and management strategies.[149] [150] Conversion from tillage to no-till has been shown to result in positive, negative, or no-change in SOC.[151] In general, the rate of change in SOC due to change in tillage practice is greater in warmer and wetter climates than drier and cooler climates, meaning that SOC gains and losses will occur more quickly in warmer and wetter places.[152]

When soil type is also considered, Ogle et al. (2019) found enhanced amounts of SOC throughout the soil profile under no-till versus tillage in sandy soils of tropical moist/wet, tropical dry, warm temperate moist and cool temperate moist climates, as well as loamy, silty and clayey soils in tropical moist/wet, warm and cool temperate moist climates.[153] Their analysis was less conclusive for all soil types in cool and warm temperate dry climates, and loamy, silty, and clayey soils in tropical dry climates.

Table 1. Examples of agricultural management practices that can increase organic carbon storage in soil and promote a net removal of CO_2 from the atmosphere and their main modes of action on the SOC balance (adapted from Paustian, 2014).[154]

Management Practice	Increased Carbon Inputs	Reduced Carbon Losses
Increased productivity and residue retention	X	
Cover crops	X	
No-till and other conservation tillage	X	X
Manure and compost addition	X	
Conversion to perennial grasses and legumes	X	X
Agroforestry	X	X
Rewetting organic soils		X
Improved grazing management	X	X

In agricultural systems under no-till, carbon preferentially accumulates in upper layers of the soil profile (0-30cm) over the short term[155], and some have suggested that SOC might decrease in deeper layers, causing no overall change in total SOC content[156] [157] or even a decrease in total SOC.[158] However, these results tend to be based on studies that only measure SOC accumulation to a depth of 30 cm, which has been suggested to be insufficient for understanding change in SOC across the soil profile.[159] [160] Regarding frequency of tillage, Blanco-Canqui et al. (2021) found that reduced tillage practices are in some cases as effective as no-till for accumulating SOC, confirming that more research is necessary to determine the effects of different types of

tillage practices across various soil types and climates. Additionally, a recent meta-analysis suggests that no-till results in overall SOC increases throughout the soil profile, including at depths of up to 100 cm, but authors also note that this outcome is highly variable and site-specific.[161] Variability of SOC accumulation in no-till systems based on climate, soil type, and moisture have led some to suggest that no-till is not universally applicable as a carbon emissions mitigation strategy and should not be discussed as such, but minimizing tillage should still be considered where appropriate because of its potential to improve soil health.[162]

Additionally, because the potential SOC benefits of no-till can be easily reversed, integrating no-till into outcome-based C emission mitigation strategies (where payments are for measurable change, rather than for use of a practice) is difficult due to the problem of ensuring persistence of C stocks that increase because of implementation of no-till. [163] [164] [165] More research on the topic of tillage frequency and its relationship to SOC persistence is necessary as policymakers grapple with creating realistic and useful timeframes for mitigation projects.[166] Again, as noted previously, reducing tillage has a positive impact on soil health parameters, including reducing erosion and susceptibility of soil aggregates to disruption, improving soil's ability to capture and retain water, and reducing daytime soil temperature. [167] Additionally, the soil health benefits associated with reduced tillage increase over time[168] and can be increased with the use of companion practices, such as cover cropping.[169]

Cropping Decisions

Cropping decisions, including using seasonal cover crops (also referred to as green manures), continuous cropping (rather than allowing a fallow period), high-residue crops, and permanent or rotated perennial grasses can increase C input into soils, thus increasing possible C sequestration.[170] Cover cropping and maintenance of crop residues have been found to contribute to SOC while also increasing soil health in terms of erosion control,[171] [172] increased aggregate stability, increased infiltration rate,[173] and metabolic activities of microbes.[174] There are also additional agronomic benefits associated with use of cover crops, such as weed suppression and enhanced pest management.[175] A meta-analysis[176] that used data from 139 plots at 37 sites demonstrated that cropland with a cover crop had significantly higher SOC stock than reference croplands. Aside from cover cropping and residue retention, another strategy for increasing SOC is choosing varieties or species with greater root mass to deposit C deeper into the soil profile where turnover of SOC is slower.[177]

Organic Matter Amendment

A more direct way to increase soil organic matter, and thus SOC, is through the addition of plant-derived C from external sources, including compost, manure, and biochar.[178] [179] However, because the production and transport of exogenous C sources originating in a distant location entail a number of greenhouse gas emission sources, the extent to which these sources represent additional SOC gains depends on a life-cycle assessment approach that takes into account all emissions associated with sourcing, production and use, and fossil fuel offset values.[180] [181] This net life-cycle C value will vary depending on the distance between the point of production and the point of use, as well as the system of production.

Compost and manure both represent forms of C that can be readily added to agricultural areas and can increase SOC content both through the added carbon in the amendment itself, and

through improving soil physical attributes,[182] nutrient availability,[183] and microbial biomass, [184] which in turn improves plant productivity and therefore increases the return of plant residues to the soil. The increase in SOC from the amendment is not considered to be sequestered since it was simply moved from one location to another, but to the extent that amendments improve soil performance and thus increase plant productivity and residue, this amounts to a real and additional mitigation of emissions through increased sequestration.[185] [186] Because soil carbon can reach a point of saturation, as previously discussed, the SOC accrual benefit of organic amendment applications depend on the level of SOC prior to amendment application (as a baseline), and the amount of compost added.

Biochar, a carbon-rich solid produced through the thermochemical process of pyrolysis, can impact SOC storage and net atmospheric CO_2 removals in several ways. Since biochar is highly resistant to microbial decay and can persist for hundreds of years or more, adding biochar to soil is an effective way to add carbon to the soil for long term storage.[187] Biochar added to soils can also interact with native organic matter to either stimulate or reduce its rate of decomposition.[188] [189] Biochar can also affect agronomic performance by promoting plant growth and increasing crop yield, thereby increasing C inputs from the plant matter itself.[190] Finally, biochar is thought to reduce N_2O emissions from soils by altering soil physicochemical properties, which can modify the microbial communities responsible for N_2O production and consumption.[191] Further research is necessary to determine conditions under which biochar products can best contribute to net CO_2 removals from the atmosphere.[192]

Improved Grazing Land Management

Since grazing lands are usually not tilled, increasing SOC stocks under perennial grasses relies mainly on enhancing C inputs from plant roots and residues.[193] Forage species, soil fertility, and climate or seasonal weather are important factors impacting pasture or range productivity and therefore overall CO_2 capture. However, excessive grazing removes large amounts of photosynthetic plant tissue such that total plant productivity and therefore carbon uptake and soil carbon stocks can be reduced.[194] Strategies to limit overgrazing include managing animal density on controlled areas of pasture or rangeland, with the frequency of livestock movement to new areas determined by assessing forage removal; this is called rotational grazing. [195] An intense form of rotational grazing is adaptive multi-paddock (AMP) grazing, which involves high stocking rates (large numbers of livestock/area) for short durations and frequently moving livestock to allow a recovery period for the vegetation between grazing events.[196] [197] A recent study of AMP C sequestration potential showed a 4-year C sequestration rate of 3.59 Mg C ha^{-1} yr^{-1} in AMP grazed pastures and found that overall emissions from the grazing system were offset by soil carbon sequestration.[198] [199] Despite this finding, the dynamic nature of AMP systems makes it difficult to compare across grazing systems due to the inability to effectively replicate experiments,[200] and thus, it is difficult to definitively measure the efficacy of AMP systems. Because the interactions that determine vegetation productivity and soil carbon in grazing systems are so complex, further research is necessary to determine the effects of different grazing systems on SOC stock, as well as other greenhouse gas emissions associated with livestock production.[201]

IV. Models for Ecosystem Services Valuation

Wunder defines payment for environmental services as "voluntary transactions between service users and service providers that are conditional on agreed rules of natural resource management for generating offsite services."[202] The term "payment for environmental services" is also known as payment for ecosystem services or PES.[203] In plain language, "PES policies compensate individuals or communities for undertaking actions that increase the provision of ecosystem services such as water purification, flood mitigation, or carbon sequestration."[204] PES schemes are considered to be "part of the broader class of incentive- or market-based mechanisms for environmental policy" because they "rely on incentives to induce behavioral change". There are more than 500 PES programs worldwide, with annual transactions totaling $36 to $42 billion.[205] The benefits of ecosystem services are generally categorized into four buckets: cultural (e.g., recreation, science and educational, spiritual); supporting (e.g., soil formation, pollination, nutrient cycling); provisioning (e.g., food, raw materials, genetic resources); and regulating (e.g., carbon sequestration, waste decomposition).

Another category of benefits, called co-benefits, recognizes additional outcomes of ecosystem services such as improved public health, enhanced biodiversity, and creation of green jobs. Maximizing economic, environmental and public health co-benefits is one of several guiding principles and a statutory requirement set forth in the funding guidelines for investment of California's greenhouse gas reduction fund financed through its cap-and-trade program revenue.[206] [207] The California Air Resources Board (CARB) has established methods for how to assess numerous co-benefits when evaluating funding priorities through the California Climate Investments program including jobs, air pollutant emissions, travel cost savings, vehicle miles traveled, energy and fuel cost savings, water savings, soil health and conservation co-benefits, climate adaptation co-benefits, community engagement, and heart and lung health, among others.[208] [209]

Further, a Scenario Tool for Assessing the Health Benefits of Conserving, Restoring and Managing Natural and Working Lands in California is under development through research led by the UCLA Fielding School of Public Health, Department of Environmental Health.[210] The tool (expected late 2022/early 2023) will be used to answer questions such as:

- What are the health benefits of improved air quality resulting from reductions in wildfire risks due to better management?
- What are the health benefits of increased green cover, tree canopy, and park space on urban populations in historically underserved areas of the state?
- What are the physical and mental health benefits to California residents due to an increase of access to or use of large rural natural and working lands?

One interviewee noted that figuring out the economic value of nature is crucial for protecting nature (e.g., better air quality leads to reductions in healthcare expenditures related to asthma). As noted by representatives of CARB, this tool could be used to make decisions about how land management can benefit people across the state and may generate buy-in for PES programs from a broader coalition of supporters.

A. Compliance Programs

Regulatory compliance programs that provide opportunities for ecosystem service valuation include market-based programs such as greenhouse gas emissions cap-and-trade programs and incentive-based programs that are coupled to water quality/pollutant reduction regulatory programs.

A.1 Cap-and-Trade Programs

Cap-and-trade programs limit air pollution and put a price on it, creating a market for allowances and offsets. A cap is established for pollution limits that are ratcheted down over time (i.e., they are made more restrictive) to achieve an emission reduction goal. Allowances, which are in the form of a certificate or permit, allow a regulated entity to emit carbon dioxide. One allowance is equivalent to having the legal right to emit one ton of carbon dioxide. Allowances are purchased at auction, but entities are also able to trade allowances on secondary markets.[211] [212] [213]

A regulated entity can meet its cap-and-trade obligations through emissions allowances (i.e., it must have enough allowances to cover its emissions), through reduction of on-site emissions, or through the use of offsets. Offset provisions represent a project-based greenhouse gas emission reduction outside of the capped regulated sector. Offset project types in U.S. compliance markets that are related to natural and working lands include: avoided agricultural methane emissions from livestock; forest projects that sequester carbon (e.g., reforestation, improved forest management, avoided conversion, and urban tree planting); and rice cultivation activities designed to reduce greenhouse gas emissions (only applicable to certain regions of the U.S.)[214] [215] [216] [217] [218] [219]

The use of offsets in compliance markets is a small percentage of a regulated entity's covered emissions, but offsets provide compliance flexibility, including an option for low-cost emissions reductions and other co-benefits.[220] [221] The purchase of one offset equals a reduction of one ton of carbon dioxide emissions. Offsets in the compliance market must meet strict protocols and standards established by the regulatory agency. At a minimum, they must comply with PAVER requirements, meaning they are: Permanent (non-reversible, lasts in perpetuity); Additional (beyond business-as-usual); Verifiable (measurable, must be confirmed and monitored); Enforceable (clearly defined, exclusive ownership); and Real (the offset project results in a true net reduction of emissions as opposed to shifting emissions to another location).[222]

Payment for ecosystem services in cap-and-trade systems can be achieved through one of two mechanisms. The first is through development of ecosystem service value offset projects that generate credits for sale; purchasers of the credits can resell them in the marketplace or "retire" them to meet regulatory requirements. The other mechanism is to use the revenue generated from the auction of allowances to advance climate progress. The following sections describe the two U.S. cap-and-trade programs and the opportunities for investment in ecosystem service value within those programs.

Regional Greenhouse Gas Initiative

Started in 2008, the Regional Greenhouse Gas Initiative (RGGI) was the first cap-and-trade initiative in the U.S. It requires fossil-fuel-fired electric power generators with a capacity of 25

megawatts and greater to hold allowances equal to their carbon dioxide emissions over a three-year control period.[223] Participating states include Connecticut (CT), Delaware (DE), Maine (ME), Maryland (MD), Massachusetts (MA), New Hampshire (NH), New Jersey (NJ), New York (NY), Rhode Island (RI), Vermont (VT), and Virginia (VA). Pennsylvania is in the process of finalizing its CO_2 regulations to allow it to participate. In October 2019, Pennsylvania Governor Wolf signed an executive order instructing the Department of Environmental Protection to begin a rulemaking process that will allow for the state's participation in RGGI; with the approval of the Independent Regulatory Review Commission, the state now appears to be poised to enter RGGI in 2022.[224] [225] Each participating state sets its own regulations based on the RGGI Model Rule.

Under RGGI, 3.3% of the regulatory requirement can be met by offsets.[226] RGGI authorizes offsets in five project categories: landfill methane capture, sulfur hexafluoride (this offset type is only available in CT, ME, NY), forestry or afforestation, end-use efficiency (available only in CT, ME, NY), and avoided agricultural methane (i.e., manure management).[227] In New Jersey, only three types of offset projects are eligible for award of offset allowances: landfill methane capture and destruction; sequestration of carbon due to reforestation, improved forest management, or avoided conversion; and avoided methane emissions from agricultural manure management operations.[228]

Only one offset project (landfill methane destruction) has thus far been awarded allowances in the RGGI region; there are no projects to date that have been awarded in a category that would address natural and working lands (e.g., in the forestry or afforestation category or manure management).[229] For RGGI compliance, offset projects must be located within one of the RGGI states that award offset allowances. As noted by CARB representatives, the carbon market auction price helps set the value for offset credits on the open market. California auction allowance prices are historically higher than RGGI allowance prices (e.g., a California allowance price was $18.80 in May 2021 while a RGGI allowance price in June 2021 was $7.97).[230] [231] This price differential, coupled with the requirements that projects must be within the region, may provide an insight as to why an offset project developer would be less inclined to both develop and apply an offset project in the RGGI region.

In the short-term, the incentive to develop an offset project for the RGGI market appears weak. Three states (MA, NH, RI) have decided they will no longer award offsets. Staff are needed to oversee and implement an offset program, and if there are little or no offset projects occurring, states may choose to invest their resources elsewhere. It is worth noting that all RGGI member states have agreed that regulated entities can use offsets awarded by any other RGGI member state. For example, a power plant in RI would not receive any offsets from RI (since the state no longer awards offsets), but that same power plant can use offsets awarded by ME or NY to meet its regulatory requirements.

California Cap-and-Trade Program

The largest carbon market in the country is the California Cap-and-Trade Program. Launched in 2013, it is the fourth largest program of its kind in the world. The Program covers approximately 80% of the state's greenhouse gas emissions. Around 450 businesses, such as electric power plants, industrial plants, and fuel distributors, must comply with the program. Under the Cap-

and-Trade Program, emission allowances are distributed by a mix of free allocation and quarterly auctions. The portion of emissions covered by free allocation varies by industry. The California Air Resources Board (CARB), which has had long-time authority over mobile sources of air pollution, implements and enforces the program. California linked its program with the Cap-and-Trade System of Quebec (as of January 2014).[232] The linkage allows businesses to use emission allowances issued by either of the participating jurisdictions. The Western Climate Initiative, Inc. offers technical and administrative services to support the implementation of trading programs within the linked jurisdictions. It is fully funded by the participating jurisdictions.[233]

The California Cap-and-Trade Program allows for limited use of offset credits by covered entities (up to 8% of actual emissions). Offset credits provide both an incentive to achieve reductions in non-covered sectors, as well as a limited, but important cost-containment tool for businesses covered by the Cap-and-Trade Program. Starting in 2021, by statute, the allowed use of offsets drops to half (4%).[234] Part of the reason for this change is to ensure that a larger majority of reductions in emissions is coming from the regulated sectors themselves. More than 221 million offset credits have been issued as of June 2021.[235]

Although the allowed use of offsets has dropped, offsets still play an important role in greenhouse gas emissions reductions. For one, interviewees from CARB noted that offsets are not subtracted out from the state's greenhouse gas emissions inventory, which tracks California's progress toward its greenhouse gas reduction targets; thus, these offsets are truly additional to the reductions that are being tracked by the inventory. Rather than assessing offset additionality based on the project-by-project assessment common in programs such as the Clean Development Mechanism, CARB defined additionality as going beyond what is required by law and beyond a conservative business-as-usual scenario for each project. "Conservative," in the context of offsets, means "utilizing project baseline assumptions, emission factors, and methodologies that are more likely than not to understate net greenhouse gas reductions or greenhouse gas removal enhancements for an offset project to address uncertainties affecting the calculation or measurement of greenhouse gas reductions or greenhouse gas removal enhancements."[236] Requirements and safeguards are in place to ensure conservative measures are incorporated into the Cap-and-Trade Regulation as well as the project-specific protocols. The interviewee gave the example of a facility investing in a new boiler system. Emissions reductions won't be immediate, so the facility purchases offsets for the short term. Without offsets, the facility may not have been able to invest in the boiler system. The offsets allow the facility to meet its emissions obligations while it is saving up to install the new system that will reduce its onsite emissions in the long run. In addition, the income landowners earn from selling offsets can be invested in additional conservation efforts. For example, a CARB interviewee noted that in California, some of the large landowners are environmental organizations. They purchase the land for conservation purposes, and if their project meets the regulatory and offset protocol requirements (e.g., offsets must be permanent, additional, verifiable, enforceable, real), they may use the revenue stream from offsets to advance their conservation work. We heard about offset revenues being used in a similar way in Maine. A large nonprofit developed a carbon offset project on 100,000 plus acres of forestland. When asked why the nonprofit was interested in monetizing carbon, the representative responded that it provides "funding to advance conservation work." Although companies may purchase offsets to cover a small percentage of

their overall compliance obligation, offsets serve as important cost-containment because they may be less expensive than buying carbon allowances.[237]

Within the California compliance offset program, project categories include livestock (emissions reductions associated with installation of biogas control for manure management on dairy cattle and swine farms), mine methane capture, ozone-depleting substances (from refrigerants), rice cultivation projects, U.S. forests (avoided conversion, improved forest management, and reforestation), and urban forestry (eligibility includes projects undertaken by municipalities, on educational campuses, and by utilities). Most of the offset credits - over 80% - are from forest projects. The rice cultivation protocol and urban forest protocol have not been used. Offset projects do not need to be physically located in California but are geographically restricted to the United States (including U.S. territories as well); projects are further limited to the major rice-growing regions in California and the Mid-South (Arkansas, Missouri, Mississippi, and Louisiana) where the Denitrification Decomposition (DNDC) biogeochemical process model to quantify changes in methane and nitrous oxide emissions has been calibrated with empirical data.[238] [239] CARB's forest protocol does not cover Hawaii. The interviewees from CARB noted that forest offset projects are located in 37 U.S. states. Alaska Native Corporations and tribes have some of the largest forest offset projects in the California Cap-and-Trade Offset Compliance Program.

Cap-and-Trade Offset Project Example for Ecosystem Services

On the cap-and-trade compliance side, one approach to receiving payment for ecosystem services on natural and working lands is through carbon offset projects which can generate credits that can be sold to meet regulatory obligations. An example of such a project was described by a representative of The Nature Conservancy (TNC) regarding a forest carbon project to increase timber stock resulting in offsets intended for sale in the California market. In 1998, TNC purchased 185,000 acres of forested land along the St. John River (Maine) from International Paper. TNC values forests for their role as a watershed, as habitat, and in sustaining biodiversity and human communities.[240] The organization also focuses on the role of forests in capturing and storing carbon. The purchase of the St. John River Forest was the largest land purchase in the organization's history at the time, costing $35 million.[241] The organization set aside part of the land as an ecological reserve, and over the last twenty years, it has conducted sustainable timber harvest on the remainder of the property while gradually increasing its overall carbon stocking. TNC also completed some strategic trades to acquire additional parcels of high ecological value and has sold some lands after placing a conservation easement on them.

In 2018, TNC entered into a ten-year agreement with Climate Trust Capital, a U.S.-based private investment fund, to develop a carbon offset project on 120,000 acres of the 160,000 acres now owned by TNC on the Upper St. John River. As part of the project, TNC committed to maintain current timber stocking for a period of one hundred years, has increased the area of the property to be maintained as ecological reserve, and, at least during the first ten years, is committed to harvesting no more than 15% of the annual timber growth within the portion of the property outside of the ecological reserves. These management changes will accelerate carbon sequestration and offer the possibility of selling additional credits.

The TNC representative explained that TNC chose to develop the project for the regulated (i.e., compliance) market because of the price differential. Carbon credits typically sell for more in the regulated market than the voluntary market. He noted that the transaction cost is also higher, but the size of their project makes it "financially worthwhile." The interviewee talked about the "significant expenses" of developing an offset project due to the costs of annual reporting (including documenting saplings and dead trees) and verification (episodic forest inventory conducted by foresters on-the-ground) required under the protocol.

Climate Trust Capital provided an up-front payment to TNC and covered all the initial project development costs, such as carbon inventory and modeling. Climate Trust Capital will receive a percentage of the offset revenue during the ten-year agreement term, while the majority of the offset revenue will go to TNC. As of July 2021, the carbon inventory has been completed and verified, and the project has been reviewed and approved by the registry and CARB, and offset credits have been issued.

With respect to risks such as tree mortality caused by a disease or forest fire, each project is required to contribute a percentage of offsets to a buffer pool. These offsets are not sold, and in the event that 10% or more of a property burns and has complete mortality, the buffer can be applied. One of the concerns of private landowners who want to participate in carbon markets, according to the interviewee, is that "there is a lot of gray area with insect infestation as opposed to forest fire." It is less clear when a buffer kicks in in the case that insects cause damage or death to trees. Another barrier for forest landowners in Maine specifically is that CARB imposes restrictions on forest management that go beyond Maine's requirements. For example, CARB has restrictions on clear-cutting and age management, which are permissible in Maine, and some commercial landowners are reluctant to shift their management or accept additional restrictions.

Asked why TNC wanted to get into the business of monetizing carbon, the interviewee said that revenue from the sale of offsets will advance the organization's conservation work. He shared that anticipated gross revenue over the life of the project is $20 to $25 million, though he cautioned it could end up being less. In the case of the Upper St John River Forest, for the last twenty years, revenue from commercial timber harvest has covered annual expenses including property taxes, road maintenance, and property management, and at times has been sufficient to fund other conservation work. Now TNC is shifting toward more carbon revenue and less timber revenue from the property and has also further diversified its revenue through a lease for maple syrup production from a portion of the property. TNC is sensitive to the fact that reduced timber harvesting has some impact on related employment opportunities.

At a broader level, TNC is interested in gaining more experience with forest carbon offsets, because it sees this as a tool that can be used by both TNC and private landowners to help TNC accomplish its goals of benefitting the climate while conserving forests important to biodiversity and people. The TNC representative noted that in Maine, forest carbon offsets are receiving greater attention. The Maine Climate Council was convened by the Governor and legislature and has prepared a climate plan for the state, including an emphasis on the importance of forest carbon. The Governor has since convened a Task Force to advance state policy and forest carbon incentives for forest landowners, including ways to help smaller landowners participate in offset markets. At the request of the Governor's office, TNC and the Trust for Public Land completed a

feasibility study to explore options for permanent, sustainable funding for natural climate solutions, and the legislature has renewed funding for land conservation.

Participation in compliance markets has been an attractive option to some landowners because, as noted in the example from TNC, the price the project developer receives by selling carbon offsets is often higher than in the voluntary markets (prices vary between compliance markets, too). But several interviewees noted that the cost of monitoring and verification cuts into the project developer's revenue, making project development worthwhile (at least financially) for only the largest projects. The other way is to use cap-and-trade revenue to advance climate progress.

Cap-and-Trade Auction Proceeds Investment in Ecosystem Services

In California, Cap-and-Trade auction proceeds support California Climate Investments (CCI).[242] Money raised through auctions goes into the Greenhouse Gas Reduction Fund. From that fund, the legislature makes appropriations to different agencies to administer programs that facilitate the reduction of greenhouse gas emissions or otherwise align with the purpose of the Global Warming Solutions Act of 2006 (AB 32).[243] Interviewees from CARB noted that on the climate investment side, the legislature required CARB to quantify the climate benefits of these funds as well as other environmental, economic, and public health co-benefits, all based on scientific input. The focus with respect to quantification of benefits, including greenhouse gas emissions reductions, is more about directionality and assurance of the benefits, rather than precision of the magnitude of the benefit estimate, as the funds are used for multiple benefits and state priorities. The program helps support innovation and adoption of climate mitigation practices and is not required for regulatory compliance which requires stringent emissions accounting.

There are numerous programs in various agencies that have been funded with appropriations from the CCI program that relate to natural and working lands. Examples include the California Department of Fish and Wildlife Wetlands Restoration for Greenhouse Gas Reduction Program to restore or enhance coastal and inland wetlands and mountain meadows to increase carbon sequestration and provide other benefits; the California Department of Conservation Regional Forest and Fire Capacity Program to increase regional capacity to prioritize, develop, and implement plans to improve forest health and fire resilience and increase carbon sequestration in forests; CAL FIRE's Urban and Community Forestry Program for urban tree planting, urban forest management, and utilization of urban forest waste wood; the California Natural Resources Agency Urban Greening Program which includes establishing, enhancing, and expanding community spaces and parks, tree plantings, and green infrastructure; CalRecycle's Organics Grants Program to support construction, renovation, and expansion of facilities to preprocess, digest, or compost organics into compost, soil amendments, biofuels or bioenergy, including diversion of agricultural waste (e.g., orchard waste). [244] [245] [246] [247] [248] [249] CCI supports CAL FIRE's Forest Health Program for restoration and reforestation projects for multiple benefits: forest resiliency and sustainability to ensure future forest existence, mitigating climate change, protecting communities from fire risk, improving air and water quality, and strengthening rural economies.[250] [251] Activities eligible through this program include: forest fuels reduction; prescribed fire; pest management; reforestation; biomass utilization; conservation easements and/or land acquisition; and research through the Forest Health Research Program.[252] The Forest Health Research program investigates priority topics in support of the California Forest Carbon

Plan Implementation.[253] For example, it supports a long-term research study of six different thinning and prescribed burning regimes in the Teakettle Experimental Forest of the Sierra Nevada Mountains to understand the impacts of these treatments on forest carbon stability in the wake of drought and wildfires.[254] CCI funds have also gone to the Strategic Growth Council's Climate Change Research Program to benefit communities and ecosystems, including natural and working lands.[255]

CCI supports CalRecycle's Community Composting For Green Spaces grant program to increase the number of community groups operating small-scale composting programs in green spaces within disadvantaged and low-income communities, including increasing the capacity of such composting programs.[256] Green spaces include, but are not limited to, community gardens, urban farms, and other public spaces where small-scale composting is appropriate and will help to promote diversion of food and organic waste from landfills, while also providing compost to help improve soil health and thus adaptation to climate change. [257] [258] This program includes a grant to the California Alliance for Community Composting to develop a network of community compost sites across the state to support composting, organization and site development, community engagement, farming, education, volunteer support, and tree planting.[259] [260]

CCI also funds the California Wildlife Conservation Board's Climate Adaptation and Resiliency Program, which supports projects that protect and restore natural ecosystems to provide climate change adaptation and resilience, assist natural and working lands managers in implementing practices that provide climate adaptation and resilience, facilitate the reduction of greenhouse gas emissions, increase carbon sequestration in natural and working lands, and provide other social, economic and environmental co-benefits.[261] For example, this has funded ranchers switching to regenerative grazing to increase drought resiliency, rebuild soil organic matter, and increase sequestration of carbon, along with improvements to biodiversity.[262]

The California Department of Food and Agriculture (CDFA) Healthy Soils Program is funded in part with CCI and is described in greater detail in the section on "Agricultural Land Voluntary Practice-Based Incentive Programs." CCI also supports CDFA's financial assistance to dairy and livestock farmers through its Alternative Manure Management Program (AMMP) to implement practices that involve handling and storing manure in ways that do not include use of an anaerobic digester and support management of manure in a dry form. [263] [264] Changing manure management practices to be handled in a dry form can help reduce methane emissions. [265] Practices that are supported include: pasture-based management; alternative manure treatment and storage (such as compost bedded pack barns); and solid separation or conversion from flush to scrape collection of manure in conjunction with some form of drying or composting.[266] Demonstration projects regarding new technologies and practices, as well as farmer-to-farmer outreach programs, are also included in this program. [267] Farmers have successfully coupled this program to the California Healthy Soils Program whereby the compost they develop through the AMMP can be applied to their pastures for increasing organic matter and carbon sequestration.[268]

Under the CCI framework, the agencies receiving funding are responsible for determining the eligibility requirements for the programs they administer. Responding to a question about how the legislature prioritizes funding allocations, a CARB representative indicated that by law,

programs must facilitate greenhouse gas emissions reductions, but the amount of emissions reduced is not necessarily the main criteria for deciding funding amounts. Instead, the priority is to fund programs that address a variety of state goals and provide multiple co-benefits, such as improving public health in pollution-burdened communities (e.g., urban tree plantings), reducing energy costs (e.g., installing energy efficiency measures in homes), or supporting innovation through clean technology, demonstration programs, and research.

When asked about the impacts to agriculture resulting from the California Department of Fish and Wildlife (CDFW) Restoration for Greenhouse Gas Reduction program, a CARB representative indicated that some agricultural land could be "lost" (i.e., restored to wetlands or meadows) while at the same time, this program could provide productive use for fallowed land. A representative from the CDFW noted that none of the funded projects for their Wetlands Restoration for Greenhouse Gas Reduction Program are part of current or former agricultural land. However, degraded grasslands have been part of the program and imply severely degraded grassland that has lost its ability to maintain ecological functions, resulting in loss of vegetation/grasses, soil erosion, increased flooding, poor water quality, etc. In California, the CDFW representative noted that although none of the projects have been on agricultural lands, it is possible that damage from any poor land-use practices - including overgrazing - or other factors such as climate change could be considered under this program. CARB representatives noted that there are agricultural interests that oppose taking agricultural land out of production (whether for ecosystem restoration, economic development, or other reasons), but overall, there has been little conflict surrounding California Climate Investments. A CARB representative noted that conflict could arise, for example, if there were plans to expand solar in areas where solar fields require land and may compete with other land uses.

In New Jersey, RGGI auction proceeds are allocated by the Global Warming Solutions Fund Act to three state agencies: the Economic Development Authority (NJEDA), the Board of Public Utilities (NJBPU), and the Department of Environmental Protection (NJDEP).[269] These agencies are required to spend funds within specific program areas: energy efficiency, renewable energy and carbon abatement projects (NJEDA); projects to reduce demand or costs to low- and moderate-income residents (NJBPU); local government programs to reduce greenhouse gas emissions (NJDEP); and a 10% carve out "to support programs to enhance the stewardship of the State's forests and tidal marshes that provide important opportunities to sequester or reduce greenhouse gases."[270] There is not a carve-out for production agriculture; however, as previously noted, woodlands contiguous to, part of, or beneficial to a tract of land devoted to agricultural or horticultural use can qualify for farmland assessment in New Jersey and therefore could also provide enhanced opportunities for carbon sequestration.

During the current three-year funding period (2020-2022), the funding is devoted to four initiatives:

- Clean, equitable transportation;
- Promoting blue carbon in coastal habitats;
- Enhancing forests and urban forests;
- New Jersey Green Bank (focused on clean energy investment and job growth).

The State of New Jersey notes that two objectives critical for priority ranking of projects funded under the blue carbon and forest categories include a) a net reduction in greenhouse gas emissions *or* a net sequestration of carbon and b) the projects provide co-benefits. The exact portion of the 10% allocation is determined by the Commissioner of NJDEP.[271] [272]

A.2 Incentive-Based Regulatory Programs

There are other compliance programs that provide opportunities for payment for ecosystem services that are not cap-and-trade. These markets and programs provide incentives for point source and non-point source entities to meet and ideally to go beyond a legal requirement to reduce water pollutants such as nitrogen, phosphorus, and sediment. We refer to these programs as regulated water quality programs.

Maryland's Water Quality Trading Program

The State of Maryland's Water Quality Trading Program (WQTP) sets up a public market for pollutant reduction credits (one credit equals one pound of pollutant reduction for one year). Regulated entities can include point source dischargers, such as wastewater treatment plants, that are subject to total maximum daily load limits (TMDLs) set by the U.S. Environmental Protection Agency for the Chesapeake Bay. (TMDL is the maximum amount of a pollutant allowed to enter a waterbody so that the waterbody will meet and continue to meet water quality standards for that particular pollutant).[273] These entities can purchase pollutant reduction credits to help meet regulatory obligations. They can also generate credits (such as through making plant upgrades) if they reduce pollutants more than their permit requires.

Non-regulated entities can also generate credits in this program. Practices must be Chesapeake Bay Program-approved practices. These include but are not limited to: oyster aquaculture, urban tree planting, and restoration of nontidal wetlands. The value of credits is determined through market forces. With regard to oyster aquaculture, only farmed oysters are eligible at this time. An online tool calculates the nitrogen or phosphorus reduction per oyster.

The program is jointly managed by the Maryland Department of the Environment (MDE) and the Maryland Department of Agriculture (MDA). A representative of the MDE explained that the program establishes a framework for trading to occur, but the agencies do not get involved in specific trades. Managing departments are not involved in negotiating terms of contracts. Instead, buyers and sellers of credits come to their own terms. Most of the credits are generated by regulated entities and verified through the entities' monthly discharge monitoring reports. As of 2020, about 49,000 nitrogen, 5,800 phosphorus, and over 1 million sediment credits have been traded through this program. A publicly accessible Water Quality Registry provides a ledger of credits, status, location of trades, and parties involved.[274] The Water Quality Market Board is a public marketplace where persons looking to buy or sell credits can identify the watershed, year of activity, and other information that relates to the credits they are looking to buy or sell.[275] MDA is responsible for certifying credits from any agricultural source. MDE is responsible for managing the rest of the program, including certifying credits from other sectors, managing the registry, and handling the market board/marketplace.

Agriculture operations can participate in Maryland's WQTP through a companion Nutrient Trading Program, but as of Fall 2021, none have taken advantage of this opportunity. Certain agronomic practices, such as planting cover crops, are eligible to produce credits. Practices must be built, inspected, certified, and operated according to USDA NRCS specifications. Landowners or farmers cannot retire full farms from active production. Cost-share funds can be used for the farm operation to meet baseline water quality criteria but may not be used to generate credits. A Nutrient Trading Tool is available to calculate credit generation for farms based on current and proposed practices.[276] Through research underway via its Healthy Soils Program (discussed further in this paper), Maryland expects to add carbon credits to its Nutrient Trading Tool under the WQTP that would allow farmers to stack nutrient and carbon credits. [277]

MDE representatives explained that the lack of demand has been a barrier to farmers participating in the WQTP; financial support from the State of Maryland for enhanced nutrient removal has been effective at cleaning up wastewater treatment plant discharge. However, a recent evaluation of stormwater permittees has found that several stormwater utilities are not meeting their goals, and thus, demand for the WQTP may rise. Another challenge articulated has been the process. "It takes some pretty specific knowledge to navigate the tools and legal resources to establish contracts under the trading program." One MDE representative advised that it would be useful to have aggregators that can purchase bulk credits at a lower cost and sell them to the regulated entities, in part because it would facilitate connections between buyers and sellers.

In May 2021, Maryland reauthorized and modified the Clean Water Commerce Act, which requires MDE to transfer $20 million annually (from June 2, 2021 to June 30, 2030) from the Bay Restoration Fund to a new Clean Water Commerce Act account to purchase "environmental outcomes" to achieve Maryland's goals under the Chesapeake Bay TMDL.[278] The Chesapeake Bay TMDL establishes pollution reductions of nitrogen, phosphorus, and sediment across Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia, and the District of Columbia and sets pollution limits necessary to meet applicable water quality standards in the Bay and its tidal rivers and embayments.[279] There is a carve out of at least 35% of these funds to procure environmental outcomes from agricultural practices, including priority for projects that are "a fixed natural filter practice" pursuant to the Maryland Code of Agriculture, or an agricultural ditch management practice.[280] Fixed natural filter practices include: planting of riparian forest buffers and herbaceous cover; tree planting on agricultural land; wetland restoration; pasture management (including rotational grazing); and watering systems implemented as part of the conversion of cropland to pasture.[281] Although such practices are not conducted for soil carbon sequestration purposes, sequestration of soil carbon could be an ancillary benefit of this program.

Pennsylvania Resource Enhancement and Protection Program (REAP)

In Pennsylvania, the state offers tax credits for farmers and landowners to increase compliance with the Clean Streams Law.[282] [283] The program, referred to as the Pennsylvania Resource Enhancement and Protection Program (REAP), was created in 2007. A representative from the Pennsylvania Department of Agriculture noted two primary considerations for developing the program:

- Increasing compliance with the Clean Streams Law to limit pollutant runoff, including into the Chesapeake Bay watershed to meet Pennsylvania's commitments to reduce runoff as a partner of the Chesapeake Bay Program. Note however, that the REAP program is statewide.

- Spurring innovation by increasing use of technologies and techniques such as precision application of nutrients.

The program allows farmers, businesses, and landowners to earn state tax credits in exchange for the implementation of conservation Best Management Practices (BMPs) on Pennsylvania farms. The practices are primarily meant to reduce nitrogen, phosphorus, and sediment pollution runoff from agriculture operations, but some practices, such as no-till agriculture, also provide carbon benefits. The representative from the Department of Agriculture shared that one of the most common practices included in applications is planting of cover crops. To be eligible for the program, a farm operation (plow or till over 5,000 ft^2) must have an Agricultural Erosion and Sedimentation Control Plan (on all acres, regardless of whether the acres are owned or rented), and any farmer/landowner with animals and/or who spreads manure must have a current Nutrient Management Plan or Manure Management Plan.[284] The Agricultural Erosion and Sedimentation Control Plan (E&S Plan) is designed to limit soil loss from accelerated erosion to the soil loss tolerance (T) over a planned crop rotation. The soil loss tolerance (T) is the maximum amount of soil loss, in tons/acre/year, that a given soil type can tolerate and still permit a high level of crop productivity to be sustained economically and indefinitely; the annual rate of erosion varies based on soil type, slope, and crop rotation,[285] among other factors.

Program applicants cover the up-front costs of implementation and, depending on the practice, are reimbursed 50% to 90% of their out-of-pocket expenses in the form of tax credits that can be used to pay Pennsylvania state income tax. Eligible categories include Planning BMPs, Equipment BMPs, and Constructed BMPS, and these expenses can include: labor and materials (including up to half the cost of equipment); design work; and certification of practices (certification done by a conservation district or agricultural engineer). For example, farms located in a watershed (often but not necessarily within the Chesapeake Bay Watershed) that has a TMDL are reimbursed at a rate of 90% for soil health testing, buffers, and practices that keep animals out of waterways.

REAP is unique because it is one of the only programs in the country to reimburse farmers for the purchase of no-till equipment (planter or drill) and precision nutrient application technologies. This observation was made by a number of interviewees, who also pointed out that equipment costs are often a barrier to implementing soil health and conservation practices. Almost half (49%) of REAP's 2019 allocation of $13 million supported equipment.[286] REAP also allows for trade-in or selling of no-till equipment/precision fertilizer application equipment. The representative explained that the trade-in policy was developed to enable farmers to improve their planters or precision capabilities as their operations grew. It was intended to help a farmer try out no-till with a smaller (less expensive) planter and then upgrade to more capability (and cost) as they grew more comfortable with no-till. When farmers trade-in no-till equipment prior to the 7-year maintenance lifespan, they are typically getting a bigger and better machine – that enables them to do more no-till acres, or to no-till with better success. In fact, the REAP

guidelines stipulate that they must be "trading up." The representative noted, "Surveys of Pennsylvania farmers and other drive-by surveys of Pennsylvania farm ground have shown a steady increase in the use of no-till and precision nutrient application."

REAP also allows non-farm Pennsylvania businesses/entities to participate in the program; this is conceived as a way for the business community to help farmers put conservation practices on the ground by sponsoring a farmer's project. In 2018, there were 10 sponsors. In 2019, the number of sponsors grew to 51. Responding to a question about who sponsors projects, the Department of Agriculture interviewee said that the vast majority of sponsors are people who want to save money on their taxes, as the sponsors pay farmers 90% of the value of the tax credit while saving 10% on their own state tax bill. Certified Public Accountants and financial advisors have become familiar with the program and have facilitated connecting sponsors with farmers. When this connection is made, the farmer fills out the eligibility questions on the application, but the sponsor is the lead and submits the application. The sponsor receives the tax credits and reimburses the farmer.

Many times, the sponsor and farmer do not know one another pre-project. This is certainly not the case for all sponsors. There are local businesses (such as banks) that have connections with the agriculture community and that choose to sponsor. The rationale for including sponsorships in the program was to encourage businesses or higher income earners to get involved with their local agriculture community. Program managers are considering options for recognizing sponsors who participate for altruistic reasons, such as through some sort of advertisement potentially developed in partnership with locally based non-profits. One challenge in recruiting more community-minded sponsors is that sponsorships are difficult to administer and explain. Each year the program provides between $10 and $13 million in tax credits.

The Pennsylvania State Conservation Commission manages a companion program to REAP called the Conservation Excellence Grant Program (CEG) which provides financial and technical assistance to farmers to implement BMPs on agricultural operations in high-priority areas (related to Pennsylvania's Chesapeake Bay Implementation plan).[287] The program helps farmers navigate and pool funding from diverse sources, including non-governmental organizations such as Lancaster Clean Water Partners, businesses, municipalities, federal programs like USDA NRCS EQIP and other sources. Farmers do not have to apply to REAP in order to participate in CEG. For farmers who are applying to REAP, CEG can assist with access to up-front funding, reducing a barrier to participation for farmers who cannot afford to wait for reimbursement. Farmers who participate in CEG and REAP do not receive "double" payment for the same practice(s). REAP subtracts any funding a farmer receives to implement program-eligible practices before issuing the tax credit award.

B. Voluntary Markets For Ecosystem Services

There are quite a few voluntary PES market-based programs operating or emerging across the country. These include programs where producers are paid for greenhouse gas emissions reduction benefits of natural and working lands in the absence of a regulatory requirement. The following sections describe the drivers for the development of these programs, standards and protocols for project integrity, and voluntary PES program examples for forests, grasslands, and agricultural lands.

B.1 Market Drivers

Demand for ecosystem services in the voluntary markets is being driven by various factors including but not limited to: anticipation of regulatory requirements; changes in financial markets; corporate social responsibility; and the educational mission of colleges and universities. Buyers for these ecosystem services include businesses, governments universities, and individuals. As an example, to meet short-term mitigation goals, some cities (e.g., Austin, Texas[288]; Palo Alto, California[289]) are purchasing carbon offsets in the voluntary markets.

Real or Anticipated Regulations

Regulations or anticipation of regulation can help drive the development of the voluntary marketplace. For example, the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) is one of several measures the International Civil Aviation Organization (ICAO) is using to achieve the global aspirational goals of the international aviation sector (2% annual fuel efficiency improvement through 2050 and carbon neutral growth from 2020 onwards).[290] CORSIA relies on the use of emissions units from the carbon market to offset the amount of CO_2 emissions that cannot be reduced through the use of technological and operational improvements, and/or sustainable aviation fuels. ICAO member states' participation in CORSIA is voluntary in both the pilot phase (2021through 2023) and the first phase (2024 to 2026).[291] Voluntary market offset programs eligible to meet the first phase of CORSIA include these six registries: American Carbon Registry; China Greenhouse Gas (GHG) Voluntary Emission Reduction Program; Clean Development Mechanism (CDM); Climate Action Reserve; The Gold Standard; and Verified Carbon Standard.[292]

Changes in Financial Markets

Increasingly, investors are aware of and concerned about the environmental impacts of decisions made by companies and governments, leading to "an increasing demand for integrating Environmental, Social, and Governance (ESG) criteria into investment decisions".[293] This can be seen in the growth of green bonds. The European Investment Bank issued its first green bond in 2007, the proceeds of which were used for energy efficiency and renewable energy projects.[294] By 2017, "over $155 billion worth of public and corporate green bonds had been issued." [295] Government regulations can influence the degree to which environmental impacts influence investment decisions. As examples, the United Kingdom offers a tax break for investments made into organizations that have a social purpose (through the Social Investment Tax Relief program).[296] In 2016, the U.S. Department of Labor revised guidelines for the Employee Retirement Income Security Act to allow pension funds to consider social and environmental goals when selecting between investments with otherwise equal risk and return.[297] Although the Labor Department under President Trump changed these rules in October 2020 to make investments solely on pecuniary considerations, in March 2021 the Biden Administration noted it will not enforce the 2020 rule change and it will revisit these rules in accordance with Executive Order 13990 which requires federal agencies to review rules that are not consistent with public health and environmental protection needed to tackle the climate crisis.[298]

For investors, addressing climate change may be approached as a way to reduce risk. Larry Fink (CEO of BlackRock, Inc., the world's largest asset manager), in his annual letter to CEOs (2020), announced that BlackRock will ask companies it has invested in to disclose plans "for

operating under a scenario where the Paris Agreement's goal of limiting global warming to less than two degrees is fully realized". Fink advised that BlackRock will avoid making investments in companies like coal producers that "present a high sustainability-related risk" and will move "more aggressively to vote against management teams that are not making progress on sustainability".[299] It has been reported that BlackRock backed three of four candidates nominated by activist investors of Exxon seeking to elect board members who will address climate change and move Exxon toward cleaner energy; the landmark shareholder election in May 2021 resulted in at least two new board members who pledge to address climate change.[300] Other institutional investors that joined the challenge to Exxon's leadership included the California Public Employees Retirement System, New York State Common Retirement Fund, and California State Teachers' Retirement System.[301]

Moody's Investors Service, a ratings agency, considers the climate risk that a particular location faces and adjusts credit ratings accordingly. In 2019, Moody's purchased a majority stake in Four Twenty Seven, a publisher and provider of data, market intelligence and analysis related to physical climate and environmental risks; this firm now sits within the Moody's ESG Solutions Group.[302] Moody's will use data from the firm to compare municipal climate mitigation/adaptation plans.[303] Disclosure laws can make information about climate risks more transparent. In France, Article 173 of the French Law on Energy Transition and Green Growth requires climate change-related reporting from institutional investors.[304] [305]

Corporate Social Responsibility

Corporate social responsibility (CSR) is a management concept "whereby companies integrate social and environmental concerns in their business operations and interactions with their stakeholders."[306] In 2015, a clear majority of the world's largest companies (92% of 250 companies) produced a report on their CSR efforts.[307]

Some companies are mandated to incorporate CSR. In India, The Companies Act obligates companies meeting minimum thresholds for turnover and profits to spend 2% of their net profit to address social issues, such as environmental sustainability.[308] There are, however, now a number of factors influencing a voluntary movement towards greater corporate consciousness, including changing consumer behavior towards socially responsible consumption,[309] and a body of research that shows positive effects of CSR on employee performance and commitment.[310]

Despite its growing popularity, there is no universal standard for CSR, whether from a quantification, verification, reporting, goal setting, or other perspective. The lack of standardization is in part due to the multiplicity of actors. Corporations, consulting firms, investors, consumers, advocacy groups, non-profits, international organizations, and governments at all levels play a role in CSR. And companies have different priorities, from health care to education and the environment, and pursue different strategies to achieve their objectives, such as by focusing within their supply chain or making business operations transparent to individual consumers.

Several frameworks have been developed to improve transparency around CSR goals and outcomes. Two prominent frameworks that guide corporate action on climate change are the Science Based Targets Initiative (SBTi) and CDP. CDP was "the first platform to link

environmental integrity and fiduciary duty."[311] A non-profit, CDP oversees a global disclosure system on environmental action, with data from over 9,600 companies, 800 cities, and 120 states and regions.[312] An independent scoring methodology based on CDP's annual reporting process rates companies and cities on transparency and environmental performance.

A collaboration between CDP, the United Nations Global Compact, the World Resources Institute, and the World Wide Fund for Nature, the SBTi calls on companies to set science-based emissions reduction targets in line with a 1.5°C future.[313] To join, companies must submit a letter of intent, develop a target, present the target for independent analysis by SBTi, publicly announce the target, and report annually on progress made towards achieving the target. To date, more than 1,000 companies have joined.[314] Companies and organizations that have a physical presence in New Jersey and that are part of SBTi include, but are not limited to, Mondelez, Mars, NRG, Walmart, Whirlpool, and the Port Authority of New York and New Jersey.

Numerous organizations are researching and promoting CSR. Examples include the U.S. Chamber of Commerce Foundation's Corporate Citizenship Center, which convenes business leaders, conducts research, and disseminates information on best practices in CSR.[315] The Conference Board of Canada, a not-for-profit think tank, publishes studies on the topic (e.g., sustainability reporting, impact valuation, and third-party verification).[316]

Interviews were conducted with representatives of two multinational corporations about their involvement with PES and their CSR strategies. Both are "members" of SBTi, having committed to reduce their greenhouse gas emissions. For example, one of these companies (Company A) aims to be carbon neutral by 2030 (at their own sites). The other (Company B) seeks to reduce supply chain emissions per ton of product 30% by 2030 and absolute operational emissions 10% by 2025 (emissions caused directly or indirectly by the company's operations).

One of these interviewees explained that since their company purchases products from farmers, it is in their interest to support initiatives and programs that help farmers to remain productive in the face of climate change. Addressing climate change is essential to "maintain operations." One approach the company takes is to fund programs that reduce the intensity of emissions caused by the production of certain crops within their "supply shed". A supply shed is a group of suppliers providing similar goods and services that can be demonstrated to be within the company's supply chain acknowledging that it may not be feasible to demonstrate which specific suppliers provide the goods and services, but it should be demonstrable that they are in the group that do.[317] Both representatives interviewed noted that the supply shed concept can be an important opportunity for farmers to receive payment for ecosystem services. Smaller farmers within the same supply shed could be aggregated to meet supply chain emission reductions.

The interviewee from Company B explained that in general, their corporation pays for outcomes (e.g., emissions reductions achieved, water quality targets met, biodiversity areas developed) versus practices (i.e., paying for practice implementation). Another approach is to provide training to farmers on no-till, cover crops, and other practices that can lower emissions and increase climate resilience (e.g., providing training assistance; financial support; technical support in research and development; moving from single-year commodity sale contracts to multi-year products and services contracts). The corporation sees an opportunity to deepen

relationships with its clients by partnering on projects that can reduce emissions and generate carbon credits. Essentially, the corporation is helping other companies meet CSR goals, while also working towards its own CSR goals.

The interviewee from Company B also shared his views on trends that will affect PES. He expects demand for carbon removal offsets to increase, especially from technology, finance, and other industries with large carbon footprints that do not have natural assets in their supply chain. He anticipates that companies that have committed to emissions reductions will be under greater pressure to be transparent about how they have achieved reductions. In his view, one of the main challenges in quantifying emissions reductions is that the data are about something that did not happen. If a farmer reduces stress on soil by using less fertilizer, what the farmer has done is avoid the impact of greater fertilizer use on the soil. A real constraint is that "much of our basic understanding of soil carbon dynamics at a global market scale is still evolving." The interviewee noted that satellite data will likely be critical for the future of farmed carbon and suggested that data quality guidelines cannot be developed in a vacuum but must be grounded in/by commercial purposes (lacking today).

The representative from Company A, also spoke of the value of satellite data for PES. He noted that the process of monitoring, reporting, and verification (MRV) is expensive; however, there are alternative approaches to MRV that are cheaper and that do not compromise the quality of accounting. For example, the company worked with a corporate partner in the Northeast to conduct satellite verification of practices on more than 20,000 acres of land. The partner has access to a public Landsat database and uses algorithms to look at surface residue, tillage, and absence or presence of cover crops. The company had been doing verification in the traditional way (having someone physically on-site to see that practices have been implemented). When they compared the results from the two approaches, they were consistent. Verification using satellite data costs pennies to the acre and is a fraction of the cost of the traditional approach. They have also lowered the cost of MRV by using biogeochemical modeling to quantify carbon sequestration. The representative claimed that many people view soil carbon measurements as the "holy grail." It costs roughly $120 per sample to send soil to a testing laboratory. This interviewee questioned how many samples you can take on one farm, for example, before you have paid all your money to a laboratory. Models do have high uncertainty, but the company has calculated its uncertainty in the model and compared it to measurements taken from pilot soil samples and determined the level of uncertainty in the model is similar to the variability of the soil samples. The representative mentioned that some programs use a model to quantify sequestration and then they "true up" with on-the-ground sampling. But according to the representative, this approach multiplies errors from both the model and the sample. The interviewee's recommendation is that someone (such as a government agency) create a handful of sentinel sites possibly at land grant universities across the country to collect data and improve models.

The representative from Company A is involved in a larger effort to develop a new standard for soil carbon sequestration and explained that a lot of groups have gotten involved in soil carbon sequestration, but there are not any rules, and it is sort of the "wild west." Soil is a complex biological system, so the way you measure carbon sequestration in soil versus trees is different. Staff with the USDA shared a similar sentiment. They advised that carbon markets were

designed for point-to-point source emissions. Working lands "do not fit well into these market schemes" because "it's a non-point source of emission reductions," which raises a number of issues, such as how to model or estimate emission reductions or carbon sequestration and the uncertainty associated with those estimates. They noted that working lands also raise issues around how baseline is determined and how to treat additionality and early actors.

The representative from Company A sits on a technical working group to provide overall guidance on adapting the Greenhouse Gas Protocol to be more relevant for working lands. Once the process is complete, this updated protocol will be the "bible that everyone refers to." Important questions the representative noted that need to be answered include: 1) What is the level of incentive that gets a farmer to change practice(s)? 2) How long does that incentive need to stay in place so that there is a level of stability in the market and the incentive can be removed?

Company A is involved in pilot projects in the Midwest. Unlike Company B, which pays for outcomes (i.e., amount of carbon sequestered), Company A pays for implementation of practices. Farmers are paid annually on a per-acre basis to adopt conservation practices like reduced tillage and precision nutrient management over the life of a contract (which can vary according to the program). The company does this to reduce uncertainty for farmers over payments.

Many of the farmers the company works with are also its suppliers. The representative explained that some corporate inventory reporting rules require emissions reductions in the supply chain (Scope 3 emissions). The representative pointed out that working with farmers within the supply chain allows for collective investment in climate smart practices from multiple participants in the value chain, which can more easily result in scaling of investment and climate impacts. The representative also noted that the supply shed concept relieves some of the burden of a partner having to provide traceability to an exact farm. As long as they work with farmers in the supply shed and invest in these practices, they can have claim to some of the removals in that supply shed.

When asked about the motivation for the company to engage in research, pilot studies, and other efforts around climate change, the representative from Company A responded that when the Paris Agreement was being negotiated, some major players in the agriculture sector were branded as the "bad guys." At least initially, the company's actions were about changing the perception of agriculture, showing that it can be part of the solution to climate change. Other influencing factors are the various ways that agriculture is already being negatively impacted by climate change. When asked directly about opportunities to profit financially, this interviewee said there is potential to develop products that drive carbon benefits, such as seed treatment that can enhance root mass for better nutrient uptake.

Educational Mission

More than 450 colleges and universities are working towards the goal of carbon neutrality.[318] Ten have achieved neutrality (Allegheny College; American University; Bates College, Bowdoin College, Colby College; Colgate University; Colorado College; Dickinson College; Middlebury College; University of San Francisco).[319] Interviews were conducted with several university

representatives about their involvement in PES, to learn how it may be used to reach carbon neutrality and if there are opportunities related to natural and working lands.

Duke University has pledged to be carbon neutral by 2024 and expects to achieve its goal through a combination of on-campus reductions, renewable energy, and carbon offsets. The Duke Carbon Offsets Initiative (DCOI), established in 2009, leads the university's carbon neutrality strategy including managing its offsets portfolio. One of DCOI's primary goals is to create academic value from offsets by finding opportunities for students and faculty to be involved in projects and through sharing knowledge with the wider academic community.

Representatives of DCOI told us that Duke generates its own offsets (including its Lloyd Ray Farms swine waste-to-energy project and expected offsets from its Pocosin Wetlands Restoration Project in development) and purchases offsets from external projects. The university generates offsets to be used towards its carbon neutrality goal and does not sell them in a marketplace. Duke typically works through the protocols of established registries and has a third party verify emissions reduction outcomes of its projects.

Another way that Duke verifies project outcomes is through a peer review process. Duke is a founding member of the Offset Network, a collaboration of higher education institutions that supports offset projects "that provide educational and research opportunities for students, faculty, and staff." Duke serves on the Offset Network's Peer Review Committee, and thus had a role in creating the peer verification and peer review pathways. Institutions of higher education can enlist their peers from other institutions to verify projects that reduce Scope 3 emissions. The benefits of doing so include cost savings (it is less expensive to have a peer institution verify a project than a third-party verifier through an established registry) as well as educational opportunities for faculty and students (who are involved in reviewing and verifying the project). Duke's Urban Forestry Protocol has been accepted through the Offset Network; it was the first protocol to go through the peer review process. Duke has also had its urban forestry projects peer verified by peer institutions.

When asked about their criteria for selecting offset projects, the Duke representatives explained that for generated offsets, some of the projects were inherited (i.e., the projects started before the office was established). When they have had the chance to select projects, they typically look for ones that have co-benefits (e.g., social benefits such as reversing historic red-lining or environmental benefits such as wildlife corridors) and that are geographically close to campus to facilitate student participation, such as urban forestry in Durham. Purchased offsets are usually connected in some way to the university (for example, a project that a faculty member learns about through their professional network). Staff of DCOI advised that the University set a relatively early neutrality date of 2024 with the understanding that offsets would be used. In their expert opinion, no university counting Scope 3 emissions at this time would be able to reach neutrality without offsets. Purchasing a large quantity of offsets can be expensive. Duke is starting to explore sustainable funding solutions. It is looking at models from other universities, like University of Maryland and Arizona State University which charge internal departments a fee or tax on airline miles traveled.

B.2 Standards and Protocols

Typically, voluntary market projects comply with protocols of third-party standards organizations, and emissions reductions are verified by third-party auditors. Most standards for offsets that are sold in the voluntary market have criteria in place to ensure that offsets meet PAVER requirements (described previously). Standards frequently mentioned by interviewees include: Verified Carbon Standard (Verra); Gold Standard; American Carbon Registry; Climate Action Reserve; Nori. It is outside of the scope of this study to analyze the various protocols and standards. Interviewees shared insights about their preferences, based on their experiences and their own internal research.

This section briefly reviews interviewee observations about the standards and protocols, and it is in no way meant to endorse one protocol or standard over another.

No one standard appears to be preferred among interviewees, who were project developers. Based on interviews, the general process seems to be that: 1) project developers are aware of these standards, but there are no comprehensive studies that compare the benefits/drawbacks of standard and protocols for different project types; 2) project developers conduct their own internal research to determine which protocol and standard are the most appropriate fit for their project type; and 3) in cases where there is no existing protocol to cover a certain project type, project developers work with a recognized standard to create a new protocol.

PAVER Requirements

Several interviewees questioned the accepted wisdom that "legitimate offsets" are those that meet PAVER requirements. The two issues most commonly cited have to do with permanence and additionality.

With respect to permanence, an interviewee shared that permanence is a huge issue in the Northeast. Farmers are generally hesitant to sign on for a ten-year term to change the way they go about their business (i.e., implementing new practices). They may be willing to try out a program for five years, but some carbon markets are asking for terms of upwards of 100 years. This is a huge disconnect between what the markets want and what a farmer is willing to do.

Additionality can have the unintended effect of penalizing environmentally conscious farmers. The way that additionality is commonly framed is, absent the motivation of the sale of credits, would the action (i.e., the practice, change in practice or management style) have occurred? If the action would have occurred regardless (i.e., business-as-usual), the offset does not meet the additionality requirement. Ecosystem Services Market Consortium (ESMC) reports that "Markets strive to only award credits to actions that wouldn't have occurred without the incentive provided by the market." [320] ESMC notes, "This rule inherently determines that any good actions already occurring cannot be rewarded…" [321] Several interviewees noted that innovative farmers who are early adopters of practices that sequester carbon are disqualified from market participation. According to one interviewee, the additionality requirement unfairly discriminates against farmers who are "of their own volition… are doing the right thing and figuring out how to do it by the skin of their teeth."

More risk-averse farmers learn about new practices from early adopters. A policy that effectively punishes farmers for implementing climate beneficial practices "too soon" seems counterproductive, especially considering that "Adoption of beneficial practices and impacts remains relatively low" in the agriculture sector.[322] Further, the determination that an offset is additional is "highly subjective."[323] An interviewee said, "A lot of times you can pretty easily make the argument that even when the transition was made, farmers were considering in the back of their mind, 'hopefully someday I can get an ecosystem service payment for carrying out this transition.'" This practitioner questioned, if a farmer can make that claim, will the farmer's offsets meet the additionality requirement?

B.3 Forest Program Models

Family Forest Carbon Program

The American Forest Foundation (AFF) and The Nature Conservancy (TNC) created the Family Forest Carbon Program to facilitate participation of family forest owners in the carbon market. To be clear, forest owners are not technically excluded from the market, but requirements for long-term contracts (upwards of 100 years) and the high upfront and long-term costs of MRV often limit participation to all but the largest projects (5,000 acres on up). AFF and TNC are making it easier for smaller landowners to participate in the market by enrolling landowners in a 10- to 20-year contract. Through a collaboration with Verra, AFF and TNC are pursuing an approach to carbon accounting that will reduce the per-property costs of MRV. This new approach measures forest stock changes. Instead of measuring carbon on all participating properties throughout the duration of their program contract, every year the program measures the carbon impact based on a random sample of enrolled properties. The methodology includes what the interviewee noted as another innovation that provides assurance to carbon buyers that the credits produced are truly additional, by comparing project area stock changes against a measured baseline of non-project area stock changes. The methodology is pending accreditation (expected fall 2021).

The Family Forest Carbon Program was first launched as a pilot in the Appalachian region of Pennsylvania. It is a performance-based program that focuses on specific forest management activities. Forest owners are paid for one of two practices: 1) Growing mature forests by limiting the harvest and letting larger, higher quality trees grow; or 2) Enhancing future forests which promotes regeneration by reducing competing vegetation following or preceding a regeneration harvest.

Payments for each practice are calculated using an estimate of cost to complete the practice and carbon impact, so that those whose land has the greatest potential to sequester carbon earn more. To be eligible to participate in the program, landowners must have at least 30 acres, and other eligibility requirements depend on the specific practice. Landowners receive payments throughout the contract period as a way to incentivize them to keep up with the practice. It is anticipated that carbon captured from landowners enrolled in the program will be available for purchase in the form of verified carbon credits.

When asked why the program was launched in Pennsylvania, the representative of AFF advised that a small percentage of forest landowners there (around 10%) have management plans. In AFF's experience, most forest landowners want their land to be healthy, to be a habitat for wildlife and a legacy for their family; however, because of the lack of management planning and expertise, there is a gap between their goals and what is happening on the ground. The program serves to fill a gap, providing technical assistance to help landowners develop plans for their woodlands that result in ecological benefits. Technical assistance is administered through forester visits. The forester collects data, reviews the landowner's goals, and offers recommendations and information on where to find additional resources. Resilience to address climate change impacts is a concern but not stated as an active part of the program goals.

The program is supported by corporations and foundations including: Amazon; 3M; VF; Domtar; Vulcan Materials Company; International Paper; Richard King Mellon Foundation; J.M. Kaplan Fund; WestRock Foundation; Doris Duke Charitable Foundation. During the next phase, the program will expand to the rest of the central Appalachian region. By 2030, AFF and TNC hope to catalyze the enrollment of 54 million acres nationwide. As the program moves forward, the intent is that revenue from the sale of carbon credits will be used to expand and administer it.

The Family Forest Carbon Program is not the only voluntary program available to forest owners who want to participate in carbon markets. For example, TNC manages two other programs: Working Woodlands and Forest Carbon Co-Ops.

Working Woodlands

In the Working Woodlands program, landowners commit to managing their forest sustainably by signing forested acres into a conservation easement and accepting a long-term management agreement (10-year, customized plan). In return, the program provides landowners a comprehensive assessment of the forests, wildlife and carbon on their property and offers certification by the Forest Stewardship Council, allowing products from lands enrolled in the program to be sold under the FSC-certified label. TNC also brings carbon finance to interested landowners. According to a representative of TNC, there are 17 Working Woodlands carbon projects, most of which are improved forest management projects. About 80% of landowners take advantage of carbon finance, but many do not want to be involved in the details, so TNC manages the sales of the carbon credits on the voluntary markets. TNC sells only to corporations that have been pre-approved based on an internal TNC evaluation focused on progress made toward their climate mitigation commitment. The interviewee from TNC explained that these companies want to mitigate unavoidable emissions (i.e., corporate travel, commuting). He advised that one buyer set up a "really good mitigation hierarchy" by enacting a carbon tax. Unit directors do not want to pay the tax, so they look for ways to reduce their emissions. The representative made clear that TNC does not want corporations/governments/people to "just offset their way out of this" (i.e., climate change) and noted that offsets are a bridge strategy.

When asked what the motivation is for landowners to join this program, the representative shared that "landowners have a strong interest in the legacy of the property." Roughly half of landowners want to learn more about conservation easements, while 30% to 40% have no interest in it (for them, a program like the Family Forest Carbon Program may be more appropriate). Of those who are open to having a conservation easement, one of the main drivers

for joining this program is the opportunity to sell products under the FSC-certified label. With the label, landowners can access new markets and sell products at a premium. Carbon finance is an added bonus and generally covers the direct and opportunity cost of the Improved Forest Management practices they have adopted.

To apply for the program, landowners must have a minimum of 2,000 acres. The program currently covers about 625,000 acres in TN, KY, PA, MI, and NY. Participating landowners include private individuals as well as hunting and fishing clubs.

Forest Carbon Co-Op Program

The Forest Carbon Co-op (FCC) program involves forest landowner aggregation, whereby TNC and partners facilitate groups of landowners coming together to pool their management approach, carbon verification, and provision of credits. This approach can make voluntary offsets markets available to medium-sized landowners of between 200 to 2,000 acres.
The first FCC project is Cold Hollow Carbon in Vermont, a partnership between TNC and the Vermont Land Trust that enrolls family owners of mid-sized forests in a 40-year contract to sustainably manage their lands. This program has also received funding support from Amazon. As of August 2021, 10 landowners (8,600 acres) were enrolled in the program, all located in Northern Vermont. They are not required to put their land into a conservation easement, but a representative of TNC advised that as the program is built out, easements may become mandatory. Landowners produce carbon offsets for the voluntary market. TNC and the Vermont Land Trust sell the credits in aggregate. The representative of TNC shared that most of the credits are purchased by corporations who have gone through TNC's internal review process.

In TNC's experience, corporations do not want to take title to the credits, so they are retired in a public registry on behalf of the corporations. Asked for his view on why corporations are participating in the voluntary markets, he said that there is an "interesting shift globally to making commitments to 2040 that are meaningful, that sync up to keeping global warming at or below 2º C." With that shift, "it's almost like voluntary space is turning into more of a compliance space for companies." This representative noted that corporations are anticipating that carbon and climate will become more of an issue over the mid- to long-term, and they are taking action to be prepared.

TNC manages a number of forestry projects in locations throughout the country; areas that TNC prioritizes are those with the "highest likelihood of contributing to biodiversity" based on the concept of a "resilient and connected network" identified by TNC scientists as being resilient to climate change and important as corridors for ecological diversity. He advised that one of the reasons the Family Forest Carbon Program was launched in central Pennsylvania relates to the finding of the resilient and connected network. That is, through a nationwide analysis, it was determined that Pennsylvania is critical for maintaining connectivity for ecological flows; also, Pennsylvania has significant forest products. Based on the scientific assessment, TNC is also starting to build in a vulnerability score to its forest management plans. For example, stands of forest that are homogenous have a higher vulnerability score.

Maryland Forest Conservation Act

Maryland's Forest Conservation Act of 1991 is intended to minimize the loss of forests to land development and ensure that priority areas for forest retention and planting are identified and protected prior to development.[324] [325] Contiguous blocks of forest, wildlife corridors, and areas on steep slopes, erodible soils, or next to streams or wetlands are priority areas for retention and planting. The law applies to homeowners and developers whose action triggers sediment erosion (40,000 square feet of disturbance or greater) and establishes minimum standards for the amount of mitigation, afforestation, and reforestation which must exist on a site at the completion of a development project.[326] It is administered by the Maryland Department of Natural Resources (DNR) and implemented by DNR and local governments. Developers subject to the Act need to submit for review and approval a Forest Conservation Plan (FCP) and Forest Stand Delineation (FSD); each are prepared by a licensed forester, landscape architect, or other qualified professional.[327] The FSD identifies existing forest cover and environmental features of a proposed development site; the FCP describes the limits of disturbance for the proposed project and how existing forested and sensitive areas will be protected during and after development, including whether tree planting will be required and a plan for their long-term maintenance and protection.[328] A representative from DNR explained that zoning for the property in question determines the percent mitigation needed. Developers must provide public notice and have a two-year maintenance agreement and a forest conservation easement on what they are mitigating. The law is flexible in that it allows for different approaches to mitigation: tree plantings (like street trees) or retention of an existing forest.

The DNR representative noted most people prefer planting because it can be done at a 1:1 ratio (your project needs 10 acres, you plant 10 acres). Retention offsite needs to satisfy a 2:1 ratio. According to the interviewee, the higher ratio for retention was implemented to satisfy environmental groups concerned that retention was an "easy out" for developers. There is a mitigation hierarchy: on-site first; if that is not possible, within the same watershed as the development; if not in the same watershed, a third option is for the developer to purchase credits in a forest mitigation bank.

The interviewee said that an entire industry has emerged. Brokers connect mitigation bankers to developers and manage all the necessary paperwork (for example, easements and land records of forest mitigation banks). Yet, the interviewee characterized forest mitigation banking as a "catch 22." Without development, there is no demand for a mitigation banking program. A last option for mitigation is to pay into the reviewing agency's fee-in-lieu fund at the rate stated in the statute or local ordinance. A developer can satisfy mitigation requirements through fee-in-lieu only if the state and local government (where the development is occurring) agree. The interviewee noted that the fee-in-lieu option seems to drive the price of mitigation bank credits, which are always a bit less per acre than the fee-in-lieu amount; in these instances, the government is responsible for planting the replacement trees within the county or watershed utilizing the fee-in-lieu funds. According to the representative from Maryland DNR, from 1992 to 2017 (25 years) 229,485 acres of forest have been reviewed under the Act. Of those, 138,158 acres were retained, approximately 84,615 acres were cleared, 21,584 acres were planted, and 7,161 acres were banked.

B.4 Grassland Program Models

Western Sustainability Exchange/Montana Grasslands Carbon Program

In Montana, the Western Sustainability Exchange (WSE) assists ranchers in accessing carbon markets. WSE's mission is to "conserve the abundance of the Northern Rockies, by promoting good stewardship on the family ranch" through various initiatives, one of which is the transformation of the food system. For nearly thirty years, WSE has offered a certificate that recognizes ranchers whose practices are sustainable. A representative of WSE advised that "a big part of being sustainable is managing your grazing," and producers who apply for the sustainability certificate are asked directly about their grazing practices. Beef from cattle raised in a sustainable manner is purchased by companies including Xanterra Parks and Resorts. Through the certification process and years of providing training and technical assistance, WSE has become an expert in grazing management.

Several years ago, WSE was approached by NativeEnergy (a carbon offset project developer) to establish a program based on a model quantifying carbon sequestration using high intensity, short duration grazing (also referred to as adaptive multi-paddock grazing). The representative of WSE explained this practice mimics the historic grazing patterns of native ungulates. The goal of this type of rotational grazing management is non-selective, resulting in animals grazing all of the plants more equally. The interviewee noted the other important priority must be to establish and maintain soil cover. Animals are moved frequently, giving grazed areas time to "rest." However, the WSE representative said that this practice has not been widely accepted by academia or land management agencies who often prefer "light stocking," which may result in less use of the range in general, but repeated grazing of preferred forage species. Over time, these "decreaser" plant species (plants that decrease under excessive grazing pressures) are grazed out of existence. High intensity, short duration grazing can "easily be abused." If not done correctly, it will lead to overgrazing and increased bare ground. But if it's done right, the interviewee claims that it produces a "much healthier plant and soil community."

NativeEnergy proposed a program that would pay ranchers to implement this more aggressive grazing strategy. The Montana Grasslands Carbon Program launched about five years ago and was designed to be risk-free to the ranchers that participate. WSE recruits and assists ranchers with program enrollment, budgeting, planning, and infrastructure development (to support transition to new practice), contract negotiation with NativeEnergy, and soil sampling. As of August 2021, five ranches are enrolled in the program (78,000 acres) with more under recruitment. Ranchers submit a proposal outlining costs to transition to high intensity, short duration grazing. These transition costs can be substantial; for one ranch alone, it can cost hundreds of thousands of dollars for labor and necessary infrastructure such as fencing, and installation of pipes and tanks to supply water for cattle in more remote paddocks. Through its "Help Build" program, NativeEnergy funds part of the up-front costs, which is essentially an advance on carbon credits the rancher will generate during the 30-year term of the contract. Help Build funding is usually available during the first five to seven years of contracts, which are transferable and can run with the land. Additional funding for up-front costs comes from other project collaborators: Xanterra Parks and Resorts, Allbirds, and Everlane. NativeEnergy also has companies lined up to purchase the credits, pending third-party validation.

In addition to receiving funding for infrastructure and labor, ranchers will be paid for carbon sequestration. The amount paid for infrastructure will be subtracted from the revenue earned for sequestration, and the rancher will be paid the difference over time. Questioned about project validation, the WSE representative said that they are still working out the details with the third-party verifier, Aster Global. This is a new standard for grazing-generated carbon credits that will be registered through Verra. Baseline soil samples were taken at the project outset. The model methodology for estimating net annual carbon uses monitored changes in grazing activity over time to estimate the net change in carbon on an annual basis; modeled data will be compared with soil carbon measurements every few years. When ranchers apply to the program, they are asked to report on their current grazing practices, which informs the baseline. They subsequently report their actual grazing activity at the end of each season.

Although the ranchers do realize increased costs in labor to move fence and cattle, these costs may be offset by other savings, and if not, the costs can be offset by additional income from the carbon credits. The adaptive multi-paddock strategy improves forage production, thus extending the grazing season, reducing the amount of supplemental hay needed to feed the livestock (purchased or grown by ranchers), and translating into savings from equipment (including fuel and maintenance costs) and labor. Moving animals more frequently also helps interrupt the lifecycle of parasites that may be present in the pasture, resulting in less frequent treatment, or omitting the need for treatment, of livestock with pesticides. In the long term, improved soil health is anticipated to absorb and store more water, reducing the demand for irrigation on the ranch, also resulting in savings for producers.

Audubon Conservation Ranching Initiative

Food certification is also used as an incentive by the Audubon Conservation Ranching (ACR) Initiative. Their representative noted this program was started to scale the conservation of habitat for grassland birds, which are the fastest declining species of birds in North America, but that grasslands also sequester carbon, and that Audubon science has shown that climate change is the greatest threat facing birds, with only 320 million acres of grassland remaining in the U.S. Audubon's representative explained that finding ways to preserve grasslands is important, not only for fighting climate change and increasing bird populations; grasslands filter water, provide shelter for bees and butterflies, and livelihoods for ranchers. "Everything we do has an equal part bird, biodiversity, and soil purpose."

For Audubon, sustainable beef production is key to protecting grasslands. The Audubon representative explained that "what we as a society choose to eat is a main driver of land use decisions." Some people are moving towards a plant-based diet out of concern for the environment, but this decision can be detrimental for grasslands. The interviewee said that "without cows, very few grasslands would remain." Roughly ten years ago, Audubon changed its approach to animal agriculture, seeking to support and improve it, not eradicate it. The interviewee noted, "we must have a strong vibrant grass-based agriculture industry."

Through Audubon's program, ranchers that adopt regenerative grazing practices and meet certain program requirements can receive an Audubon certification that beef products are grazed on bird-friendly land. Incentives also include technical assistance delivered through the Audubon range ecologist network; several of their range ecologists are technical service providers who can

write contracts for federal or other cost-share programs (e.g., with USDA NRCS). Technical assistance has included cost-sharing infrastructure (e.g., fencing or removal of eastern red cedar, which has been "severely" encroaching on grasslands, making grazing difficult) and knowledge sharing (for example, planning for rotational grazing). Participating ranchers must allow livestock to freely graze on open grassland and monitor the health and welfare of their animals. They are prohibited from using feedlots or animal by-products or antibiotics in feed, and they must adhere to protocols for habitat management and environmental stewardship which vary based on the eco-region. Nearly 3.5 million acres (more than 130 ranches in Colorado, Missouri, New Mexico, North Dakota, Texas, California, Nebraska, Montana, and Wyoming) are enrolled in the program.

Program enrollment is year-to-year. Ninety-eight percent of the ranches that were enrolled since the program launch in 2017 have remained enrolled. Compliance is verified on an annual basis by a third-party verifier, Food Alliance. Audubon staff and contractors conduct annual bird surveys, vegetation, insect and pollinator monitoring. Audubon has also raised over $1.2 million to now expand soil carbon monitoring across all ranches using the Verra Carbon Standard for Grasslands. As per the Audubon representative, "this is an important data point that will provide additional decision support to ranchers for soil and habitat management, as well as open up new opportunities for ecosystem monetization."

When queried about issues surrounding green food labels (e.g., differentiating labels and knowing which labels adhere to standards they claim can be confusing for consumers), Audubon's representative agreed that there is a "legitimate concern out there about certification fatigue and confusion", but the representative noted that their program is making progress in making beef more sustainable, they are working with a niche sector of the industry, and their certification is unique in that it is the only one tied directly to birds. The organization has secured a number of partnerships with groups like Ducks Unlimited, who help to promote certified products. In April 2021, Audubon announced a partnership with Panorama Organic Grass-Fed Meats (America's largest domestic grass-fed organic beef brand) to certify their entire supply chain. Soil and habitat management plans are being developed for every family rancher in the Panorama Organic network of over 1 million acres of rangeland and grasslands, which will bring total ACR enrollment to over 3.5 million acres, with plans to double the Panorama network to 2 million acres certified by Audubon by 2030.[329] Audubon does not currently exchange money or revenue-share with participants or market partners. There is no charge to producers to carry the Audubon certification.

Ducks Unlimited Carbon Program

Ducks Unlimited (DU) is an established carbon project developer, with respect to grasslands. The organization is an accredited land trust, and works in a variety of ecosystems including grasslands, forests, peatlands, wetlands, and croplands. DU's work in carbon offsets has focused on grasslands in the Prairie Pothole Region of the U.S., with DU's representative noting that "prairie grasslands are distinguished by scientists as the most endangered ecosystem in North America." Through its Ducks Unlimited's Carbon Program, landowners are paid for their greenhouse gas rights. All of the grassland carbon projects have a perpetual conservation easement forgoing future development rights (the easement and greenhouse gas rights are handled as separate transactions). Participating properties are often large in size, either a number

of small fields that have been aggregated or a parcel of 5,000 acres or more. Properties are monitored annually for any infractions of the easement or carbon contract. DU works through established standards. The organization led the development of an Avoided Conversion of Grasslands and Shrublands (ACoGS) methodology, which was approved by the American Carbon Registry in 2013. The following year, DU generated the first ever ACoGS credits, completing a market transaction for 40,000 carbon offsets. DU often sells the credits to corporations.

The ACoGS methodology quantifies emissions avoided from prevented conversion of grassland and shrublands to commodity crop production. It is intended to incentivize avoided soil carbon loss and agricultural greenhouse gas emissions through the placement of grasslands under conservation easements that preclude cultivation. As noted by the American Carbon Registry, grassland and shrubland soils are significant organic carbon reservoirs that will continue to store carbon below ground if left uncultivated. Other practices with greenhouse gas implications such as fertilizer application may be avoided through this activity; livestock and emissions from associated enteric fermentation and manure deposition are also accounted. The most current version of this protocol was published in 2019.[330]

Responding to a question about how the value of an offset is determined, the interviewee noted several issues that affect prices. The first has to do with the year stamped on the credits (referred to as vintage). For a grasslands project to be economically feasible, the representative said it needs to be a minimum of 5,000 fully eligible historic grassland acres, given current market prices for offsets and the transaction costs associated with generating those credits. To meet this threshold, project developers may "lump a bunch of [credit] years together." The challenge is that private industry prefers current or recent vintages and tries to discount older vintages. This preference for recent vintages can "inadvertently stymie good projects" by making them financially unviable. Buyers also prioritize projects in their backyard. The interviewee gave the example of historically higher demand for offset projects in Colorado, where a number of buyers of carbon credits are also located, than in North Dakota, where a bulk of DU's carbon projects are located and the highest rates of grassland conversion have occurred. Credits from North Dakota-based projects have typically sold for less than those of Colorado-based projects. In the past, DU had to hire brokers to help sell credits from North Dakota. However, the DU representative noted seeing a "big influx of demand" for carbon credits.

B.5 Agricultural Land Voluntary Marketplace Program Models

A next generation of marketplaces are emerging expressly to address farmer and rancher interest in payment for ecosystem services, to address barriers cited by their developers in traditional voluntary offset programs and regulatory compliance markets, and/or to address supply chain emissions. These marketplaces are consortia of non-governmental organizations, academia, private sector partners, and government agencies.

BCarbon, Inc.

DU and Audubon Texas are two of many entities involved in the BCarbon initiative led by the Baker Institute at Rice University to develop a protocol for carbon storage in grasslands that can be utilized throughout the United States and around the world. An interviewee from Rice

University's Baker Institute explained that the inspiration for this work came after witnessing the destruction of Hurricane Ike (2008). Areas to the east of Houston, which are relatively undisturbed prairie lands, fared "fairly well." The Severe Storm Prediction, Education, and Evacuation from Disasters Center at Rice University identified two million acres of land in the Houston/Galveston region that could be set aside as buffers to lessen the impact of future storm surge events. The challenge was to figure out how to set that land aside, because according to the interviewee, "In Texas we aren't going to regulate. Just not possible politically." They settled on what they refer to as ecological service transactions as the most viable solution. From a practical matter, there seemed to be the greatest opportunity in selling carbon storage in soil. After reviewing existing protocols and finding that they would not work for Texas landowners due to barriers to entry (e.g., the interviewee noted good stewards are excluded due to prior sequestration activities), they made the decision to develop their own protocol and formed a working group (the Baker Institute Soil Carbon Working Group) in 2019. The working group now has participation from over 70 institutions, corporations, and non-governmental organizations and includes more than 200 participants (including some government agencies such as Texas Parks and Wildlife Department, the New Mexico Department of Agriculture, the North Dakota Trust Lands, and USDA).

A BCarbon representative noted, the group has developed eleven working principles including one on diversity, equity, and inclusion, a first for carbon protocols. The BCarbon representative also noted that the working group's bias is pro-landowner and that, "in Texas with as much private property as we have, if we don't have a system that is sensitive to property rights, then we aren't going to get started." The BCarbon system also requires soil testing, which was the key criteria to establishing the credibility of the credit. The interviewee emphasized that they are not requiring what they referred to as "traditional additionality", although they will issue credits only for "fresh carbon" (i.e., only additional carbon in the soil column that has been added to the soil in the year the credit is issued). The BCarbon protocol does not count surface carbon and does not allow for tilling. The BCarbon representative explained that "common additionality requirements can prevent good stewards who might have been conducting regenerative grazing in the past from realizing any benefit and restrict those who can participate to a very small number." The respondent also concurred that this marketplace is a mode for buyers to get ahead of a regulatory program. Under BCarbon, the key concept is reaching scale of carbon dioxide removal and storage as fast as possible – a concept that requires a marketplace that is free to transact and push the landowners forward to realize more income from better management practices.

Landowners commit to soil carbon storage for ten years and are able to renew after the first ten years for each subsequent year provided they sell credits and further agree to renew the ten-year commitment, making this a "rolling" ten-year commitment that can extend over time. A baseline carbon measurement is taken, and any carbon stored above the initial measurement would be eligible for sale. The BCarbon representative noted, "we view the ability to sell carbon as a property right, just like growing potatoes." Soil carbon measures will be verified every three to five years thereafter. Landowners are free to implement practices as they see fit. The working group does not mandate (or even recommend) specific land management approaches; however, this program is designed for grasslands. "We are not interested in plowed soil," noted the interviewee. Similar to expressions of interest by other interviewees, the BCarbon developers

are examining the potential for carbon measurement via remote sensors, which may reduce the costs of scaling the program, while maintaining the credibility that their current testing protocol generates.

The BCarbon interviewee explained that the marketplace will be voluntary and at this time, "we do not place restrictions upon whom may purchase our carbon credits." The instruments for the purchase of credits will be contracts between buyers and sellers with an expectation that there will also be assemblers of credits who will have contracts with landowners. BCarbon itself will not be involved in the buying or selling of credits but instead simply issues credits based on applications submitted pursuant to its adopted protocol.

The representative noted that carbon capture technologies that oil and gas companies are proposing to install are expensive while it is much cheaper to buy carbon storage capacity in grasslands. There are several hundred million acres used to grow forage for cattle in the United States, and forage land could be converted to carbon-sequestering grasslands if the price and yield were sufficient. The working group has heard from landowners that an extra $20 or $30 of revenue per acre would make a huge difference for their profit margins. Given the motivations on both sides, the BCarbon representative anticipates that prices will rise as oil and gas companies begin to purchase carbon storage, and that commitments to 50% emissions reduction by 2030 (as identified by the current U.S. administration) will drive demand for grassland soil carbon credits. The goal of BCarbon is to "create something that would work for climate and Texas." The interviewee also noted that the British Consulate is engaged in their working group as they support "anything that gets the United States off the dime of talking about these issues in a more realistic way. The practicality of what we are doing may be its saving grace."

Like other marketplaces, they will have a buffer pool (10%). Trades will be allowed and will be recorded in blockchain to ensure transparency. Asked whether their protocol will be adopted by one of the existing standards, the interviewee said they had approached several standards organizations, but these groups were focused on their own standards which the BCarbon interviewees suggest are not as innovative.

BCarbon formed their own certification entity, housed in Houston, and received their first carbon credit applications in June 2021. As of August 2021, BCarbon is processing 85,000 tons of credits, with 10,000 tons of those credits being in Yorkshire, United Kingdom. BCarbon has adopted a metrics protocol that will be used to evaluate all carbon credit applications. A verification firm, GSI Environmental, has been retained to review all applications and determine whether their application meets the BCarbon standards. That review process is ongoing as of August 2021, with the first credits expected to be issued in fall 2021.

According to the BCarbon representative, the long-term goal of BCarbon is to help the United States reach scale in natural carbon sequestration and make a dent in the U.S. carbon footprint of 6.5 billion tons of emissions. They believe that BCarbon can be certifying 25 million tons of credits in five years or less, toward the goal of helping the U.S. realize carbon dioxide capture and storage in grasslands of upwards of 1 billion tons by 2035.

Much of BCarbon's work has been conducted by volunteers with some corporate and foundation support. A per-ton fee for processing credits will be charged. The BCarbon representative believes the current price for credits will be between $17 and $20 per ton, which should cover soil testing requirements, and as the credits rise in value, the testing costs will become less significant for the participants.

Ecosystem Services Market Consortium

Another group in the process of developing a marketplace for carbon is Ecosystem Services Market Consortium (ESMC). An interview was conducted with ESMC representatives who explained that their non-profit began work in 2017 to create a national marketplace for ecosystem services. ESMC's role is in protocol development and approval with third-party certification bodies, credit quantification, monitoring and reporting, and working with third-party partners who verify and certify any credits sold in ESMC's program using ESMC's protocols. Some projects with buyers identify producers to work with; some identify regions and production systems for which buyers need quantified impacts/credits. Sellers (i.e., farmers and ranchers) are able to stack credits, earning revenue from the provision of multiple ecosystem services. Buyers have the opportunity to purchase carbon, water quality, and water quantity credits, and in some regions and systems, biodiversity credits. The vast majority (80% to 90%) of current member demand from buyers is tied to corporate social responsibility pledges for scope 3 (supply chain) emissions, while other buyers will include those purchasing carbon offsets from the voluntary market. For corporate social responsibility, businesses have to take action within their own supply chain and in supply chains they are sourcing from. Members often bring their agricultural suppliers to ESMC because they need to quantify and report on supplier outcomes. Unlike other markets, in this model, the entire supply chain participates; hence, some of their members are agricultural producers (suppliers) and some are buyers.

Sellers will be able to participate from any location in the U.S. Protocols are organized regionally (12 geographic regions based on USDA Land Resource Regions, overlaid with agricultural production zones). When farmers or ranchers enroll, ESMC staff and third-party trained enrollment specialists provide information about practices and management system changes that can lead to increased soil carbon sequestration, reduced greenhouse gas emissions, improved water quality and water quantity, and where appropriate, increased biodiversity outcomes in their region, but it is up to the farmers or ranchers to decide which practices to implement.

The most popular cropping system practices in many regions are cover crops and reduced- or no-till, but these practices have variable impacts in different geographies, so ESMC is committed to exposing producers to different practices and systems. For instance, agroforestry is a resilient system, but is difficult to convince farmers to adopt. ESMC is having discussions about how to incorporate this system into its program from a protocol perspective. With respect to livestock, the biggest focus currently is on Adaptive Multi-Paddock grazing, but the use of cover cropping systems in grazing systems is also promoted.

A representative of ESMC explained that some buyers request certain practices be implemented. Asked how buyers decide which practices they want, the ESMC representative responded that they may have read literature about practices and their effectiveness. Sellers are required to show

additionality; in this instance, to show that what was done was additional to baseline and business-as-usual. Soil carbon testing will occur every five years (or ten years if the standards determine ten years is adequate). Soil carbon and all greenhouse gases will be modeled on an annual basis using the DNDC model. Carbon offset credits will be registered with the Gold Standard, or if other approved protocols are utilized, with the governing registry that approved the protocol. The APEX model is used to quantify water quality and in some cases water quantity.[331] The ESMC representative explained the COMET tools developed by USDA are not being employed as they were not developed for market-based approaches and have a high level of uncertainty, even though some are advocating for them to be used in the market.

The marketplace launched as a pilot in 2019 in the Southwest and in the Midwest in 2020. The national marketplace is on track to launch in 2022. The interviewee explained how the pilots work. Members of ESMC drive demand for credits. Members tell ESMC staff which assets they want from where. Some members have expressed interest in stacking carbon and water quality credits. Other members are not interested in stacking and only want carbon credits, so the demand varies.

ESMC has more than 80 members from across the agricultural supply chain and value chain, including General Mills, Danone, Cargill, Nestle, Arizona State University, Cornell University, TNC, World Wildlife Fund, and the National Corn Growers Association, among others. The interviewee advised that ESMC is working closely with members to determine the price for the credits, noting that water quality assets are priced at a very local level and that water quantity markets are only traded currently in western states. ESMC commissioned a study of fees and payments in existing markets where they currently operate. Through its research arm, ESMC is tracking how much they can lower fees over time, based on investments they have made in new technologies to measure, report, and verify assets. ESMC is also studying practices, including adaptive multi-paddock grazing. ESMC's research arm has more than $20 million in funding, the bulk of which is from the Foundation for Food and Agriculture Research (FFAR), and some of which has been provided by the USDA. Some funding comes from members who are also investors. There are two membership levels. Founding Circle (corporate) is $75,000 for two-year rotating members. Membership for non-governmental organizations is based on annual income and ranges from $5,000 to $10,000. Members have access to certain benefits in the future, which includes first right of refusal on credits or potentially a discount on credits, though the benefits have not been finalized. Non-ESMC members may also participate as buyers, such as local municipal or regional water quality authorities that may want to purchase Scope 1 water quality assets.

C. Agricultural Land Voluntary Practice-Based Incentive Programs

Several programs apply conservation practices to specifically achieve climate benefits among other soil health and ecosystem benefits. These include state incentive programs such as the California Healthy Soils Program, the Maryland Healthy Soils Program, the New York Climate Resilient Farming Program, as well as healthy soils programs of non-profits such as the Restore California Perennial Farming Initiative and Ducks Unlimited's Cover Crop and Livestock Integration Project.

California Healthy Soils Program

The California Department of Food and Agriculture (CDFA) implements the California Healthy Soils Program (HSP). The HSP has two components: the HSP Incentives program which provides financial incentives to ranchers and growers to implement conservation management practices that sequester carbon, reduce atmospheric greenhouse gases, and improve soil health, and HSP Demonstration Projects which "showcase" implementation of healthy soil program farming and ranching practices. More than 27 practices are eligible for the HSP.[332] As of July 2021, estimates provided by CDFA find the HSP Incentives Program has been achieving approximately 100,000 MT CO_2e greenhouse gas reductions annually while the Demonstration Projects have achieved approximately 4,000 MT CO_2e greenhouse gas reductions annually.

The HSP is funded through a portion of the proceeds of California's Cap-and-Trade Program (California Climate Investments or CCI). In 2018, HSP also received funding from the California Drought, Water, Parks, Climate, Coastal Protection and Outdoor Access for All Act of 2018, and Program funding has increased from $7 million (during the first two funding cycles) to nearly $30 million (third funding cycle). Data provided by colleagues at CDFA indicate an average cost of $593 per acre for incentive program projects, with costs for demonstration projects being higher at approximately $3,500 per acre. Funding priorities include projects benefiting farmers or ranchers who identify as belonging to a socially disadvantaged group pursuant to the Farmer Equity Act of 2017 and to projects benefiting "priority populations" (pursuant to California law, these include projects located within and benefiting individuals living in low-income communities and households and projects within and benefiting individuals in disadvantaged communities, which are areas within California disproportionately burdened by and vulnerable to multiple sources of pollution). [333] [334] [335] [336] [337] [338] Despite the increase in funding, an interviewee with CARB shared that "For us to meet our carbon neutrality goals, we need much more of this than what we can afford to incentivize. We are thinking of other programs and ways to meet the state emissions goals."

Program outcomes are quantified using the COMET-Planner Tool that was developed through a partnership between Colorado State University and the USDA NRCS and customized for California. COMET-Planner provides estimates of potential carbon sequestration and greenhouse gas reductions from adopting USDA NRCS working lands conservation practices. CDFA worked with Colorado State University and NRCS to modify COMET-Planner to better represent what is happening on the ground in California where growers produce over 400 types of crops. The COMET-Planner reports the average regional greenhouse gas and carbon sequestration benefits of NRCS conservation practices, as modeled in the COMET-Farm tool. As per interviews with representatives of CDFA, USDA NRCS, and Colorado State University, COMET-Farm was modified to include incorporation of additional crops (e.g., wine grapes, olives, almonds, carrots, lettuce, broccoli); because of the improvements to COMET-Farm, the California COMET-Planner Tool now represents 90% of California cropland acres. The tool also is integrated with the potential payments that users might be eligible for under the HSP.

The HSP includes two practices not in the national version of COMET-Planner: compost application and whole orchard recycling. According to a CDFA representative, NRCS does not currently have compost application as an NRCS practice. CDFA worked with subject matter experts to develop compost application rates for croplands and orchards that would be

incentivized under the program. CDFA first considered appropriate application rates that would not impact groundwater quality and then determined what level of payment would incentivize farmers to participate in the program. With respect to whole orchard recycling, a representative from CDFA explained that although NRCS has practices that include chipping of trees, they do not necessarily include the incorporation of the chips back into the soil. The CDFA HSP version of COMET-Planner was modified to include these two CDFA practices.

Practices associated with the HSP Incentives Program include cover crops, no-till, reduced till, mulching, compost application, and conservation plantings, among others. Some practices are "one and done," such as planting a hedgerow, whereby a farmer is paid once for implementing the practice. For other practices, like cover crops, farmers commit to a three-year term. Farmers are paid when they successfully implement a practice which is verified by CDFA. For three-year practices, farmers are paid each year. For one-time practices they are paid whenever the practice is verified, which can be any time during the three-year grant agreement. Payments for most practices are based on the USDA NRCS Environmental Quality Incentive Program (EQIP) rates for California. USDA NRCS expects a cost-share from farmers; to allow coverage for total practice cost, CDFA HSP payment rates are double that of NRCS EQIP rates. There is no match or cost-share requirement for farmers in the HSP, but farmers can combine or match with funds from USDA NRCS EQIP. The maximum grant amount has varied in the different funding rounds; in 2020, the maximum award was $100,000 with an approximate average of $67,000. Applications are competitively scored based on the amount of greenhouse gas emissions and water savings, among other criteria. The program is oversubscribed. Most participants are medium-sized farmers, but there is a sizable contingent of small and organic farmers.

Farmers do take soil samples for soil organic matter testing prior to project implementation and one and two years following the implementation. Verification is conducted by HSP staff, who have improvised during the COVID pandemic by receiving geotag photos with metadata to verify that a practice has been implemented.

The HSP does not track whether reversals are happening (i.e., once the program ends, if a farmer stops the practice), so they do not calculate outcomes beyond a three-year period. An interviewee from USDA NRCS noted that the HSP encourages behavior changes and that conservation legacy effects vary with different conservation practice implementation. For example, the risk for reversal with a windbreak establishment is extremely low, while cover crop reversal risk can be higher. However, CDFA and CARB representatives explained that the program is designed to be flexible enough to incentivize farmers to try these practices for three years with the expectation that they will continue the practice, as well as encourage other farmers to adopt these practices. A CDFA representative noted that it is too soon to know about the retention rates, but the programs are beginning to have some post-project reporting.

For HSP incentive payments, a previously implemented practice cannot be implemented on the same field, but farmers can implement that practice on a new field or a different practice on that same field. The staff have also had to be flexible in terms of allowing for delays due to California wildfires or drought; however, if a farmer does not implement a practice, the farmer does not get paid.

Since the program is voluntary and short-term, some have questioned whether participating in it precludes farmers from participating in carbon markets (given that markets require permanence and robust verification). In other cases, farmers have complained about not being eligible to participate if they have implemented these practices on their fields prior to the program.

The HSP Demonstration Program supports three-year projects intended to collect data and/or showcase conservation management practices that mitigate GHG emissions and increase soil health, creating a platform for promoting widespread adoption of conservation management practices in California. A CDFA respondent explained that these projects recognize that not every farmer is ready to implement a practice, and therefore this is a form of peer-to-peer education where farmers can observe how someone else is doing. Outreach requirements include a minimum of one annual field day per year, including a minimum of 40 farmers/ranchers per year for a total of 120 different individuals.[339]

The projects are conducted by university Cooperative Extension programs, federal and state experiment stations, Resource Conservation Districts, Native American Tribes, and farmers and ranchers in partnership with these organizations. Projects include implementation of the practices eligible under the incentives program, as well as "Type A projects" (additional practices for which a greenhouse gas quantification methodology is not currently available and thus, field measurements and scientific data are required to fulfill requirements for demonstration of sequestration potential; addressing knowledge gaps regarding impacts and co-benefits; and developing a standard protocol for practices identified by CDFA). Applicants are encouraged to publish in peer-reviewed and open-access scientific literature.[340]

Soil carbon measurements are required prior to initial implementation of a practice, and at one, two, and three years after implementation. Greenhouse gas emissions measurements are required for projects that will include Additional Practices for Demonstration and Data collection.[341] Project verification is similar to that in the Incentives program (i.e., CDFA staff make field visits).

CARB's method for estimating GHG emissions reductions in concert with the COMET-Planner tool are to be used for quantifying GHG emissions from demonstration projects.[342] [343] [344] For Type A projects where there are not yet greenhouse gas quantification methods, grantees report annual greenhouse gas emissions based on on-farm measurements.[345]

Challenges in the California Healthy Soils Program

In discussing challenges to the overall HSP, a representative from CDFA noted that the CDFA periodically issues solicitations for additional practices to be considered for addressing greenhouse gas emissions within the agriculture sector. Although interesting suggestions have been proposed, there is an existing gap between proposed practices and the ability to quantify greenhouse gas emissions and achieve carbon sequestration. Although the HSP Demonstration Program can provide funding to projects to collect greenhouse gas data from such projects, in the long-term, this remains a gap in the field.

Although HSP Incentives Program projects are required to collect soil samples and report data to CDFA before and after practice implementation, the three-year nature of the program is not

necessarily enough time to see changes in the soil, and therefore this metric alone should not be used to measure program success.

Although CDFA provides technical guidance on soil sampling and recommended labs, there may be a large variation in the technical expertise of farmers/ranchers or the technical service providers they may have access to, thus increasing the variability of the data CDFA receives from the farmers and ranchers.

Pursuant to 2018 legislation, a technical assistance grant program was created to aid farmers and ranchers applying to a "climate smart agriculture program" such as the HSP as well as alternative manure management programs and water efficiency and enhancement programs; this new program prioritized funding for organizations directly working with socially disadvantaged farmers and ranchers. [346] [347] This program also offers funding for organizations to help farmers implement their "climate smart agriculture" project. [348] Eligible organizations include Resource Conservation Districts, Cooperative Extension, and nonprofits with demonstrated technical expertise in designing and implementing agricultural management practices to support CDFA's climate smart agriculture incentive programs.[349]

In partnership with California's Strategic Growth Council, in 2020 CDFA launched its Healthy Soils RePlan mapping tool that has automated several aspects of the HSP application process. [350]As per the CDFA representative, this tool has made application to the program much improved for farmers, who no longer have to draw maps. The tool includes a disadvantaged communities data layer as well as a compost eligibility layer, for which the interviewee noted that the soil organic matter cannot exceed 20% in order to be eligible for the compost application practice under the HSP.

Potential for Public Private Partnerships

The Environmental Farming Act Science Advisory Panel, which advises the HSP, received several proposals to expand the HSP with the support of partners in the private sector. Stakeholder workshops were conducted by CDFA and CARB in 2020 on the development of a framework for public-private partnerships. Proposals involved creating a clearinghouse site for producers hosted by the state that links to private partner organizations and a letter of support from the State for such programs. A representative of the CDFA expressed that the CDFA wants to support as many partners as possible, but in a uniform way and to ensure partner practices fit within state and federal regulations and are meeting certain requirements. With respect to the clearinghouse, there has not yet been a critical mass of interested partners to ensure it would be robust enough to be useful to producers.

The Advisory Panel received some proposals from private sector actors that are working more on the market side, but they aren't doing much with them at this time. Because there is no universal standard for market-based practices or an accepted model for market programs, it is difficult for the department to say, "here are the minimum guidelines your program should meet". Large private companies with their own supply chain have asked if they can directly fund HSP. These companies want to change or improve practices in their supply chain and do not want to develop their own infrastructure if they can leverage an existing program, such as HSP. CDFA must ensure there are no statutory limitations, to receive private sector funds into the HSP.

Ecosystem Services Database

California is also in the process of building out its Ecosystem Services Database, which is designed to communicate to a wide audience the social and environmental benefit generated by farmers and ranchers in California. A CDFA representative estimates that maybe 20% of the farmers in California have submitted information to the database; the information is not verified by CDFA. CDFA plans to populate the database with demonstration projects and incentives practices which have been verified. The database is meant to be partly educational, showing the farm community examples of successful practice implementation and perhaps motivating other growers to conduct these practices. It may also get them to think more broadly about their work, such as the benefits that it can have for insects and wildlife. It is also a marketing tool, giving farmers the chance to promote their projects and the ways they are helping the environment.

Restore California Zero Foodprint Program

A consumer-driven complement to HSP is the Restore California Program. Launched in 2020 and managed by non-profit Zero Foodprint (ZFP), the initiative provides micro grants to farmers to sequester carbon relying on the conservation practices of the California HSP and COMET-Planner as its carbon modeling tool.

Funding for the program comes through a table-to-farm model. Members initially included restaurants that would add a voluntary 1% charge to customers' dining receipts, and these funds would go into a healthy soil carbon fund, managed by a social impact bank. The COVID pandemic required a modification to the model offering membership to packaged foods and beverages suppliers, produce distributors, composters, and other related businesses. An additional funding model is available for members who offset their direct emissions (Scopes 1 and 2) with gold standard carbon offsets; they can address their ingredient-related emissions (Scope 3) through the ZFP Restore fund for healthy soils.

A representative of ZFP explained the motivation for members to participate in the program. It gives them the "ability to tell an optimistic story about taking climate action." Restaurants and diners have "farm-to-table fatigue." With farm to table, one does not know if a restaurant purchases 1% or 100% of the food they are serving from a particular farm and if those choices even lead to any change. The Restore program offers a way to take direct action, by sending money from consumers to farmers and having it be contractually linked to implementation of carbon sequestration practices.

The program is structured as a reverse auction. Farmers who apply to the program "name their own price." They say which practices they plan to implement and how much it will cost. Restore structured the program this way because they are not familiar with the cost of practices, and they felt they would either be over- or under-paying the farmers in trying to establish payment rates. Farmers also list any co-benefits of the practices. Applications are reviewed for the outcomes they expect to achieve and the cost. Projects that will achieve the most total carbon sequestration per dollar - those that have the best "Climate ROI" - are ranked higher. As of August 2021, the program has awarded $560,000 to 31 carbon farming projects expected to sequester 18,000 tons of carbon. Applicants are capped at $25,000 per project. Grant recipients receive half the award up-front and the other half upon completion of the project. The program has expanded to

Colorado in collaboration with Boulder County and City of Denver and is in the process of expanding to other U.S. locations, including Georgia and the Northeast. The interviewee shared that ZFP is eager to collaborate with university dining. With this type of partnership, emissions associated with university dining could be assessed, and a voluntary surcharge could be applied to a local carbon farming project. Opt-in rates would be expected to increase over time with greater awareness. The ZFP representative noted that carbon farming presents both a research opportunity and would provide carbon reduction/insets at no cost to the participating university.

Maryland Healthy Soils Program

In 2017, Maryland Governor Hogan signed legislation (House Bill 1063) charging the Maryland Department of Agriculture (MDA) with developing a Maryland Healthy Soils Program, the purpose of which is to: improve health, yield, and profitability of soils; increase biological activity and carbon sequestration in Maryland soils by promoting practices based on emerging soil science; and promote more widespread use of healthy soils practices among farmers in Maryland.[351] To carry out the program, MDA should provide incentives, including research, education, technical assistance, and - subject to available funding - financial assistance to farmers to implement such farm practices and determine whether the program may be implemented in a manner to enhance other Maryland and federal programs that provide financial assistance to farmers.[352]

According to a representative from the MDA, the program is broadly about soil health and therefore is not focused exclusively on carbon sequestration. MDA is evaluating existing programs to maximize co-benefits of practice adoption for water quality, soil health, and climate change. For example, this representative explained that MDA has a longstanding cover crop program (which also complemented the USDA NRCS EQIP program) that was explicitly tied to nutrient reduction for water quality purposes and supported through the previously mentioned Bay Restoration Fund as well as through the Atlantic Coastal and Bays Trust Fund. MDA has expanded incentives within the cover crop program to achieve greater co-benefits. In addition, to meet the intent of the legislation, MDA developed two multi-year projects (one funded through the National Fish and Wildlife Foundation and the other through USDA) to explore additional soil health practices, including: multi-species cover crops, conservation tillage, variable rate technology for applying nutrients, composting, forest and biomass plantings, nutrient management, prescribed grazing and other practices that support soil health on approximately 7,200 acres across the state.

As part of these pilot projects, MDA is conducting physical assessments of soil structure (e.g., earthworm activity, water infiltration rates) soil chemistry, and samples of soil respiration and active carbon. The farmers are implementing practices on at least one field while leaving a control field that is sampled as well. Other aspects of this initiative include peer-to-peer farmer education workshops and demonstration projects. MDA is working on these projects with research partners at University of Maryland and USDA NRCS, with the work informed through a Soil Health Advisory Committee.

Further, MDA is developing a carbon assessment and credit calculation component to the previously mentioned Maryland Water Quality Trading program that could allow farmers to stack carbon and enhanced nutrient credits. MDA representatives explained there is an

opportunity to quantify carbon sequestration and avoid greenhouse gas emissions in addition to water quality benefits. As such, MDA is exploring incorporation of coefficients for emissions reductions and carbon sequestration from soil health practices by integrating information from the COMET-Planner tool into the Nutrient Tracking Tool for evaluating a farm with respect to not only nitrogen and phosphorus benefits, but also for carbon emissions reduction and sequestration benefits.

Concurrently, the MDA has been evaluating projected avoided emissions and carbon sequestered from conservation practices installed statewide, as well as anticipated greenhouse gas reductions through 2030 in the state's "2030 Greenhouse Gas Reduction Action Plan (GGRA)." The GGRA includes a menu of recommended USDA NRCS conservation practices for cropland management, land use changes to add herbaceous or woody plants, and grazing with estimates of potential greenhouse gas emissions reductions per-acre per-year based on the COMET-Planner tool. This "menu" is an initial reference for the Soil Health Advisory Committee in development of the Maryland Healthy Soils Program. A challenge cited in the GGRA is securing permanent program funding.[353]

Finally, although not specific to the Healthy Soils Program in Maryland, when asked about challenges identified by other state program interviewees to adopting soil health practices or practices to improve water quality, interviewees referenced barriers in the cost of equipment. To address this barrier, Maryland has two programs that help offset agricultural equipment costs: the Low Interest Loans for Agricultural Conservation (LILAC) and the Maryland Income Tax Subtraction Modification for Conservation Equipment. Guaranteed by the Maryland Water Quality Revolving Loan Fund, LILAC loans are typically offered at 3 to 4% below market rates, and in addition to funding Best Management Practices on farms, farmers can purchase conservation equipment, adopt new technologies, and cover start-up costs for major projects that are not usually covered.[354] In the second program mentioned, farmers can subtract from their Maryland income tax return up to 100% of the costs associated with buying and installing certain types of conservation equipment (to control soil erosion and protect water quality) including conservation tillage equipment (such as no-till planters); liquid manure injection equipment; poultry or livestock manure-spreading equipment, GPS devices, and integrated optical sensing and nutrient application systems (vertical tillage equipment can be subtracted at 50% of its cost).[355]

New York Climate Resilient Farming Program

The New York State Department of Agriculture and Markets and the New York State Soil and Water Conservation Committee (NYSSWCC) oversee a competitive grant program, the New York Climate Resilient Farming Program, which cost-shares implementation of Best Management Practices (BMPs) that sequester carbon, reduce greenhouse gas emissions, and improve on-farm climate adaptation and resiliency. Practices are done to USDA NRCS standards. It is a reimbursement program, so farmers are paid after the practice is implemented (typically a three- to four-year timeline). A representative of the Department of Agriculture and Markets said that what is unique about their program is that they have established a per-acre reimbursement rate based on an average of three years of USDA NRCS EQIP rates plus an additional percentage to help incentivize these practices. As long as the practice standard is followed, farmers will be paid the reimbursement rate. This makes the program easier to

implement, but it also saves the farmers time because they do not have to itemize all of their expenses. The representative further explained that this approach also provides farmers with more certainty about the costs and benefits of participating in the program. The cost share is 75% (program)/25% (farmer) for most practices (some costs are covered 100% by the program, including signs for cover crops, because the Department views these as a great farmer-to-farmer marketing tool). Farmers can use federal funding (e.g., EQIP) to cover their match; in some cases, equipment costs that directly relate to the BMP may be eligible for a match, or the farmer can provide in-kind services. Farmers are also eligible to reapply to the program; some practices such as cover crops do require a new mix of seed or different field to be used when reapplying.

Funding is allocated in three tracks. Track 1 is Agricultural Waste Storage Cover and Flare systems which include waste storage and transfer, manure and agricultural waste treatment, and nutrient management. Track 2 is Water Management Systems which include irrigation water management systems, stream corridor and shoreline management systems, riparian buffer systems (e.g., riparian forest buffer and tree/shrub establishment and preparation), prescribed rotational grazing and access control systems, and green infrastructure practice components from the New York State Stormwater Design Manual. Track 3 is the Healthy Soils NY track which includes soil conservation systems (e.g., forage and biomass planting, conservation cover crop rotation, conservation cover, residue and tillage management, mulching, strip cropping, etc.), prescribed rotational grazing systems, and riparian buffer systems. Eligible expenses include the BMP system implementation costs; architectural and/or engineering services; consultant and legal services; other direct expenses (e.g., funds for cultural resource impact determinations for ground disturbing BMPs); equipment directly related to the BMP; outreach and technical assistance costs for soil health training; cover crop signs; and soil health testing. The NYSSWCC approves a funding amount for the three program tracks. The Department of Agriculture and Markets relies heavily on Soil and Water Conservation Districts, who carry out the program on a local level. Staff at the districts are instrumental in farmer recruitment, they provide technical assistance to farmers to plan and apply for cost-share assistance, with cost estimates, and with practice implementation. To determine who receives program funding, applicants are independently reviewed and ranked, and the ranked list is approved by the New York State Soil and Water Conservation Committee. Ranking is based on a scoring method that considers two distinct but complementary goals: mitigation and adaptation/resiliency. Farmers who are trying to accomplish both goals will rank higher. If there is a broader societal benefit to what they are doing, such as an economic benefit, they will rank higher. Funding is awarded until exhausted. Funding comes from the New York State Environmental Protection Fund. Within the fund, there is an appropriation for the Climate Resilient Farming Program (about $4 million annually). The fund is financed to a large part through a dedicated portion of real estate transfer taxes.

The Department quantifies greenhouse gas emissions reductions achieved under the program using COMET-Planner. They are having conversations with the Colorado State University developers of COMET-Planner about the potential to modify the tool to incorporate more New York-specific coefficients. A Department representative explained the challenge, “Farming is a living, breathing system, and it is often hard to get a handle on what we are trying to accomplish out there. We are really trying to work on a better protocol to estimate or measure our impact with more soil health testing.”

A representative from New York State also explained that farmers in New York have been very receptive to the program and that demand has exceeded funding. These programs are strictly voluntary, incentive-based contracts with the Soil and Water Conservation Districts; however, the New York representatives noted they do not currently have a handle on how long farmers will implement these practices into the future.

Ducks Unlimited Cover Crop and Livestock Integration Program

Ducks Unlimited also manages a soil health program, the Cover Crop and Livestock Integration Project, in addition to its carbon offset program. This program offers opportunities to develop associated wildlife benefits and provides financial assistance to interested farmers to improve soil health and enable economic benefits by increasing nutrient and water availability to plants and reducing fertilizer loss. Native prairie habitat is important for sustaining migratory bird populations. The DU interviewee noted that conventional row crop agriculture was coming into previously glaciated landscapes dominated by native prairie and converting it to farmland more than a century ago, with more recent increases in corn and soy in the late 1990s and again in the mid-2000s. These conversion practices emit carbon and have negative impacts on waterfowl habitat. In the mid-2000s, DU biologists began running biogeochemical models of carbon stocks, and the organization now has expertise in carbon and nutrient cycles. During the last five years, they have developed a robust soil health program in the Dakotas. While focused on soil health, carbon sequestration can be a co-benefit. The program is funded through philanthropic sources and public grants, including a recent Regional Conservation Partnership Program grant from USDA.

Through the program, DU supports farmers who are interested in transitioning from a conventional farming system. Farmers agree to a five-year term and commit to not draining their embedded wetlands or to not cultivate grasslands, to adopt soil health practices (no-till, cover crops, livestock integration), and to allow DU to do on-farm soil monitoring or data collection. In return, DU cost-shares practice implementation (seeds, grazing infrastructure, watering facilities), provides technical assistance, and pays for educational opportunities (free or reduced rate).

The educational piece is an important part of the program. DU formed a number of partnerships that enable the organization to send landowner families and ranch hands to attend educational events of their choosing, where they can learn about different practices and systems, how to implement them, and the benefits of doing so. An additional educational aspect has been research conducted on farms to better understand nest survival of waterfowl in cover crops associated with no-till farming practices. A representative of DU explained the reason for supporting educational opportunities, “Simply paying cost-share and saying, ‘landowners go do this and change generational behavior’… leads to low sustained adoption rates.” Because DU is focused on changing generational behavior, it is less interested in quantifying and selling environmental outcomes. The representative commented, “We have to make sure market mechanisms are not just gerbil wheels. As soon as you stop feeding it, the desired momentum stops. Is it better to pay for an outcome or to pay for changing behaviors that can come about with or without a carbon market?”

V. Considerations for New Jersey Agriculture

Discussions with several interviewees noted the overarching challenge that New Jersey's high land values place on agriculture in the state in which property owners are known to hold on to farmland for future development purposes while leasing their land to farmers until such time that they may decide to sell. Approximately 54% of the farmland acreage in New Jersey is leased, while 67% of New Jersey farmers are "part-time farmers" i.e., farming is not their primary occupation.[356] In such cases, the land may be less viable as a candidate for carbon sequestration because these farmers are less likely to invest in new practices, programs, or equipment that could increase the potential for carbon sequestration, given that development may be more lucrative to such a landowner than farming. In addition, the long-term viability of carbon sequestration on such parcels is at greater risk from disturbance due to future development, than compared to a farm that is not leased or in farmland preservation.

Despite this overarching challenge, a scan of the landscape of payment for ecosystem services models has been informative in characterizing opportunities for terrestrial agriculture and carbon mitigation. Our review has identified examples of the various programs related to regulatory compliance, non-regulatory incentive-based programs, as well as emerging marketplaces and partnerships among the private sector, nongovernmental organizations, and the public sector to align sustainability goals with conservation goals that can further sequestration of carbon in the agriculture sector. The sections below identify barriers, gaps, uncertainties, and research needs, and highlight opportunities for enhancing carbon mitigation through ecosystem service valuation in New Jersey agriculture identified by the authors as well as interviewees.

A. Carbon Sequestration Potential/Quantification Considerations

There are several key unknowns with respect to the duration of carbon accumulation and persistence in soil caused by agronomic practice changes, and quantification of carbon stored at a particular site beyond a baseline. Increased monitoring, reporting, and verification (MRV) of soil carbon necessary for creating marketable credits can be costly as well as challenging, particularly for landscapes that are heterogenous. MRV of greenhouse gas emissions reductions also presents challenges, as these values are fundamentally about avoided emissions from something that did not occur; i.e., if a producer changes a practice that avoids or reduces the use of fertilizer on soil, the ecosystem service value would be quantified for the greenhouse gas emissions that did not occur. An overarching issue in payment for these ecosystem services revolves around whether programs are outcome-based (and therefore rely on quantification of greenhouse gas emissions reductions achieved) or practice-based programs (which pay for implementation of practices to sequester carbon or reduce emissions). As previously mentioned, interviewees observed that carbon market emissions measurements are better suited for point sources than measurements on natural and working lands.

Work to quantify soil carbon is ongoing in New Jersey. Data exist from the USDA NRCS that characterizes the soil carbon storage down to a maximum depth of 2 meters for New Jersey agricultural lands.[357] Soil carbon data for forest lands are available from the US Forest Service and are incorporated into the NJForest Adapt tool.[358] USDA NRCS - NJ has been conducting a spatial analysis of cropland soils, including pastureland, to identify where carbon may be

depleted due to past agricultural or other land use practices and has recently released its AgLand Priority for Carbon Sequestration web application.[359] The ultimate goal is to develop a map of soil carbon sequestration potential to complement existing information for forest land. Another goal is to identify areas where soil health initiatives and climate smart conservation practices[360] could increase carbon stocks. In addition, university scientists are conducting research to characterize soil carbon stocks and sequestration rates on New Jersey farmland, grasslands, and forest lands.[361] [362]

There are different models that are used to quantify soil carbon. One interviewee suggested that the DNDC model, as opposed to the COMET tools, is more accurate regarding the rates of sequestration, noting it is better able to incorporate measurements made at greater depths in the soils. This interviewee asserted that the COMET tools would undercount rates of sequestration they are observing at their research sites. Recognizing unknowns related to carbon sequestration quantification and monitoring, USDA in 2021 launched a multi-year monitoring and assessment effort to quantify the benefits of its Conservation Reserve Program (CRP) as well as improve USDA's existing models and conservation planning tools. USDA noted that the primary goals of this effort are to calibrate, validate, and further improve the quantification methodologies within the DayCent model and the COMET tools utilized by USDA; this will allow USDA to better target the CRP program toward climate outcomes by estimating the climate benefits of CRP practices relative to cropping systems with and without working lands conservation practices in similar landscapes and soil types.[363]

Understanding the complex processes within the soil component of the carbon cycle is essential for accurate modeling and for generating recommendations to improve carbon sequestration underground. Carbon contributions of plant roots by turnover and exudation vary by species, stresses, nutrition etc.[364] [365], and the biogeochemical processes that are stimulated in the rhizosphere (the zone immediately surrounding the roots) will provide feedback loops[366] [367] to evolve a characteristic microbiome and associated food web community.[368] Study of the structure and management of the underground ecology continues to emerge as a field that will contribute useful information to apply to models of the carbon cycle as well as better characterization of soil health.

Key opportunities going forward include:

- Establish an authoritative baseline of carbon stocks, identify and further assess priority areas for increasing soil carbon, and conduct scenario analyses of potential carbon gain pathways on agricultural lands in New Jersey building upon research underway and working through continued collaboration between USDA NRCS-NJ and academic research partners.

- Determine the most appropriate conservation practices based on the specific soil, terrain, and agriculture type to assist the farming community in pursuing soil carbon gain pathways.

- Customize programs and practices with consideration of the unique character and features of agriculture in New Jersey: dominance and variety of specialty crops, as

opposed to large-scale commodity crops; small acreage of many farms; proportion of part-time farmers; high percentage of leased farmland; strong organic agriculture niche.

- Evaluate the relative efficacy and impacts of different tillage practices across various soil types to maximize carbon storage. This could be based on sampling at various soil depths and understanding the impacts of tillage frequency.

- Evaluate the effects of different grazing systems on forage production and quality, below-ground contributions of nutrients and carbon, SOC stock, and other associated greenhouse gas emissions associated with livestock production.

- Assess root contributions of C from various plant species, multi-species cover crop, and crop rotations to rhizosphere dynamics and related effects on the soil microbiome, soil food web, and ultimately soil carbon stocks; analyze effects of root structure and exudates on soil structure and water retention and drainage.

- Analyses regarding current and projected climate change impacts on factors that influence soil carbon sequestration processes in New Jersey such as temperature, water availability, water runoff and erosion, and soil health, coupled with an assessment of how New Jersey agriculture can prepare for these impacts while minimizing greenhouse gas emissions.

- Assess conditions under which soil amendments such as biochar and compost improve soil conditions such that plant carbon uptake is increased; comparison of amendment characteristics (including C footprint) and their effects on soil and SOC stock for development of appropriate protocols and application rates of soil amendments for New Jersey soils.

- Establish sentinel sites across the country and perhaps by county in partnership with land grant universities was suggested by one interviewee as a way to establish a database of values for carbon sequestration by agronomic practice and determination whether localized factors could be applied to models to reduce the expense of field sampling. For New Jersey, one approach could be to conduct a feasibility analysis and create a workplan to establish sentinel sites tailored to the most viable agricultural practices likely to result in the highest opportunity for carbon sequestration.

- Explore potential collaboration with USDA and Colorado State University to tailor the COMET-Planner Tool for New Jersey that would provide localized estimates of potential carbon sequestration and greenhouse gas reductions from USDA NRCS conservation practices.

- Facilitate information and data sharing among New Jersey-based scientists and practitioners conducting carbon sequestration research on New Jersey agricultural land to enhance practice implementation in New Jersey.

B. Market-Based Regulatory Cap-and-Trade Program Considerations

Market-based regulatory compliance programs such as cap-and-trade to date have not offered an opportunity for production agriculture to receive payment for ecosystem services for the purpose of carbon sequestration. A possible exception would be for agricultural producers with woodlands that could qualify for ecosystem services payments for carbon storage benefits of forests on their property as compliance offsets in either the California or RGGI cap-and-trade programs. As noted, conservation organizations have developed forestry offset projects on their lands (including land in the Northeast) for compliance with the California Cap-and-Trade program; the offset revenue stream can be used to advance their conservation work. Although no forestry offset projects have been awarded offset credits under RGGI, sequestration of carbon due to reforestation, improved forest management, or avoided conversion of land located in New Jersey (or partly in New Jersey and partly in another participating RGGI state) may be eligible for generating carbon offsets acceptable for compliance within the RGGI region, provided they follow all appropriate protocols. As previously noted, in the short term, the incentive for development of an offset project for the RGGI market appears weak for various reasons, including the fact that allowance prices in California are historically higher than RGGI. Also of note is that the RGGI states of MA, NH, and RI no longer award offsets.

Therefore, with respect to regulatory compliance markets:

- Generation of carbon offsets acceptable for compliance in the California Cap-and-Trade Program - through reforestation, improved forest management, avoided conversion of forestland to a non-forest land use, or urban forestry projects - can be an opportunity for New Jersey landowners to sequester carbon through regulatory compliance markets.

- Generation of carbon offsets acceptable for compliance within the RGGI region - through reforestation, improved forest management, or avoided conversion of land located in New Jersey - is a potential (albeit considered unlikely) avenue for New Jersey landowners to sequester carbon through regulatory compliance markets.

C. Voluntary Market Opportunities

Voluntary markets to address greenhouse gas emissions are emerging for a variety of reasons: companies committing to reduce emissions for CSR purposes; organizations anticipating regulation; academic institutions, nonprofits and individual consumers seeking to offset their emissions; and as an ancillary benefit of other regulatory programs, for instance those that restrict development. As outlined in the previous chapter, there are various program models (e.g., Western Sustainability Exchange, Audubon Conservation Ranching, Ducks Unlimited Conservation Program, TNC's Family Forest Carbon Program, etc.) whereby nongovernmental organizations and private companies invest in landowners by providing technical and financial assistance to implement practices (on primarily forests and grasslands) that meet multiple goals of conservation, soil health, soil carbon sequestration, while providing financial benefits to the producers in terms of reduced operating costs and generation of carbon credits for sale on the voluntary market or for corporations to meet emissions reduction commitments.

Representatives from across the agricultural sector are participating in the design of marketplaces for carbon sequestration in agriculture as described by interviewees from BCarbon and ESMC.

Interviewees noted that producers are participating in development of the marketplace through sequestration pilot projects. Practices to be included in these marketplaces include soil management and crop production practices, grazing practices, agroforestry, and storage of carbon on grasslands.[369] In at least one market (ESMC), stacking of credits to include water quality assets is of interest to some buyers. Food, agriculture, and beverage companies looking to address Scope 3 "supply chain" emissions would be likely potential buyers of credits from agricultural producers or partners with agriculture to address emissions within their "supply shed."

Below are opportunities for addressing carbon in the context of the voluntary market that can be considered:

- Farmers and landowners can generate carbon offsets for the voluntary market through practices that help to sequester carbon; these include but are not limited to: improved agricultural management (reduced fertilizer use, improved water management, reduced tillage, improved crop planting and harvesting, improved grazing practices), avoided conversion of grasslands, avoided conversion of forest land, and compost addition to grazed grasslands. [370] [371] [372] [373]

- Partnerships between conservation organizations, or in some cases private-sector project developers, and property owners enable landowners to produce carbon offsets (e.g., forest carbon sequestration or grazing practices on grassland) for sale on voluntary markets whereby conservation organizations and/or offset developers provide technical, financial, and administrative assistance, while landowners can realize agricultural, conservation, and financial benefits.

- Farmers have opportunities for direct support for conservation practices (such as reduced tillage and precision nutrient management) from corporations seeking to meet CSR goals to address greenhouse gas emissions if they are within the "supply shed" (i.e., within the group of suppliers providing similar goods and services within the company's supply chain) of the entity seeking to reduce its supply chain emissions.

- Aggregation of smaller farmers within a supply shed may provide additional opportunities for agricultural producers to participate in the voluntary carbon market.

- Emerging voluntary marketplaces for ranchers and farmers are piloting ecosystem service credit generation with carbon sequestration as an explicit credit type.

- Consider an evaluation of both the level and duration of incentive that will result in producers changing practices long-term to provide stability in the market, allowing for the incentive to be removed once the practice is firmly established.

- Development restrictions (e.g., to minimize forest loss such as those provided for by Maryland's Forest Conservation Act) provide opportunities for land mitigation banks to conserve lands, generate credits for landowners, and provide multiple ecosystem services, including carbon storage.

D. Voluntary Practice-Based Opportunities

Implementation of practices that can improve soil health, farm resiliency, improve crop yield, and improve water quality can also help mitigate carbon emissions by avoiding or reducing emissions as well as enhancing opportunities for agriculture to act as a carbon sink. Federal, state, and nonprofit programs provide opportunities to leverage results for producers as incentives and motivation to wider adoption.

D.1 USDA Program Considerations

USDA programs, such as the previously mentioned Environmental Quality Incentives Program (EQIP), provide agricultural producers with financial and technical resources to implement conservation practices to improve resource concerns (e.g., soil health, plant productivity, water quality, air quality, and wildlife habitat, among others) while improving agricultural operations. USDA recently established a pilot program in 10 states (not including New Jersey) to support climate-smart agriculture and forestry through EQIP, identifying climate-smart conservation practices USDA considers critical for reducing greenhouse gas emissions and sequestering carbon.[374] [375] Interviews with USDA NRCS-New Jersey office program staff provided insights on the opportunities and challenges associated with NRCS practice-based incentive programs available to agricultural producers that can help to enhance soil carbon sequestration. As one interviewee noted, "EQIP is primarily a fix-it program where we might go out into a field and find a problem like compaction and prescribe a practice to fix it." As related to carbon and climate, there are resource concerns such as aggregate instability, soil organism habitat loss or degradation, organic matter, and compaction that are addressed in the program. In addition, the soil health practice of adding soil carbon amendment was added to the EQIP program in 2020. The interviewee from NRCS indicated that uptake for the EQIP program in New Jersey is relatively robust, but that numerous opportunities exist to expand practice adoption, especially as it relates to producers implementing a suite of soil health practices (versus single practice adoption).

Less well-known in New Jersey but widely utilized in other parts of the country, and with perhaps more potential for carbon sequestration than EQIP, the interviewee identified the Conservation Stewardship Program (CSP), which provides an annual land-use payment for conservation performance by undertaking additional conservation activities and improving, maintaining, and managing existing conservation activities. Most producers that are approved for this program have already been implementing conservation practices on their land, and CSP provides funds to enhance a practice (e.g., if already practicing prescribed grazing, CSP would pay for enhancements such as grazing management, to improve plant selection for wildlife, or to reduce soil compaction).[376] As the interviewee noted, once a producer realizes the initial conservation benefit of applying a conservation practice, they can then build on that and get a payment for maintaining, tweaking, and enhancing the practice for 5 years with the potential for renewal. Our interviewee noted that the CSP is very undersubscribed in New Jersey. One barrier to CSP is that unlike EQIP (which allows the producer to select which fields/properties they want to enroll in), for CSP a producer is expected to enroll all the land in their operation. There are rules, however, for how to opt out a tract of land. The interviewee noted that additional programs which could enhance carbon sequestration include the Regional Conservation

Partnership Program and the Conservation Innovation Grant Program. NRCS also supports the Healthy Forests Reserve Program which can enhance carbon sequestration.[377]

Other interviewees suggested that lowering the cost to implement BMPs such as cover crops would help broaden participation, for example, if they could rent their land for livestock grazing of cover crops, which is a practice NRCS does not currently subsidize. The NRCS interviewee pointed to a 2019 five-year Conservation Innovation Grant underway by North Jersey RC&D that is exploring different termination methods for cover crops, including livestock grazing; the result of the project will help NRCS inform decisions about practice eligibility.

Opportunities to expand NRCS incentive programs include:

- Develop a regional testing program where, for example, Cooperative Extension (as suggested by an NRCS interviewee) could test out various practices on New Jersey farmland and conduct more demonstrations and on-farm trials to help farmers understand which practices work.

- Develop a deeper understanding of agricultural producer uptake for incentive programs (including state-based and non-profit funded), including an evaluation of the payment level and duration of incentive necessary to make participation in agricultural practices that can enhance sequestration worthwhile in order to expand participation in current programs or in designing and implementing complementary programs.

In April 2021, USDA announced an expansion of the Conservation Reserve Program (CRP) which includes a Climate-Smart Practice Incentive that aims to increase carbon sequestration and reduce greenhouse gas emissions; subsidized practices include establishment of trees and permanent grasses, development of wildlife habitat, and wetland restoration. Unlike the aforementioned NRCS programs, CRP is run through the USDA Farm Services Agency.[378]

D.2 State Practice-Based Soil Health and Climate Resiliency

California and Maryland have enacted "soil health" programs which recognize the multiple benefits of practice-based programs including improving soil health, soil carbon sequestration, and greenhouse gas emissions reductions. In the case of New York's Climate Resilient Farming Program, there is also an explicit recognition that such practices are to improve on-farm climate adaptation. Climate resiliency is a benefit that interviewees mentioned as important, but not the purpose of most practices. When asked about agroforestry as an approach for sequestering carbon, one interviewee noted that it is one of the most resilient systems but the hardest to convince farmers to adopt.

Common to these programs is implementation of NRCS-based practices, while California has expanded upon NRCS practices with new (e.g., compost application) or modified (e.g., whole-orchard recycling) practices to enhance carbon sequestration.

Working with partners from throughout the New Jersey agricultural community, USDA NRCS-New Jersey is directing the development of a Soil Health Strategic Plan to help identify focal areas based on soil types and types of cropping practices that require more conservation to

increase overall soil health. As per colleagues at USDA NRCS-New Jersey, the plan will assess where and what conservation practices and programs need to be implemented across the landscape in New Jersey. This plan, anticipated in late spring/early summer 2022, will help inform priorities for NRCS as well as other agricultural partners regarding targeted outreach efforts and needed conservation initiatives.

Opportunities for a comprehensive program to address climate change, soils, and agriculture practices that would foster sequestration of carbon in agriculture include:

- Consider establishing a New Jersey Healthy Soils or Climate Smart/Resilient Farming program as a complement to, and potential expansion of, practices in current federal program offerings, including practices that allow whole farm climate benefits - to sequester carbon, mitigate greenhouse gas emissions, and enhance climate resiliency - in addition to soil health. Such a program can be informed by the anticipated and aforementioned Soil Health Strategic Plan for New Jersey and include an assessment of best practices to increase soil carbon sequestration and mitigate greenhouse gas emissions.

- Consider components of such a program that would include:
  - Flexibility to adapt to changing conditions (e.g., wildfires, pandemics) that could delay program completion;
  - User-friendly application processes and tools (e.g., California's Healthy Soils RePlan Tool noted previously, which automates mapping for applicants and identifies areas eligible for compost);
  - Resources that enable technical service providers to support and assist farmers in navigating applications, planning, and practice implementation.

D.3 Economic and Other Program Benefits

While the longer-term soil carbon benefits of implementing practices to sequester carbon are not realized immediately, the intention of incentive programs is for producers to understand and receive economic benefits of such practices so that they will continue to maintain or expand the practice and perhaps adopt other practices independent of incentive payments. Interviewees noted that there are many conservation practices that also benefit the farmer financially. One interviewee from a state agency that provides such incentives noted, "Cover crops, no-till farming, (and) precision nutrient application equipment are three good examples of practices that definitely pay off for the farmer in the long-run. Financial incentives help to clear the short-term cash-flow problems that can arise in transitioning/adopting these practices."

When asked about gaps in existing information/educational resources for landowners/farmers in New Jersey, an interviewee said what is needed is "Research to show that these [soil health] practices are economically beneficial, not just environmentally beneficial." Representatives of USDA at the federal level view the lack of information about economic benefits as one of the hurdles to addressing carbon sequestration in production agriculture. Farmers need to know what is in it for them, including potential financial returns, and the time horizon for achieving financial gains. The representatives "suspect that some of these practices do pencil out, but currently there is not much research on the financial returns to farmers. Ultimately financial

returns will vary based on regional factors such as soil type, climate, crop rotation, and current management practices." A representative of the New Jersey Department of Agriculture suggested touting cropping systems instead of certain crops. For example, an analysis could promote co-benefits of conservation tillage, such as the number of pounds of soil saved and the number of hours of labor reduced. According to the representative, the number one issue farmers always raise is labor; however, the expense of conversion to conservation tillage must also be considered, as equipment such as no-till drills can also be an impediment. A New Jersey Farmland Preservation Program representative noted, "incentive programs would do well to consider cost-sharing on conservation tillage equipment to elicit adopters."

With funds provided by the CDFA, the University of California Cooperative Extension is conducting research projects to implement and demonstrate on-farm soil health practices that reduce greenhouse gas emissions and store carbon; one project is examining the financial costs of implementing perennial hedgerows and the economic benefits to using sustainable practices in raising sheep along with the opportunity to enter into a niche fiber market where consumers are willing to pay a premium for wool to support the ecological benefits of Healthy Soil Projects.[379] USDA NRCS has developed a series of case studies on the economic benefits of applying soil health practices.[380]

As noted previously, interviewees cited the importance of quantifying the co-benefits from PES programs to build support for these programs. CARB's funding guidelines for CCI include maximizing economic, environmental, and public health co-benefits. Discussed prior is the Scenario Tool for Assessing the Health Benefits of Conserving, Restoring and Managing Natural and Working Lands in California under development by the UCLA Fielding School of Public Health, Department of Environmental Health.[381] To reiterate, the tool will be used to address health benefits of improved air quality from programs to reduce wildfire risk, or health benefits of increased green cover, tree canopy, and park space on urban populations in historically underserved areas or physical and mental health benefits from increased access to or use of rural natural and working lands.

Identifying and quantifying co-benefits can assist in helping to prioritize or rank projects for funding. For example, under New Jersey's Global Warming Solutions Fund Rules and the RGGI Strategic Funding Plan, providing co-benefits to New Jersey is one of the six objectives that must be advanced in selection of strategic funding plan initiatives.[382] [383] Co-benefits include creation of job opportunities, air pollution reductions, reduced electricity or natural gas costs, improvements in electric system reliability, and contributions to regional initiatives to reduce greenhouse gases.[384]

Opportunities to enumerate economic and other benefits of agricultural practices that sequester carbon include:

- Quantify and communicate economic benefits of BMPs that can sequester carbon, including but not limited to improved crop yields, machinery cost savings, reduced nutrient losses, reduced labor costs, increased income, etc.

- Develop a methodology for assessing co-benefits of ecosystem services, including public health, habitat, climate resiliency, and other endpoints, and quantify and communicate these co-benefits to the public, legislators, and other key constituencies.

D.4 Education, Training, Technical Assistance

Factors positively influencing farmer uptake of Best Management Practices include interpersonal contact between conservation agencies/local organizations and farmers; farmer-to-farmer communication; extension education; access to crop advisors, extension agents, and other trusted agents from soil and water conservation districts; adoption by neighbors; knowledge about the impact of BMPs on the environment; and financial incentives.[385] [386]

Demonstration projects involving peer-to-peer farmer education are employed in Maryland and California to show farmers successful practice implementation and motivate other growers to conduct these practices. Encouraging farmers to implement practices can also come from technical service providers; however, several interviewees noted that farm service providers in New Jersey have little knowledge of carbon sequestration. One interviewee said, "We have a number of organizations visiting farms all the time… I don't think a lot of people that are working with farmers are well-versed in carbon sequestration methods and practices. I feel there is a need for training." Talking about the role of cover crops in carbon sequestration, a New Jersey-based interviewee said, "There's a real deficit among service providers in helping guide farmers through this process."

Opportunities to foster program uptake and success include:

- Demonstration projects such as those funded through the California Healthy Soils program that take field measurements, showcase practices, conduct analysis on cost/benefits, demonstrate sequestration potential for other practices for which greenhouse gas quantification methods are not currently available, and require peer-to-peer outreach.

- Expand training of New Jersey-based technical service providers regarding carbon sequestration management practices and methods. Such a program could build off the Northeast Climate Adaptation Fellowship Program which is piloting training for technical service providers (including those in New Jersey) and producers on climate adaptation and mitigation.[387]

- Support technical service providers in assisting agricultural producers with implementing best management practices for carbon sequestration, healthy soils, and/or climate resilient farming techniques.

D.5 Financing Considerations

As noted previously, financial incentives are known to influence adoption of BMPs. There are a variety of programs available to support farmers in transitioning to BMPs; however, there does not appear to be a comprehensive database of such programs available to New Jersey farmers.

As previously noted, proceeds from the California Cap-and-Trade auction through the California Climate Investments initiative support programs such as the California Department of Food and Agriculture Healthy Soils Program and California Wildlife Board Climate Adaptation and Resiliency Program, as well as support for urban farms and for composting programs that will improve soil health and sequester carbon in the agriculture sector. California Cap-and-Trade revenue is also used to support ecosystem research, such as forest health research. New Jersey's RGGI investment does carve out funding for stewardship and restoration of forests and tidal marshes. As previously noted, there is not a carve-out for production agriculture; however, woodlands contiguous to, part of, or beneficial to a tract of land devoted to agricultural or horticultural use can qualify for farmland assessment in New Jersey and therefore could also provide enhanced opportunities for carbon sequestration. New York State's Climate Resilience Farming Program is supported through its Environmental Protection Fund financed in large part through a dedicated portion of real estate transfer taxes.

Both the California Healthy Soils Program and the New York Climate Resilience Farming Program allow participating farmers to combine USDA NRCS grant funds with their respective state program funds. In the case of California, there is no cost-share requirement and farmers can combine HSP funds with EQIP funds; in New York, federal EQIP funds can be used to meet the 25% farmer cost share requirement.

Conservation practices to reduce nutrient loading and meet TMDLs to improve water quality for the Chesapeake Bay (but for which carbon sequestration is a co-benefit) are financed through the Pennsylvania REAP Program (in the form of a tax credit) and the Maryland Clean Water Commerce Act (as noted previously, a carve-out of 35% for agriculture of an annual $20 million appropriation from 2021 to 2030 has been allocated, financed through the Maryland Bay Restoration Fund). In New Jersey, the Department of Environmental Protection has passed through federal Clean Water Act funds - as well as used other federal and State funds - to finance non-point source water quality restoration activities.[388] A project in the 2019 funding cycle includes BMP implementation on farms in Hunterdon, Sussex, and Warren Counties that leverages funds from USDA programs to address nutrient loading and water quality impacts.[389] Although these projects were not designed with carbon sequestration as a goal, some of the practices could have benefits for greenhouse gas emissions reduction (such as manure management) or for sequestration purposes (riparian buffer restoration).

A New Jersey based interviewee noted that County Agriculture Development Boards have "done a great job with farmland preservation...but it may be time for folks working for county ag boards to start thinking about stewardship of the land and how they can help farmers develop stewardship practices." This interviewee suggested that county boards have authority under the Agriculture Development and Retention Act (N.J.S.A. 4:1C-15). This interviewee also noted there might be other opportunities for financing or prioritizing projects to enhance carbon sequestration on farmland and forested areas through the State Agricultural Development Committee (SADC) Soil and Water Conservation Grants, as well as New Jersey's Blue Acres and Green Acres programs.

In addition to government financing of practice-based incentive programs, there are opportunities to engage nonprofits, consumers, and businesses. As previously noted, the Restore California

program through the Zero Foodprint (ZFP) non-profit is a direct opportunity for restaurants and their patrons, as well as food service businesses to fund practices accepted under the California Healthy Soils Program. Given the California HSP is oversubscribed, this program provides additional resources, as well as fosters consumer awareness through its table-to-farm financing model.

A New Jersey-based interviewee suggested the formation of a non-profit carbon mitigation bank supported by the public and/or Community-Supported Agriculture members who might, for example, offset their own travel emissions by donating funds to the bank that would then be used by their farmers to implement practices to sequester carbon.

Financing opportunities for practice implementation:

- Cap-and-trade programs offer opportunities for investment of proceeds in agricultural practices that foster carbon sequestration as well as in research to support climate action in ecosystems, as is being currently implemented in California. New Jersey could explore the suite of programs that the California Climate Investments offer to address natural and working lands, including agriculture, as opportunities for furthering climate mitigation, as well as resiliency.

- Explore opportunities for county boards of agriculture to advance stewardship and support programs that further carbon sequestration on agricultural lands.

- Explore opportunities for financing or prioritizing projects to enhance carbon sequestration on agricultural lands, including woodlands, perhaps through a combination of sources such as new or extant state programs (e.g., state water quality programs, SADC soil and water conservation grants, New Jersey's Green Acres and Blue Acres programs) and enable pooling of federal resources.

- Explore partnering with Zero Foodprint or a Restore California-like program for New Jersey that would engage with consumers, food service businesses, restaurants, and other food service institutions in a table-to-farm model that provides social-impact financing to implement agricultural practices that can sequester carbon.

- Consider creation of a nonprofit natural and working lands carbon mitigation bank supported by donors, including Community Supported Agriculture members, who may want to offset their personal greenhouse gas emissions (e.g., travel) by donating funds that would be reinvested in implementing carbon sequestration practices on participating farmers' land.

Equipment Cost Considerations

A number of interviewees discussed the cost of equipment (no-till equipment was referenced several times) as a barrier to implementing BMPs. A representative of the New Jersey Department of Agriculture shared that "Anecdotally, farmers are saying 'I need different

equipment to farm like that'" (i.e., no-till), adding, it would "be a big step for us to have equipment funded." As previously noted, a New Jersey Farmland Preservation Program representative suggested that "incentive programs would do well to consider cost-sharing on conservation tillage equipment."

A representative of USDA NRCS in New Jersey said some farmers are probably not applying for USDA funding even though they have interest in implementing BMPs because they "probably heard through the grapevine that we don't pay for equipment." The NRCS interviewee also noted that New Jersey farms are generally of a smaller size than neighboring states, and New Jersey has "a lot of soil and crop diversity; therefore, a farmer may not want to invest in buying a piece of equipment [needed to switch to a different practice, such as no-till agriculture] without knowing ahead of time how well it will work on their farm." This interviewee advised that there is much greater need among organic producers for equipment. They are smaller operations, and it's difficult to make an investment in an expensive piece of equipment, again, not knowing how well it would work on the producer's farm. That interviewee mentioned that NRCS met with farmers in South Jersey and concluded, "They aren't looking for free equipment, but a cost-share or rent-to-own, would be helpful." Representatives of USDA NRCS at the federal level said that access to equipment is a barrier to addressing carbon sequestration in production agriculture. They explained there are innovative ways to use conservation funding to overcome this barrier. For example, they talked about a conservation district in Kansas that purchased a high-boy for cover crops and worked with an agricultural co-op to lease the equipment to farmers.

As previously noted, several states in the Northeast offer grants, loans, and tax incentives to offset equipment purchases, such as the Maryland Low Interest Loans for Agricultural Conservation (LILAC) and the Maryland Income Tax Subtraction Modification for Conservation Equipment; the New York Climate Resilient Farming Program; and the Pennsylvania REAP and Conservation Excellence Grant programs. In addition, see the section under New Jersey Agricultural Land Considerations for specific discussion regarding funding equipment on preserved farmland.

- As recommended by a New Jersey-based NRCS interviewee, consider a regional program where producers could work with Extension to test out equipment on their land.

- Consider opportunities to provide for equipment purchases, lending, or rental, as well as trade-in or selling of equipment by New Jersey producers for practices that enhance carbon sequestration through state grants, loans, or tax incentives such as those provided in other Northeastern states (e.g., the Maryland LILAC and Income Tax Subtraction Modification for Conservation Equipment, the New York Climate Resilient Farming Program; and the Pennsylvania REAP and Conservation Excellence Grant programs).

D.6 Leverage Current and Emerging Programs for Climate Benefits

It is evident that there are multiple practice-based programs that provide opportunities for farmers to realize multiple benefits. The Pennsylvania REAP program helps farmers comply with the Pennsylvania Clean Streams Law which, as previously noted, requires an Agricultural Erosion and Sedimentation Control Plan limiting soil loss from plowing or tilling to at or below an established soil loss tolerance (T) threshold.[390] Eligibility for most USDA conservation

assistance programs is twice the soil loss tolerance threshold as that established in Pennsylvania, and therefore, NRCS employees in Pennsylvania plan for the more restrictive Pennsylvania threshold to ensure farmers are in compliance with the state regulations. An interviewee suggested that New Jersey could reduce soil loss and further improve soil health and enhance carbon sequestration if it were to consider approaches for a more protective soil loss tolerance threshold like that established in Pennsylvania.

The REAP Program also has a companion program, the Conservation Excellence Grant Program which does help farmers navigate and pool funding. As previously noted, farmers in California have successfully coupled CCI-funded alternative manure management practices to CCI-funded on-farm composting to increase organic matter and carbon sequestration. New Jersey interviewees mentioned the opportunities within the equine industry to develop compost from manure that would improve soil health and foster carbon sequestration while also reducing greenhouse gas emissions from manure. Some PES programs do incentivize manure management, and as such, coupling manure management to programs that also incentivize compost application to improve carbon sequestration can help producers realize multiple benefits. Further, a 2020 New Jersey law requiring large generators of food waste to source, separate, and compost or otherwise recycle their food waste (provided there is a facility within 25 miles and the cost is less than current disposal costs) could provide impetus for development of organics recycling facilities in New Jersey that could employ organic feedstock from New Jersey farmers, while also generating compost that could enhance sequestration on New Jersey lands, realizing multiple climate positive benefits.[391] A series of opportunities to address organic material management in New Jersey by the Organics Workgroup of the New Jersey Climate Change Alliance address regional manure management, community-scale composting, and large-scale organics recycling infrastructure; follow-on initiatives might be leveraged to enhance carbon sequestration on agricultural lands.[392]

Precision agriculture technologies can assist in responsiveness to climate change by optimizing output, reducing loss, and conserving resources. The Virginia Tech SmartFarm Innovation Network is one example where a network of interconnected centers across Virginia is being developed; researchers and Virginia Cooperative Extension specialists can partner with industries to develop and deploy innovative technologies to increase overall efficiency, resilience and sustainability of food, agricultural, and natural resource production systems. [393] Coupling precision nutrient management, for example, with other management practices can address erosion which is exacerbated by more intense rainfall.

Opportunities to leverage current and emerging programs:

- Develop a catalogue of opportunities (pollutant reductions, carbon, other PES) and provide assistance to producers to navigate programs and pool funding to implement practices that will enhance carbon storage.

- Explore opportunities to reduce soil loss, improve soil health, and enhance carbon sequestration by establishing a more protective soil loss tolerance threshold in New Jersey (similar to that in Pennsylvania) that could be incorporated into NRCS-NJ conservation programs and practices.

- Explore opportunities to couple practices and initiatives that realize greenhouse gas emissions reductions (such as alternative manure management to produce compost) with those that sequester carbon (such as on-farm application of compost) to realize even greater climate benefits for agricultural producers.

- Survey the current state of adoption and implementation of precision agriculture technologies and develop training and programming to guide program uptake.

- Identify and explore opportunities to leverage practices with emerging programs (such as the development of compost or other organic soil amendments in New Jersey to comply with recent food waste legislation) to reap multiple producer and climate benefits.

E. Marketing Opportunities

Interviewees noted marketing opportunities for producers who implement soil health practices that help to store carbon, among other benefits. The Audubon Conservation Ranching Initiative offers an Audubon certification for cattle raised on "bird-friendly" land that is also addressing soil health and carbon sequestration through grazing practices. The Western Sustainability Exchange which includes the Montana Grasslands program certifies ranches, farms, and food businesses that meet sustainability criteria, including soil health practices. A representative of North Jersey RC&D noted, "We realize there are plenty of co-benefits to these [soil health] practices. We would like to work with our farmers to help them get recognized for these co-benefits."

Also noted previously, CDFA has sponsored development of the California Ecosystem Services Database which was designed to communicate to a wide audience the social and environmental benefit generated by farmers and ranchers in California. Meant to be part educational, with examples for the farm community of successful practice implementation and the broad benefits it may have, the database can be a marketing tool, giving farmers the chance to promote their projects and the ways they are helping the environment.

Marketing opportunities for New Jersey agriculture:

- Explore opportunities for growers to be recognized for social and environmental benefits of conservation practice implementation including development of a marketing medium/platform that can serve as a communications tool demonstrating social and environmental benefits generated by growers.

F. New Jersey Agricultural Land Considerations

Interviews with representatives from the New Jersey Department of Agriculture and the State Agriculture Development Committee (SADC) noted that climate change brings new challenges to agricultural land (for example, more intense rainfall and more erosion) for which farmers will need to prepare for and adapt. Hence the potential for carbon farming and reforestation in the right instances can allow landowners to benefit financially. These representatives identified challenges and opportunities with respect to provisions for working forests in agricultural landscapes as well as highlighted challenges and opportunities related to preserved farmland.

SADC representatives noted that one option producers may consider for adapting cropland vulnerable to climate impacts such as flooding is conversion to forested buffers and/or woodland. However, producers have noted challenges with the conversion of modified agricultural wetlands to woodland emanating from the New Jersey Department of Environmental Protection's (NJDEP) current interpretation of its freshwater wetlands rules. If a producer lets their land go fallow for more than five years, they will lose their ability to convert back to agricultural land in the future because it is no longer considered by NJDEP to be in "active" agricultural use. SADC representatives noted that if these fields are converted to a forest crop and managed in accordance with a woodland management plan or forest stewardship plan (each approved by NJDEP), then a producer could transition to silviculture, which technically is active agricultural use. The representatives noted that "if properly highlighted, this alternative viewpoint of these regulations could lead to a comprehensive discussion of the issue with NJDEP."

SADC representatives also noted challenges to reforestation on preserved farmland that emanate from the farmland preservation deed of easement, which is "first and foremost focused on promoting production agriculture." They noted that the long-standing practice of the SADC has been that reforestation has been limited to uplands where NJDEP's wetlands rules do not apply; it has been seen as problematic if a preserved farm owner cannot convert woodland back to cropland or pastureland if necessitated by the needs of future generations. As such the SADC representatives noted that a dialogue with NJDEP over the potential for managed modified agricultural wetlands, for example as silviculture, would be prudent to open up opportunities for sequestering carbon and providing income opportunities for farmers related to wood products and/or carbon markets.

As for the upland portions of preserved farms, the SADC representatives noted clearer guidance is necessary to determine the amount of preserved farmland that could be converted to forestry and if said conversion has to produce a timber crop (i.e., woodland management) or if other management objectives can be realized such as the provision of habitat for sensitive species, groundwater recharge, etc. (i.e., forest stewardship), particularly in marginal agricultural areas such as steep slopes or highly erodible lands.

- Explore policy/regulatory changes and potential need for legislation to further carbon sequestration through reforestation on agricultural land (preserved farmland as well as farmland not in the Farmland Preservation Program), striking an appropriate balance between retaining land for agricultural food production versus the provision of ecosystem services.

SADC interviewees noted that the time may be right to think of farmland preservation from a "whole farm" easement concept of a parcel during the land preservation process including valuing the farm, and consequently the Farmland Preservation Program easement, for its worth not only in perpetuating production agriculture, but also for a farm's contributions toward soil health, addressing nonpoint source pollution, carbon sequestration, species habitat, well-head protection, etc. Programs like the USDA NRCS Conservation Reserve Enhancement Program (CREP) do pay farmers to remove environmentally sensitive land (and often marginal agricultural land) from production and implement practices for 10 to 15 years such as creating

stream buffers to improve water quality; these practices also have other benefits such as conserving topsoil and sequestering carbon. However, SADC representatives noted that these conservation practices could be better aligned with permanent preservation programs to facilitate holistic resource management in perpetuity. There is an opportunity to contemplate a different type of agreement with a landowner when a farm is preserved so that the farmer might agree, and in return, be compensated for, the creation/maintenance of grassed waterways, riparian buffers, habitat protection, etc. in addition to production agriculture.

- Explore consideration of a "whole farm" easement approach that would value preserved farmland for production agriculture, as well as conservation practices that provide ecosystem services such as soil health, water quality, and water quantity benefits and carbon sequestration.

The SADC representatives also mentioned the Preserve NJ Act of 2016 which allows for Corporate Business Tax (CBT) funds to be used by the SADC for stewardship purposes (e.g., grants to farmers for soil and water practices) on already-preserved farms, which now includes expenditures for "projects that improve the resiliency of farmland soils." However, it needs to be determined if the CBT funds could be used to fund the purchase of conservation tillage equipment for use on preserved farmland. This would have the dual benefit of conserving valuable soil resources while enhancing farm viability given the labor savings associated with conservation tillage.

- Explore development of potential changes to statutes and/or rules, if necessary, to improve soil resiliency through the Preserve NJ Act and evaluate the authority to fund equipment to implement concomitant soil conservation practices.

Appendix A Organizations Participating in This Study

Representatives from the following organizations were interviewed for this study:

- American Forest Foundation
- Audubon Dakota
- Bayer U.S. – Crop Science
- Cargill
- California Air Resources Board
- California Department of Food and Agriculture
- Colorado State University
- Ducks Unlimited
- Duke University
- Ecosystem Services Market Consortium
- Honey Brook Organic Farm
- Hudson Carbon
- Maryland Department of Agriculture
- Maryland Department of the Environment

- Maryland Department of Natural Resources
- Native Energy
- New Jersey Department of Agriculture
- New York State Department of Agriculture and Markets
- North Jersey RC&D
- Pennsylvania Department of Agriculture
- Pennsylvania No Till Alliance
- RGGI, Inc.
- Restore California
- Rice University
- Stroud Water Research Center
- The Nature Conservancy
- U.S. Department of Agriculture, Natural Resources Conservation Service, National Energy and Environmental Markets Team
- U.S. Department of Agriculture, Natural Resources Conservation Service, New Jersey Office
- U.S. Department of Agriculture, Office of the Chief Economist
- U.S. Department of Defense, Readiness and Environmental Protection Integration Program
- Willamette Partnership

Appendix B Glossary of Terms [394]

Carbon cycle: Processes by which carbon compounds flow among reservoirs in the environment (i.e., incorporation of carbon dioxide into living tissue by photosynthesis and its return to the atmosphere through respiration, decay of dead organisms, and fossil fuel burning). In the carbon cycle, carbon flow or output from one reservoir transfers carbon to other reservoir(s).

Carbon flux (or flow): Refers to the direction and rate of transfer, or flows, of carbon between pools.

Carbon pool: A compartment, or reservoir, within the Earth system where carbon can be taken up, stored, and/or released within a carbon budget.

Carbon sequestration: Storage of carbon through natural, deliberate, or technological processes in which carbon dioxide is diverted from emissions sources or removed from the atmosphere and stored biologically in the ocean and terrestrial environments (e.g., vegetation, soils, and sediment), or in geological formations.

Carbon sink: A compartment within the Earth system that acquires carbon from the atmosphere and stores it for a specified period of time.

Carbon stock: The mass of carbon contained within a particular compartment, or pool, within the Earth system.

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